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Nature of Science Understandings and Instructional Perceptions: Moroccan Preservice Primary Science Teacher Educators' Responding Variables to a Professional Development Series

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ABSTRACT

The study explored science and science education professors' nature of science (NOS) understandings and perceptions on NOS instruction before (T1), during (T2), and after (T3) a professional development (PD) series. Using repeated measures design, findings showed an increasing trend across NOS aspects. Summary scores were used to classify participants' NOS views as *alternative*, *transitional*, or *informed*. From T1 to T3, participants (n=19) shifted from *alternative* (16%) and *transitional* (84%), to *transitional* (100%) at T2, and ended as *transitional* (53%)/*informed* (47%). There were particularly significant changes in participants' understanding of observations and inferences and the sociocultural influence on the enterprise of science. The findings did not reveal significant changes in participants' perceptions on NOS instruction. On reflective responses, however, a majority expressed a desire to learn about more NOS activities that can be used in their instruction. The study provides evidence that relatively short PDs, when implemented with explicit NOS activities, have potential to positively impact NOS understanding. While less impactful on participants' NOS instructional perceptions, it is encouraging that the majority of the participants indicated a desire to learn strategies to teach NOS. More research can help improve the efficacy of PD methods and help identify key constructs that are most relevant for perceptions of NOS instruction.

Keywords: nature of science, professional development, teacher education, preservice teachers

Introduction

Understanding the nature of science (NOS)—what science is and how scientists work—is considered an important part of science literacy in the United States (Lederman et al., 2014; McComas & Clough, 2020) and has been a fundamental, enduring goal for important reform efforts in science education worldwide (Abd-El-Khalick, 2013; Kampourakis, 2016; Lederman & Lederman, 2019). Yet, research shows that most teachers around the world have limited understanding of NOS (Capps & Crawford, 2013). Research also shows that even when teachers understand NOS, they often struggle to teach it (McComas et al., 2020; Lederman & Lederman, 2014; Wahbeh & Abd-El-Khalick, 2014).

While many NOS studies examined teachers' NOS conceptions (e.g. Abd-El-Khalick & Lederman, 2000; Brickhouse, 1990; Cofré et al., 2019; Lederman, 1992, 1999; Kite et al., 2021), only a few (e.g. Librea-Carden et al., 2021; Leden et al., 2015) examined teachers' perceptions on the relevance of teaching NOS. Teachers who understand NOS do not necessarily value the importance of teaching it (McComas et al., 2020; Lederman & Lederman, 2014; Wahbeh & Abd-El-Khalick, 2014). Studies show that teachers' intention to teach NOS influences their instructional decisions (Librea-Carden et al., 2021; Bell et al., 2016; Lederman, 1992, 1999; Mulvey & Bell, 2017). Thus, teachers' instructional practices may be influenced by their perceptions of the importance of NOS instruction.

While there is increasing international attention to NOS research (e.g., Cofré et al., 2019; Ma, 2015; Thye & Kwen, 2004; Wong et al., 2014), NOS research in Middle East and North Africa (MENA) countries is largely neglected (Alhamlan et al., 2018). Our research is situated in Morocco, where extensive reform efforts are addressing challenges, such as suboptimal teacher education, lack of facilities and hands-on supplies, and a traditional science education curriculum (Dagher & BouJaoude, 2011; Llorent-Bedmar, 2014).

Recently, the Ministry of Education in Morocco has made changes in primary school curricula including allocating additional time for science instruction (Hatim, 2020). Morocco's primary science program aims to help students realize the importance and benefits of science and to provide opportunities to work like scientists (Moufti et al., 2020). Traditional foci remain, such as on acquiring large amounts of science content knowledge (Dagher & BouJaoude, 2011) with a strong emphasis on the role of controlled experiments (Lahlou, 2019). The curriculum also requires "procedural understanding of the scientific procedure (approach)" (Lahlou, 2019, p. 82). In the Update on the Curriculum for Primary Education (2020), this is referred to as "the" scientific method, which reflects a traditional view of NOS.

One way to improve science instruction is through professional development (PD), which provides important opportunities for teachers to enhance science content and pedagogical knowledge (National Research Council [NRC], 1996). Research has shown the impact of PD on improving teachers' NOS understanding and their instructional practices (Akerson et al., 2009; Akerson & Hanuscin, 2007; Lederman & Lederman, 2019), particularly PD that incorporated explicit-reflective NOS instructions/activities (Mulvey et al., 2017).

Nature of Science

"Nature of science" is a multifaceted construct that has some generally agreed upon characteristics. These have been synthesized into goals for elementary and secondary students (Lederman, 2007). The present study focused on these characteristics: (a) *Science is made up of observations and inferences.* Scientific knowledge includes both information gathered by all the human senses and by logical reasoning. (b) ***Science is empirical.*** Scientific knowledge is based on direct or indirect observations. (c) *Science is creative.* It is a blend of logic and imagination. (d) *Science is subjective.* Scientific knowledge is theory-laden, influenced by individuals' own beliefs, prior knowledge, experience, and values. (e) *Science is socio-cultural.* Science is a human activity that involves individuals of different social, cultural, religious, political, and socio-economic status. (f) *Science has multiple methods.* Science does not follow a linear procedure or single scientific method. One can use or apply several varied ways to do science. It is not only through experiments that one does scientific research. (g) *Theories and laws are two different types of scientific knowledge.* Although both provide information about a phenomenon, theories explain why and how it happens, while laws describe the phenomenon. There is no hierarchical status between the two:

theories do not become laws. (h) *Science is tentative.* Scientific knowledge is not absolute fact. Thus, laws and theories may change or be further supported when new evidence emerges.

The present study focused on the aforementioned aspects in exploring the impact of a synchronous online PD on Moroccan preservice elementary science (content and/or methods) professors' NOS understanding and their perceptions of NOS instruction to their students before, during, and after PD. We addressed the following research questions (RQ):

(1) How do participants' NOS understandings change across the three PD sessions?
(2) How do participants' perceptions of NOS instruction vary across the three PD sessions?

Our hypothesis is that providing NOS PD will potentially improve participants' NOS understanding and will lead to positive perceptions on the importance of teaching NOS.

Methods

This study used qualitative and quantitative data in a *repeated measures design* across a series of three NOS PD interventions occurring over a three-month period. The following instruments addressed the research questions: the Arabic version of *Student Understanding of Science and Scientific Inquiry* (SUSSI) (Al-Saghir, 2019) and *Perceptions of the Relevance of Instructions and Pedagogical Practices of NOS* (PRIPNOS) surveys. We used repeated-measures MANOVA to compare before PD (T1), after the second PD (T2), and after the third PD (T3) for SUSSI and PRIPNOS responses. We also calculated the Partial Eta Squared effect size for the significant differences (5% significance level) in variables. Qualitative data included open-ended questions and prompts on the surveys, as well as on exit tickets. These responses were coded and analyzed using Miles et al. (2014) guidelines.

Participants

Nineteen pre-service elementary science education and science content professors volunteered to participate in the study. There were 14 males, and five females. Content specializations included Biology (n=5), Chemistry (n=5), Physics (n=3), and Earth and Life Sciences (n=6), and science education (n=7).

NOS interventions

Participants completed three PD sessions conducted online via Zoom, which were approximately 120 minutes each. We used presentation slides in Arabic and French, and the presenters spoke in English with French translation by one of the authors. Table 1 shows the NOS aspects addressed by each activity and the duration of each activity per PD. The intervention and activities are described below.

During the first PD, we shared with the participants the importance of teaching and learning NOS as stipulated in positional statements (i.e., National Science Teachers Association) and recommended by science educators around the world (e.g., Jenkins, 2013; McComas & Kampourakis, 2015). It served as an introductory session that included an interactive presentation about NOS; participants were asked to participate in a survey poll in Zoom to determine whether statements are a myth or truth. Common NOS misconceptions were used, such as "Experiment is the route to all scientific knowledge" (McComas, 1998, p. 64). At the end of the PD, we asked the participants to respond to exit ticket questions: "What did you learn from the PD?" and "What else do you want to learn (in the next PD)"?

Table 1

Summary of NOS Interventions

NOS-related activities and PD sessions	Target NOS aspects and Timing
“Truth or Myth” Polly Survey (PD 1)	Misconceptions of NOS
“Inquiry cubes” (PD 2)	Scientific methods, empirical evidence, observations, and inference (60 minutes)
“Card Exchange” (PD 2)	Subjectivity, sociocultural (60 Minutes)
“Ambiguous Images” (PD 3)	Subjective, Sociocultural (30 minutes)
“Mice, Men and Scientists” (PD 3)	Subjective, Sociocultural (30 minutes)
“That’s Part of Life” (PD 3)	Sociocultural (50 minutes)

The second PD was designed as a workshop that engaged participants with NOS activities that (a) they could use in their instruction, and (b) reinforced NOS aspects presented during the first PD session. Based on the initial analysis of pre-SUSSI survey responses, participants showed low mean scores on the influence of socio-cultural aspects and individual perceptions, development of scientific knowledge, and doing science in many ways. We used tested NOS activities that target understanding of the said NOS aspects including “Inquiry cubes,” (National Academy of Sciences, 1998) and "Card Exchange” (Cobern & Loving, 2020). Both activities were modified for online implementation. During this session, we asked the participants to observe the cubes as being shown to them (i.e., showing each side). Then, we explicitly asked them “How is this like what a scientist would do?” to draw their attention to the process of making observations and inferences and drawing conclusions (i.e., “what’s at the bottom of the cube?”) without following “the” scientific method. At the end of the activity, we discussed how they can make their scientific argument without going through the step-by-step scientific method and experimentation. We provided participants opportunities to share their different observations and conclusions about the cube and critique each other’s arguments. We explained how the activity is like what scientists do; scientists make different observations of the same data (as influenced by their individual perceptions to construct an explanation to a certain phenomenon. During the “Card Exchange” activity, participants worked in group engaged in a collaborative examination of NOS statements and misconceptions about science. Participants chose two statements that they most agree with at each phase (there were four phases). In the last phase, they were asked to choose the top two statements that they most agree with and explain their reasons for choosing those statements. Similar to the “inquiry cube activity,” we also asked them “How is this like what a scientist would do?” We drew their attention to the idea that scientists reach a consensus based on data and empirical evidence. Finally, participants responded to the same exit ticket questions as in the first PD at the end of the session.

The third PD was a continuation of the second PD; we continued to provide NOS activities used by Bell (2009) including “Ambiguous Image,” (Dallenbach, 1951) “Mice, Men and Scientists” (Bugelski & Alampay, 1961), and texts with ambiguous meaning (Bransford & Johnson, 1972) to emphasize the theory-laden nature of scientific knowledge and sociocultural embeddedness of science. During this session, we explicitly directed the participants’ attention to their varying responses to the ambiguous images despite looking at the same sets of pictures. The last activity was reading ambiguous texts which described a procedure on how to wash clothes. During the group discussion, we asked them to respond to the question “What does this tell you about the nature of science?” We described how scientists differ in their interpretations of the same data as influenced by their different educational backgrounds, perceptual frameworks, and beliefs. Finally, participants responded to the same exit ticket questions as in the first PD at the end of the session.

Data Collection and Analysis

RQ1: Because the participants speak Arabic, we used the validated Arabic version of the SUSSI survey (Al-Saghir, 2019) to examine NOS understanding. SUSSI has good reliability in small scale studies (e.g., Herman & Clough, 2013) and has been used with students and teachers (e.g., Kruse et al., 2021). The survey consists of six NOS constructs (considered as variables for this study): (i) Observations and Inferences, (ii) Change of Scientific Theories, (iii) Scientific Laws vs. Theories, (iv) Social and Cultural Influence on Science, (v) Imagination and Creativity in Scientific Investigations, and (vi) Methodology of Scientific Investigation. Each construct has four Likert items (except variables iii and v) with five options: strongly disagree, disagree, uncertain, agree, and strongly agree. Using Liang's (2006) SUSSI protocol, we assigned numerical values to which they agree or disagree; one is for strongly disagree and five is for strongly agree, and these were reversed for negative statements. We determined mean scores across participants for the six variables. Then, we referred to Al-Saghir's (2019) scale: > 3.5 = *informed*, 2.5-3.5 = *transitional*; < 2.5 = *alternative*, to determine the participant's levels of NOS conceptions.

To reduce response-shift bias—where participants overestimate knowledge, abilities, or behavior prior to an intervention—retrospective survey items were included (Klatt & Taylor-Powell, 2005). These paired items generally start with, "Before the workshop…" and "After the workshop…". For example, Pair 1 explored participants' perceived understanding of contemporary views of NOS and Pair 2 explored their perceived knowledge of NOS misconceptions. Statistical significance of the pairs was determined with a paired *t*-test. We also included open-ended questions in the retrospective survey items to support their responses to paired items such as "If you were to teach the nature of science to preservice teachers or elementary school students, what aspect of the NOS (e.g., creative, subjective) do you think would be most important to teach them? Why?"

RQ2: Our PRIPNOS survey has six items selected from *Views on Science, Scientific Inquiry, and Science Teaching [VASSIST]* (Herman, 2010) as a measure of participants' perceptions of their NOS instruction. These items were translated to French, which is one of the participants' spoken languages and the language of instruction at Moroccan universities. The reliability of the survey, calculated Cronbach's Alpha, was within an acceptable range (α=.70). Open-ended items were included as a complement to the Likert items and to deepen our understanding of participants' perceptions. One retrospective survey item was included in the posttest for RQ2. The pair focused on knowledge of strong NOS activities for their preservice teachers. We also added open-ended questions such as, "What activities do you think are useful for your students to better learn about the NOS? Why?" to elaborate their understanding of NOS activities. We employed the same protocol used for SUSSI analysis.

Participants' responses to open-ended questionnaires (i.e., PD exit tickets and retrospective questions) were used to cross-check SUSSI and PRIPNOS survey responses (Swart, 2019). We used Microsoft Excel translate tools to translate French responses to English and these were verified by the native-French speaking author. Responses to open-ended questions were analyzed using Miles et al. (2014) guidelines on coding as a form of analysis.

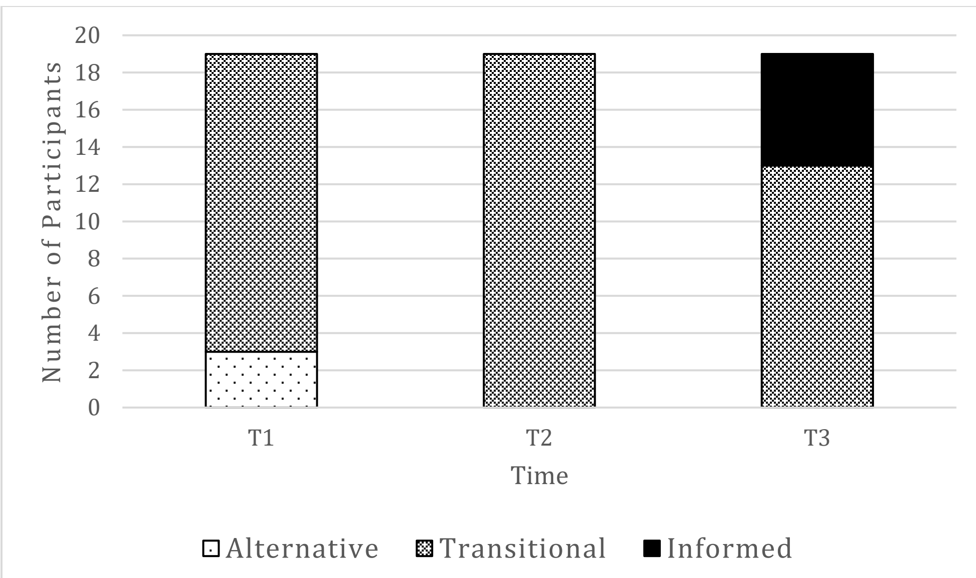
Findings

RQ1: How Do Participants' NOS Understandings Change Across the Three PD sessions?

Before the PD (T1), 19 participants were characterized as *transitional* and three as *alternative* based on summative SUSSI scores (see Figure 1). After the second PD (T2), all participants who were initially *alternative,* shifted to *transitional* NOS. Figure 1 shows results after the third PD (T3) where 31% of the participants have *informed* NOS views. Six out of 19 participants who were initially *transitional,* shifted to *informed* NOS. Analyzing the six participants who moved into *informed* NOS post-PD (T3), four have *informed* NOS in five out of six SUSSI variables and two have *informed* NOS in four variables post-PD (T3).

Figure 1

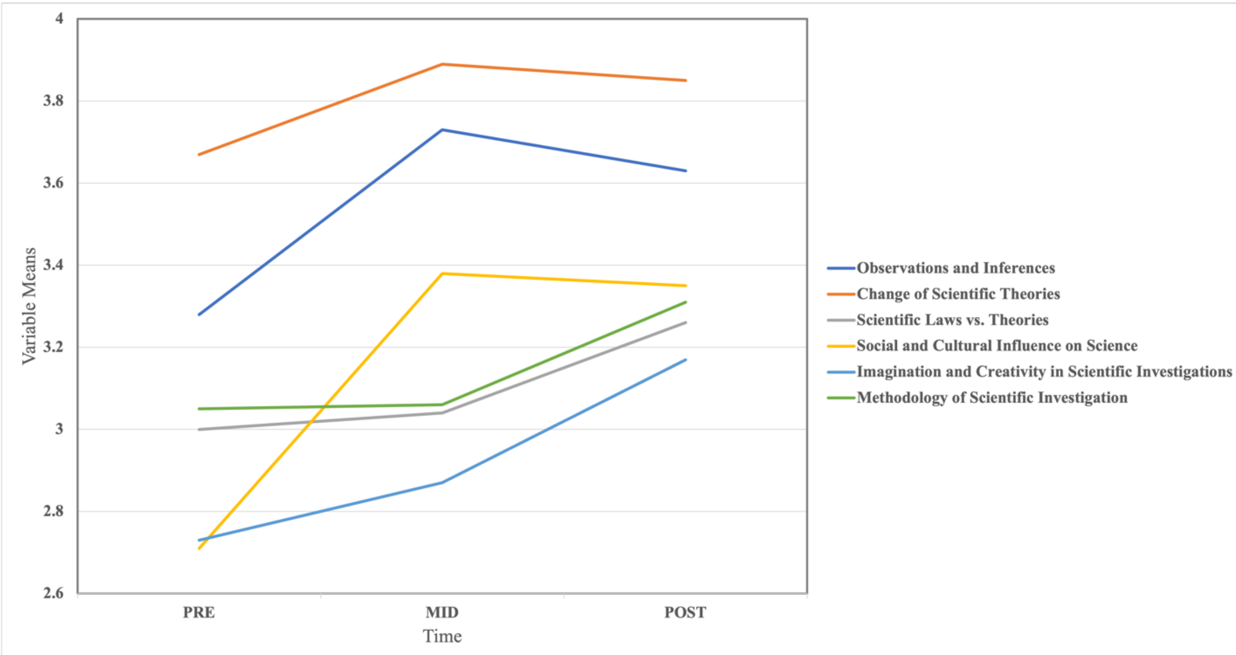
Changes in Participants' NOS Conceptions Across Three PDs



The SUSSI variable means (see Figure 2) all increased from T1 to T2, three variables decreased from T2 to T3, and three variables increased from T2 to T3. There is a general increasing trend from T1 to T3 across all variables. From the repeated-measures MANOVA test, participants' NOS understanding changed significantly (.004) with a large effect size (.93). To find out exactly where the changes were significant, we conducted a post hoc analysis using the Bonferroni correction to decrease the chance of type I error (see Table 2).

Figure 2

SUSSI Variable Mean Scores Trend for T1, T2, and T3



The changes from T1 to T2 were statistically significant for the SUSSI variables "Observations and Inference" and "Social and Cultural Influence on Science." Changes from T1 to T3 were statistically significant for the variables "Scientific Laws vs. Theories," "Social and Cultural Influence on Science," and "Imagination and Creativity in Scientific Investigations." No significant changes were found for the variables "Change of Scientific Theories" and "Methodology of Scientific Investigation." There were no significant changes in any of the variables from T2 to T3. Finally, we calculated effect size for the significant changes. The variable "Observations and Inferences" between T1 and T2 had the biggest effect size (.93), while the "Social and Cultural Influence on Science" variable showed considerable effect sizes between T1 to T2 (.78) and pre to post (.61). The "Imagination and Creativity in Scientific Investigations" variable had a smaller effect size (.58) from T1 to T3. Lastly, the variable "Scientific Laws vs. Theories" had the smallest effect size (.07) from T1 to T3.

There were significant differences in the results of the paired *t*-test of the retrospective NOS understanding items. Pair 1, A) "Before the workshops, I had a good understanding of contemporary views on the NOS" ($M = 3.79$, $SD = 0.54$) and B) "After the final workshop, I have a good understanding of contemporary views on the NOS" ($M = 4.42$, $SD = 0.61$) were significantly different $t(18) = 4.0$, $p < .001$, with an effect size of 1.09. Pair 2, A) "Before the workshops, I knew the common misconceptions about the NOS" ($M = 3.26$, $SD = 0.93$) and B) "After the final workshop, I know some common misconceptions about the NOS" ($M = 4.11$, $SD = 1.24$) were significantly different $t(18) = 5.3$, $p < .001$, with an effect size of 0.77.

Table 2

Comparisons of Participants' SUSSI Scores Across Three PDs

SUSSI Variables	PDs	Mean Difference	Sig.
Observations and Inferences	T2 – T1	.447	.001*
	T3 – T2	-.105	1
	T3 – T1	.342	.136
Change of Scientific Theories	T2 – T1	.224	.536
	T3 – T2	-.039	1
	T3 – T1	.184	.447
Scientific Laws vs. Theories	T2 – T1	.042	1
	T3 – T2	.224	.102
	T3 – T1	.266	.043*
Social and Cultural Influence on Science	T2 – T1	.671	.005*
	T3 – T2	-.026	1
	T3 – T1	.645	.015*
Imagination and Creativity in Scientific Investigations	T2 – T1	.137	1
	T3 – T2	.326	.075
	T3 – T1	.463	.031*
Methodology of Scientific Investigation	T2 – T1	.013	1
	T3 – T2	.250	.113
	T3 – T1	.263	.074

Note. * Indicates a statistically significant difference

RQ2: How Do Participants' Perceptions of NOS Instruction Vary Across the Three PD Sessions?

The repeated measures findings for PRIPNOS revealed no significant changes from T1 to T3. However, the paired *t*- test of the retrospective teaching item showed significant differences. For Pair 3, A) "Before the workshops, I knew of some good activities to help my students discover the NOS" (M = 3.3, SD = 1.1) and B) "After the final workshop, I know of some good activities to help my students discover the NOS" (M = 4.3, SD = 0.65), $t(18) = 3.3$, p =.004.

Reflections on PD

PD Exit Tickets

After the first PD, a majority (11) of participants wrote "nature of science" as a response to the "What did you learn from the PD?", which were coded NOS-related ideas; many (8) expressed methods to facilitate teaching NOS as desired learnings from the PDs. After the third PD, their responses to questions that asked about their learning from the PD indicated more nuanced ideas about NOS. For example, some participants described science as: "influenced by our society, religion, education, environment," "influenced by the theories to which we adhere," and "not absolute, but it is always an innovation given the technological development that the current world is experiencing." Some of the responses to "what else do you want to learn from the PD?" included "other example activities to teach NOS," "approaches to teach NOS," and "appropriate approaches to teach NOS to preservice teachers."

Responses to Open-ended Questions in the Retrospective Questionnaire

Many participants (7/19) identified creativity as one of the most important NOS aspects to teach preservice primary teachers "to better develop the scientific spirit in their students." However, eight participants also pointed out that experimentation is the most important. For example, one of the participants, with an informed NOS level post PD, said that experimentation "brings the preservice teachers closer to the manipulations, on the practical side." Many (8/19) seemed to adhere to a traditional didactic approach stressing the role of experimentation. There were some (6/19) who identified activities used in the workshop as useful to teach NOS to their preservice teachers. However, participants expressed constraints that can potentially hinder them from teaching NOS, such as lack of time and pedagogical knowledge, too much science content to address, and misconceptions of NOS.

Discussion and Implications

This study, situated in Morocco, adds to the existing NOS research base and addresses the limited research on NOS in MENA countries by investigating preservice primary teachers' professors' NOS understanding and their view on its instruction.

NOS Interventions and Change in NOS Understanding

In three NOS PD sessions, participants showed statistically significant gains in NOS variables occurring between T1 and T2, defying reports that short-term PDs are not likely to improve NOS views (Lederman & Lederman, 2014). The growth from T1 to T2 may be attributed to the "truth or myth" activity in PD1, which provided participants opportunities to reflect, share, and confront possible alternative NOS conceptions. Between T1 and T2, participants also engaged in explicit NOS activities during PD2, which may have also influenced their understandings. In this study there were improvements in NOS understandings that were not found in other studies, including understanding creativity (Bang, 2017). On the other hand, our findings on participants' improvement in their understanding of the socio-cultural embeddedness support previous studies (e.g., Akerson et al. 2000; Bell et al., 2016; Edgerly et al., 2021; Herman & Clough, 2016; Librea-Carden et al., 2021). This could also be attributed to the NOS intervention that emphasized the sociocultural aspect of science through activities that focused on the influence of culture, personal experiences, and beliefs on science.

Consistent with other studies is the significant change in participants' view of creativity/use of imagination (e.g., Akerson et al., 2000; Bell et al., 2011; Bell et al., 2016; Donnelly & Argyle, 2011; Herman & Clough, 2016; Librea-Carden et al., 2021). This change occurred despite the participants' strong adherence to experimentation and the emphasis on "the scientific approach" in Morocco science education (Moufti et al., 2020). The improvement in participants' understanding of methodologies and use of imagination in scientific investigation is a promising outcome. Such outcomes may be attributed to the PD NOS activities that explicitly debunked the myth of "the" scientific method (e.g. "Man, Mice and Scientists" and "Inquiry cube") and engagement in the discussion after the activities that emphasized making sense of the data to construct new ideas.

The insignificant change in understanding other NOS aspects is not surprising as past studies also showed that even with explicit NOS interventions, participants struggle in making a conceptual change (Abd-Khalick & Akerson, 2004; Lederman, 2007). This may be accounted for by participants' tendency to ignore the new information when it contradicts their prior ideas, therefore, they may have modified the new information to fit their prior knowledge, rather than vice versa (Clough, 2006). Conceptual change occurs within longer time periods (Hatano & Inagaki, 1997; Vosniadou, 2007) and may be influenced by contextual, social factors (Abd-El-Khalick & Akerson, 2004). Still, the positive outcomes in participants' NOS understanding are promising considering the relatively short NOS interventions. The retrospective items help alleviate high pretest self-evaluations that occur when participants "don't know what they don't know." The high reflective improvement in these items, the generally positive trend of SUSSI items from T1 to T3, and movement of individual professors to higher summative SUSSI levels, suggest growth in NOS understanding.

Perceptions on NOS instruction

The PRIPNOS survey, while having good reliability, did not show a significant change in participants' means across PDs. This could mean that the instrument was not sensitive to changes in instructional perceptions. Future studies could seek to develop or refine items to measure professors' NOS instructional perceptions. The lack of change in the variables could also mean there were no significant changes in these perceptions. While the retrospective item suggests a strong improvement in knowing explicit-reflective NOS activities, instructional perceptions changes may take longer to develop and be highly dependent upon first changing NOS understanding. Findings on the limited change in instructional perceptions are consistent with previous studies where even participants with *informed* NOS understanding may not necessarily have positive perceptions towards NOS instruction (e.g., Akerson et al., 2017; Summers et al., 2020).

Research suggests that science experiences are an important influence on preservice science teacher's beliefs (Azam & Menon, 2021). However, research also shows that learning NOS is not part of many science or science education courses (Lederman & Lederman, 2019). Therefore, helping preservice teacher educators value NOS instruction and be comfortable with NOS activities to implement can be important preliminary steps for preparing future teachers of science. We also argue that the present study may provide an impetus for participants to consider inclusion of NOS instruction in their science education and content courses.

Limitations of the Study

The within-subjects research design used the instruments before the PD (T1), after the second PD (T2), and after the third PD (T3). To be sure, this design reduces variance and bias by controlling factors that cause variability between subjects, resulting in greater statistical power with a smaller number of subjects. Results however, should be interpreted with caution because of threats of history and testing. For history, other events may have occurred simultaneously to influence the scores. For testing, exposure to the surveys may have led to changes in perspective.

The open-ended responses for PD reflections and PRIPNOS were limited to short phrases due to time constraints during the survey administration. As such, detailed responses are lacking in the qualitative data. Time was taken from English to French and French to English translations throughout the PD sessions that may have reduced time to respond to surveys.

Conclusion

Overall, our results showed that Moroccan science and science-education professors working to prepare preservice elementary teachers, engaging in three PD sessions, improved their understanding of NOS. Similar studies with longer periods of PD NOS interventions (e.g., Abd-El-Khalick, 2005; Kruse et al., 2021; Kartal et al., 2018; Maeng et al, 2020) showed similar gains. However, this study provides evidence that short PDs when implemented with explicit NOS activities have the potential to positively impact NOS understanding. While the PD was less impactful on their NOS instructional perceptions, it is encouraging that most of the participants indicated a desire to learn strategies to teach NOS. Reports show that teachers' intention to teach NOS is important (Lederman, 1999; Mulvey et al., 2016).

With the scarcity of NOS research in MENA countries and relatively limited science education research in Morocco (Dagher & BouJaoude, 2011), this study: a) can provide an evidentiary basis to advance NOS research in these countries, b) suggest a need for an extensive and comprehensive research agenda focused on science and science education professors of preservice elementary teachers, and c) offer strategies for online, synchronous NOS PD for preservice and inservice teachers. The logic is simple: if we want to improve children's' NOS conception, we need to ensure that teachers must have accurate and substantial understanding and pedagogical knowledge of what science is and how scientific knowledge is constructed. This ideally would be cultivated throughout their education but should explicitly be addressed in their preservice teacher education. Thus, their science and science methods professors must be continually provided with appropriate and effectively designed professional development to help them accomplish their role as key players in science education reforms.

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