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Preservice Teachers' Views of the "Social Embeddedness" Tenet of the Nature of Science: A New Method of Analysis

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ABSTRACT

It is generally accepted that a robust science education includes knowledge *of* science, as well as knowledge *about* science, or, in other words, an understanding of the "Nature of Science." However, debates around what Nature of Science is and how to measure it are far from settled, and this compromises our ability to support teachers and students develop their understanding in this area. In this paper, two approaches assessing one aspect of the Nature of Science, the degree to which is it "socially embedded," are compared. The VNOS-C was administered to a cohort of pre-service secondary science teachers and analyzed using the traditional approach as well as a new approach, using "Specialization" from a framework known as Legitimation Code Theory. The results from the standard analytical approach revealed that preservice teachers' ideas were overwhelmingly Naïve or Mixed, and that these did not change over the course of the semester. However, there was insufficient discrimination between students' ideas, particularly those in the Mixed category. The new approach was able to capture more of the nuances in preservice teachers' responses. The potential of the new approach will be discussed in terms of its utility for understanding Nature of Science theory and improving assessment in relation to the "social embeddedness" tenet.

KEYWORDS

Legitimation code theory; nature of science; preservice teachers; primary science

Introduction

Understanding the nature and structure of scientific knowledge is considered important for students of science (McComas, 2020b; see, also, McComas, 1998; Lederman & Lederman, 2019). Questions such as "what is science" and "how do scientists work" are now embedded in science curricula around the world, including the US Next Generation Science Standards, and the "Science as a Human Endeavour" strand in the national curriculum of Australia. However, Nature of Science (NOS) views are not well integrated into teaching and learning (e.g., Lederman et al., 2002). Cofre et al. (2019), in their review of NOS literature state that

"most" of the students, pre- and in-service elementary and secondary teachers held "naïve" views pre-intervention (e.g., Cofre et al., 2019). McComas and Clough (2020) also note that despite the widespread support of NOS by governments, science organizations, and some teachers, "little of what is known about accurate and effective NOS instruction is widely implemented in science classrooms" (p. 17). One of the issues identified in the research is the problem with the tools we use to assess students' views of the Nature of

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Science. NOS is multifaceted and complex, and as such, assessments of NOS have been shown to be limited and problematic, with calls for improved assessments growing. A stronger theoretical and methodological basis that characterizes knowledge more precisely might improve the chances that appropriate NOS considerations are integrated and sustained in the teaching and learning of science subjects. In this paper, LCT will be used to theorize one aspect of NOS, "social-embeddedness," in an effort to provide a more robust base on which to build understanding about teachers' and pre-service teachers' views. The ultimate aim of this theorization is to provide more clarity around NOS in curriculum and pedagogy in order to more fruitfully encourage sophisticated NOS views.

Background

The nature of science and "social embeddedness"

In one of the most enduring and highly cited frameworks related to the Nature of Science, McComas' "consensus" view (McComas, 1998, see also McComas, 2020a), a concise sense of Nature of Science ideas is presented in the way of various statements (Table 1). The "consensus" view, whilst acknowledging science as a broad and diverse enterprise, still assumes that science, at its core, and for the purposes of teaching and learning, can be described by a set of fundamental characteristics. A thorough critique of the "consensus" view and responses from its author can be found in McComas (2020b, p. 26).

These statements, also expressed variously as "tenets," or "questions" have undergone further development in a recent publication (McComas, 2020c, p. 40), with tenets being groups under larger organizing clusters, such as "The Domain of Science and its Limitations," "Tools, Processes and Products of Science," and the "Human Elements of Science." The latter of these is the focus of this paper, as it contains what is often referred to as the "social embeddedness" tenet, reflected by the statement "scientific ideas are influenced by their social and historical milieu." The "Human Elements" cluster also includes the elements "creativity is everywhere in science" and "subjectivity and bias are present in Science." Whilst there is considerable variety in the expression of the social embeddedness tenet (and in fact, all the others), and some arguments exist over its boundaries, the characteristics it represents can be found in all Nature of Science frameworks. For instance, in Dagher and Erduran's Family Resemblance Approach (Dagher & Erduran, 2016), "social embeddedness" is expressed as a more general, overarching influence. It envelopes "Aims and Values," "Methods and Methodological Rules," "Practices" and "Knowledge," illustrating that all scientific activities are situated within social and cultural contexts. The Family Resemblance Approach also distinguish

Table 1. Statements from the consensus view of the Nature of Science (NOS) (adapted from Table 1 in McComas et al., 1998, p. 513).

- Scientific knowledge while durable, has a tentative character
- There is no one way to do science (therefore, there is no universal step-by-step scientific method)
- Science is an attempt to explain natural phenomena (it is empirical)
- Laws and theories serve different roles in science, therefore students should note that theories do not become laws even with additional evidence
- Observations are theory-laden
- Scientists are creative
- Scientific ideas are influenced by their social and historical milieu

between: “Social Organizations and Interactions,” “Political Power Structures” and “Financial Systems” as different ways society and culture may influence the scientific enterprise. For instance, issues related to gender and race are captured explicitly under “Political Power Structures,” and could impact on “Aims and Values” in terms of decisions around which questions need answering. There are a range of other frameworks and critiques of the Nature of Science, far too many to adequately describe here. However, in suggesting a new approach for considering Nature of Science views, it is not necessary to situate it within one particular Nature of Science framework. The approach translates across the various different perspectives. It is intended as a practical framework which although being theoretically based, does not require dismissing existing Nature of Science (NOS[1]) theories, but working within them. A such, because the McComas consensus view is arguably the most common and most highly cited in the literature, we situate this research within this particular framework and correspondingly refer to the corresponding “social embeddedness” tenet.

In this paper, we focus only on one NOS tenet, the notion that “scientific ideas are influenced by their social and historical milieu,” or the “social embeddedness” of scientific practice. Lederman et al. (2002) explain that a sophisticated understanding of “social embeddedness” would include acknowledgment that society and culture influence science. Some examples of science being socially and culturally influenced include the pre-Copernicun geocentric model of the universe supported by the Catholic Church and the different levels of acceptance of the theory of evolution. A more recent example includes the fact that almost scientific research requires funding: “much of science relies on external funding and that funding, in turn, is controlled by governments and private foundations that have their own agendas” (McComas, 2020c, p. 55). Naïve views include that Science is free from social and cultural influences.

The “social embeddedness” tenet of NOS has been known to be more likely to be emphasized in instruction, more difficult to shift from Naïve to Sophisticated, and is also one where considerable disagreement and ambiguity is acknowledged to exist (Cofre et al., 2019; Erduran & Dagher, 2014; Irez et al., 2018; Maeng et al., 2018; Summers et al., 2020). For instance, the idea that that scientific knowledge is “influenced by social and historical milieu,” is said to overlook the rich discussion about instrumentalism versus realism; or *how* socially constructed knowledge is. Good and Shymansky (2001) explain that “it is not difficult to see how the postmodern relativist could select statements that paint science as epistemically equivalent to the social sciences or even the arts and humanities” (p. 53). Sin (2014) further explains that we are at risk of epistemological essentialism in science; we only see the positivism in school science and the social constructivism exhibited by practicing scientists. Russ (2014) also raises this paradox, claiming that we should distinguish between epistemology of scientists and the learning objectives for students in the classroom. He explains this in the context of another tenet, the “tentativeness” of scientific knowledge. Russ (2014) explains that we should “make the case for how and in what ways treating knowledge as tentative is productive for making sense of the world” (p. 392), rather than expect students to claim that scientific knowledge simply exhibits the quality of tentativeness, in an argument that would equally hold for the “social embeddedness” tenet.

[1]Abbreviation used throughout to refer to general “Nature of Science” approaches, not exclusively the consensus view

Assessment of NOS views

The diagnosis and improvement of NOS views relies on a valid assessment of them. Assessment of NOS views has involved a range of tools, including questionnaires based on NOS frameworks such as the FRA (e.g., Kaya et al., 2019), surveys based on other constructs such as curricula outcomes (e.g., Tsybulsky et al., 2018) and even dramatic performance (e.g., Burke et al., 2018). Questionnaires are commonly used as they offer a way to quickly gauge students' views and are particularly useful when comparing pre- and posttest scores to test for improvements due to an intervention (e.g., Kaya et al., 2019). The limitations associated with quantitative questionnaires or surveys are well known. Considered inherently "reductive" (Kaya et al., 2019), these kinds of instruments are not the most reliable way of capturing the complexities of NOS. Lederman et al. (2014) for example, comments on how the items depend on shared understanding of meaning between the researcher and students on the various items that is difficult to achieve (Lederman et al., 2014).

One of the most prominent methods of assessing NOS views in the literature involves the analysis of a survey known as the Views of the Nature of Science, or "VNOS" (Cofre et al., 2019; McComas et al., 2020). The VNOS instrument has been used and widely administered to groups of students, pre-service teachers (PST) and practicing teachers (e.g., Bell et al., 2001; Lederman et al., 2002, 2001; Mesci & Schwartz, 2017). The VNOS contains short-answer questions which ask for a position on NOS tenets and associated examples. The PST group has been extensively targeted, due to the potential to address NOS views as part of their teacher training. Lederman (1992) emphasizes that "the most important variables that influence students' beliefs about the nature of science are those specific instructional behaviors, activities, and decisions implemented within the context of a lesson" (p. 351), highlighting the important role PST plays in this equation. The VNOS-C is specifically targeted to the PST population and consists of 10 short-answer questions aimed to reveal PST positions on the seven tenets of the consensus view. The primary form of analysis of responses to the VNOS and many other NOS assessment tools involves an assignment of responses to scales which represent sophistication. These include a binary rating of Naïve or Sophisticated, a three-point scale of inadequate, adequate, and informed (Akerson et al., 2006), or a four (Burke et al., 2018), five (Kaya et al., 2019) or 10 (Tsybulsky et al., 2018) point Likert scale. Interviews might be used as confirmation of quantitative results with quotations provided as exemplars, as in Kaya et al. (2019) or thematically coded, as in Tsybulsky et al. (2018), though this is less common.

McComas et al. (2020) argues that whilst a range of instruments exist, many of them have attracted significant critique and "no single NOS assessment instrument will address all concerns and meet all goals" (p. 98). The VNOS, for example, whilst popular, is not perfect. In a VNOS analysis, written responses are compared to a smaller number of interviews. Rudge and Howe (2013), point out that coding of participants' initial views on the VNOS survey were highly unreliable when compared to their interviews; what seemed like sophisticated NOS views were later revealed as Naïve, and even reaching a conclusion about whether participants' views changed or not between surveys or interviews was difficult. In relation to "social embeddedness," more specifically, Tsybulsky et al. (2018) comment on the limitations of quantitative measures. When comparing their qualitative results (open-ended responses) to quantitative results (on a 10-point Likert scale from disagree completely to agree completely), they find that a significant portion of students held views not captured on this scale: "Surprisingly, we also found a third cohort among our 154 respondents, who stated that such embeddedness does not exist but should not" (p. 1261). In relation to the VNOS question specifically, Erduran and Dagher (2014) explain that the social-embeddedness VNOS question itself does not quite capture the breadth of the idea of social embeddedness, for which Summers et al. (2020) agree. They suggest that additional questions might be necessary to address this issue and provide a more nuanced description (reflecting the Family Resemblance Approach), which reflects science as a "human enterprise . . . practiced in the context of a larger culture" and its "practitioners are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded" (Summers et al., 2020, p. 4).

In this paper, I address two main limitations in relation to existing analyses of NOS views. The first is the dependence on the judgment of whether a view is sophisticated or naïve, or to assign "correctness" to students' views. I argue that particularly for considerations related to "social embeddedness," a more nuanced view is required, one that allows for consideration of the *appropriateness* of particular views instead. The second limitation is the use of descriptions of responses when characterizing social embeddedness. In using LCT, I acknowledge the utility of descriptions but take them further too, to characterize their underlying assumptions. LCT allows us to "make visible" the underlying disciplinary assumptions in a way that can have utility both within and outside of the discipline of science.

Legitimation code theory

Legitimation Code Theory is an explanatory framework for analyzing and changing practice. It extends and integrates ideas from a range of theories, most centrally the frameworks of Pierre Bourdieu and Basil Bernstein. LCT is a "toolkit" of concepts that may be used to characterize practices with the aim to make the "rules of the game" clear. The core assumption in LCT is that these "rules of the game," or the basis of achievement in education, are often tacit. By making these rules explicit, LCT allows the rules to be taught, changed, and learned. A range of recent studies in science education are recognizing the utility of this relatively new approach (e.g., Georgiou, 2020; Georgiou et al., 2014; Kinchin et al., 2019; Lee & Wan, 2022; Maton et al., 2021).

The framework of LCT comprises a multi-dimensional conceptual toolkit, where each dimension offers concepts for analyzing different organizing principles underlying practices. For instance, the dimension of Semantics explores practices in terms of semantic gravity (the degree to which meaning relates to its context) and semantic density (the degree of condensation of meaning within practices; Maton, 2014, p. 28). Crucially, LCT is "problem-oriented," rather than "approach driven," meaning the dimension you consider depends on the problem or issue you are addressing; not all will have utility for all problems and should not be used without discretion. Of the framework's five dimensions, only one will be discussed in detail in this paper: Specialization, because it relates to the notion of "social embeddedness."

The LCT dimension of Specialization is concerned with characterizing what makes something distinct, or "special," or in educational contexts: how knowledge comes to be legitimate or in simpler terms, how you come to "know" in a particular field. To compare with NOS questions, McComas and Clough (2020) explain that "those interested in the study of science ask questions like 'what, if anything, demarcates science from other human endeavours" (p. 5). Thus, Specialization can be used to understand the social embeddedness tenet.

One of the key ideas we should start with when discussing knowledge practices is the notion of "fields." Bernstein highlights the relationship between fields of "production" (like the field of science), "recontexualisation" (like curriculum) and "reproduction" (as in pedagogy and evaluation). These ideas are further explicated in Luckett (2012) and are an essential first step to avoid conflation or confusion between the characteristics of knowledge in the different realms. As has been mentioned, it is not always necessary or useful to reflect the epistemology of one field (like scientific practice) on another (like classroom teaching).

Within the dimension of specialization, LCT posits that the basis of legitimation is emphasized differently between fields, through: relative strengths of relations between practices and their objects of study, "epistemic relations" (ER); and relations between practices and their subject, "social relations" (SR). Quantifying the combinations of these relations (referred to as "organising principles") for a practice gives you "legitimation codes" or the structuring principles of knowledge claims and practices.

With reference to Figure 1, four Legitimation codes of Specialization can be described.

- The knowledge code (SR-, ER+) exhibits strong epistemic relations and weak social relations, knowing the procedures and having specialized knowledge is the basis of achievement and the individuals are downplayed
- A knower code (SR+, ER-) emphasizes the attributes of the individual as measures of achievement and the knowledge and procedures are less important
- An elite code (SR+, ER+) reflects that legitimacy is based on knowing the right procedures and knowledge but also being the right kind of knower

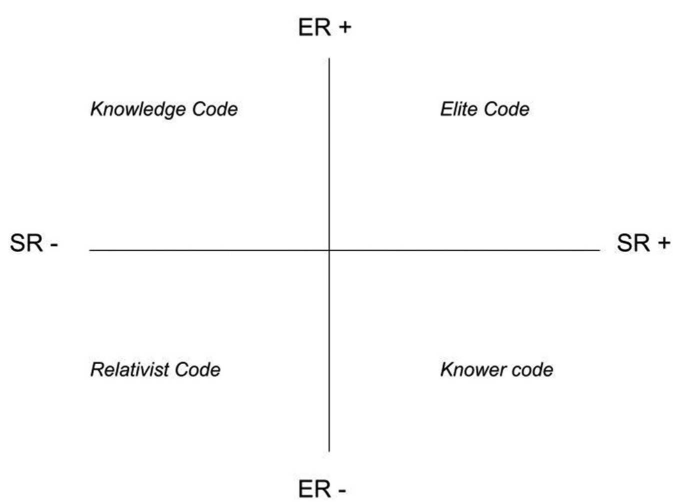

Figure 1. The four specialization codes on a specialization plane (Maton, 2014, p. 30). Knowledge codes emphasize what you know, knower codes emphasize who you are, élite codes emphasize both specialized knowledge and the right kind of knower, and relativist codes are "anything goes."

- A relativist code (SR-, ER-) de-emphasizes both (anything goes).

It is often tempting to provide illustrative examples of each code, as Maton has done when presenting the theory. For instance, in the field of architecture, your "reputation" or "brand" is just as important to your having specialized knowledge, hence, architecture described in this way reflects an elite code. In mathematics, "who you are" does not matter: It is (theoretically and hypothetically) possible to solve Fermat's last theorem as a high-school student or a professor in that your identity plays no role in determining the basis of achievement. Only the specialist knowledge is important. Thus, mathematics described in this way is known as a knowledge code.

However, these examples betray a complexity. Indeed, as Maton (2014) describes:

> A specific code may dominate as the basis of achievement, but not be transparent, universal, or uncontested. Not everyone may recognise and/or be able to realise what is requires, there may be more than one code present, and there are likely to be struggles among actors over which code is dominant. One can thus describe degrees of code clash and code match" (Maton, 2014, p. 26).

For instance, Maton and Chen identify a "code clash" between the "knowledge code" exhibited by personal approaches to learning by international Chinese students and the "knower code" represented by Higher education pedagogies in Australia (Maton & Chen, 2020). The knowledge code of the educational dispositions of the students reflected an understanding that curriculum that emphasized content knowledge, pedagogies focus on delivery of knowledge to learners and a downplaying of personal or subjective views. The knower code of the teaching practices in the online unit reflected a prioritization of personal experience and emphasizing the need for self-regulating learners to create their own understanding rather than having teachers "deliver" it.

Howard and Maton (2011) similarly identify the "code clashes" and "code matches" underlying teachers' technology integration. In their large-scale study, they find that the different codes exhibited in different subject areas either clashed or matched the code implicit in the Government policy. In noting that mathematics exhibited lower levels of integration of ICTs in contrast with English, they explain: "mathematics teachers often used ICTs to provide different ways for students to learn mathematical skills, English teachers typically described ICTs as useful for providing different ways for students to express themselves (p. 203). Finally, Ellery (2019) identifies the conflict between expectations and experiences, as they explain how learning objectives and formative assessment more clearly support "knowledge code" aims, despite both knowledge and knower code aims expressed as objectives of the course. Practically, this means that skills such as autonomy and independence, self-reflection and engagement are not as explicitly stated or developed through assessment and pedagogy.

In terms of NOS, we can understand the warning of epistemological essentialism indicated that the tendency of science teaching in schools is to be "positivist." Positivism is broadly represented by as a knowledge code in LCT (Figure 2: position A) ER+, SR- because possession of a set of specialized knowledge and skills is valued (e.g., knowing "facts," getting the right answer). In a sense, the NOS movement was a response to this, an acknowledgment that there is a social element in the scientific practice. Recall this statements from the consensus view: "Scientific ideas are affected by social and historical milieu."

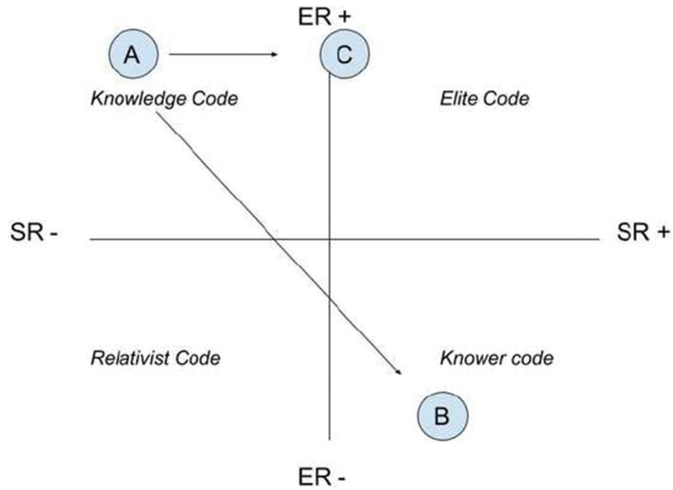

Figure 2. Examples of placements on the specialization plane. Position A represents the view that science is not 'infused with social and cultural values' (social embeddedness). Positions B and C represent views of science as being socially embedded, though to different degrees.

This statement reflects a view that there is a social element to scientific knowledge; that it is, to some degree, influenced by social and historical factors. However, a wholesale acceptance of this social influence may lead to the conclusion that science is socially constructed than not, leading to the kind of "epistemic relativism" mentioned by Romero-Maltrana et al. (2017), where science may seem "as provisional as any other form of knowledge" (p. 1737) or "epistemically equivalent to the social sciences or even the arts and humanities" (Good & Shymansky, 2001, p. 53).

This shift represents a leap from a knowledge code (ER+, SR-) to a "knower code" (ER-, SR+), which is represented as the move from position A to B in Figure 2, even though what we may have been aiming for, is the more modest shift to position C (that it "sometimes" matters who you are, not just what you know).

Essentially, this framework captures the nuances in one aspect of the nature of science; what is valued. Such nuance is not captured in previous models, or left to an elaborate discussion afterward, one that relies on an assumed common understanding or descriptions (of what students meant or what this means in terms of the NOS). Furthermore, it allows for a shift away from atomistic descriptions of students' understandings. Assignments of relative values of ER/SR acknowledge that students may hold a range of different positions, sometimes at the same time. Thus, it doesn't matter exactly "where" on the plane a practice is coded, but where "relative to" other practices. Also, it overcomes the issues of objectively labeling one view "correct" and another "incorrect" (or naïve-sophisticated, informed-uninformed). Instead, we may consider students views as appropriate with respect to the specific context through the notions of "code clashes" or "code matches."

The framework, sociological in nature, also allows science educators and researchers to engage in sociological reasoning. Maton (2014) explains that Specialization begins "from the simple premise that practices are about or oriented towards something and by someone" (p. 25). This inherently facilitates interdisciplinary thinking. Epistemic and Social relations relate to History, just as well as Science. Maton (2014) explains that a key benefit of the approach is that:

> The framework develops within and for empirical research into substantive problems . . . LCT enables research to go beyond endless and ad hoc empirical descriptions to explore the organizing principles underlying practices, dispositions and contexts. The framework allows researchers to get . . . 'under the surface' of appearances. Anlyses of their organising principles can systematically reveal underlying similarities and diffrences with other practices, as well as change over time. (p. 20)

Method

The VNOS-C was used as a pre- and posttest across at the beginning and end of second semester of a Bachelor of Science Education degree (the qualifying degree for secondary science teachers). The preservice teachers had completed one semester of Science subjects including Biology and Chemistry subjects. They also take an introduction to psychology subject. By the end of the year/second semester, they will have completed several Biology and Chemistry units and the majority have also completed an Introductory Astronomy subject. The cohort has not taken any education subjects, including "methods" subjects (Science Pedagogy subjects), which commence from the second year of their degree but did take a "Big Ideas" in science subject, and so it was expected that there might be some improvement in NOS views due to their exposure to tertiary science subjects and a general science subject.

In total, 27 pre- and post-responses were collected (that is, 27 physical tests were collected from the full cohort of preservice teachers, though not all questions were answered by all students) and three interviews were conducted two to three months after the end of semester as per VNOS-C administration recommendations. Participants completed their responses in a pen-and-paper format, and preservice teachers were given their "pre-tests" at the time of the "post-test," to determine for themselves whether their views had changed or developed.

The analysis was conducted over two cycles. First, the suggested method for analysis and reporting of the VNOS-C were followed in order to compare the "new" approach to the existing. The key question related to the statement: "Scientific ideas are influenced by their social and historical milieu" (henceforth "social embeddedness") is question 9, and it is provided below.

> Q9 (VNOS-C): Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced. If you believe that science reflects social and cultural values, explain why. Defend your answer with examples. If you believe that science is universal, explain why. Defend your answer with examples.

However, the social embeddedness tenet can be expressed in the responses of any of the 10 questions in the VNOS-C, as per Lederman et al. (2002). In this case, 12 responses from Question 1 were therefore included in the analysis. Question 1 is provided below.

> What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

It might also be expected that students would have expressed some "social embeddedness" ideas when answering questions aimed at testing subjectivity, but on the whole, these questions were not answered well, and did not reflect any "social embeddedness" ideas.

In analyzing the VNOS-C, student responses were coded as either "Informed," Naïve or Mixed. Whether a change had occurred between pretest and posttesting was also recorded.

In the second cycle, the same set of responses were re-analyzed using LCT (Specialization). Specialization measures "degrees of strength" along two dimensions, one representing strengths of epistemic relations and the other strengths of social relations. Where only epistemic relations were discussed, a point on the ER axis was plotted, on a 3 point scale (-, 0, +) (SR was coded at the 0 point). Where only social relations were discussions, a point was plotted on a 3-point scale on the SR axis (ER was coded at the zero point). Where both were mentioned, a point was plotted on the Cartesian plane.

Interviews were used to provide additional detail to student responses, in order to validate assignments to categories. Interview participants were recruited via convenience sampling (i.e., all students who had consented to take part in this aspects of the research). As per the administration protocol for the VNOS tools, interviews were used to clear up ambiguities and ensure interpretations matched respondents meaning (Lederman et al., 2002). Approval for the research was obtained from the local ethics committee.

Results

Overall, 22 responses to question 9 were coded, as they were directly responding to the question corresponding to the "social embeddedness," and 12 responses from Question 1 were also coded to this tenet (Question 1 provided below).

Cycle one pre- and post-responses for questions 9 and 1 in relation to the "social embeddedness" tenet are presented in Figure 3.

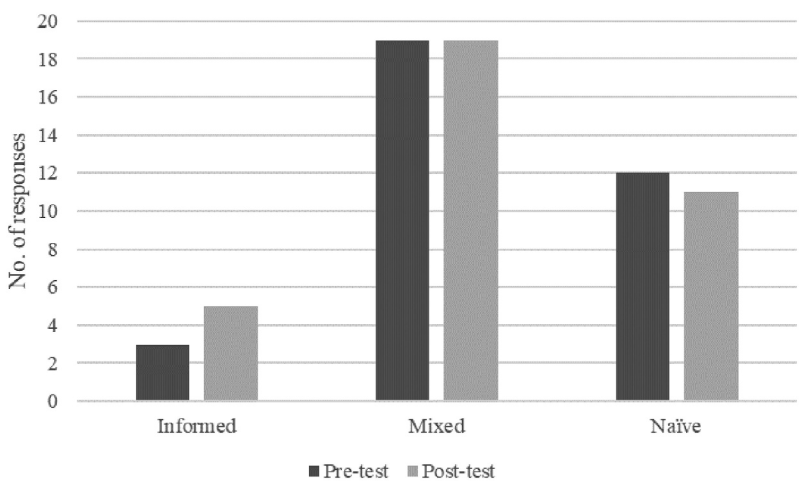

Figure 3. Traditional "cycle one" pre- and post-test responses from preservice teachers, coded as "Informed," "Mixed," and "Naïve" on the tenet of "social embeddedness."

In relation to Question 9, we find most preservice teachers held the view that science is "Universal," either outright, constituting a Naïve conception, or partially, constituting a Mixed conception (Figure 3). A small number (n = 3) in the pretest, held informed views. On the whole, the preservice teachers' views did not change across the semester, apart from one student who gave a Naïve view in the pretest and an Informed view in the posttest. Two preservice teachers did not answer in the pretest but did provide answers in the posttest, one was a Mixed, and the other was Informed.

For Question 1, although preservice teachers were not directly responding to the question about social embeddedness, some (n = 12) did discuss their views on the nature of scientific knowledge. All responses coded from Q1 to this node were similar, as they were responding to the question of "what is science" (see, Table 2 for an example). Responses were coded as either Naïve (n = 2) or Mixed (n = 10) and did not change from pre to posttest administrations. Responses coded to this node included the discussion of "facts" and "objectivity" (see, Table 2). Responses not coded to this node would be coded to the "Empirical" tenet, and included responses that discussed the scientific method, research and scientific practice (but not the nature of scientific knowledge). An informed view acknowledges that science is influenced by social and historical factors and provides an appropriate example. Typical responses are provided in Table 2 below (quotations are verbatim from preservice teachers' writing and may contain spelling errors).

In the cycle two, analysis is presented in Table 3 and Figure 4. Results show that preservice teachers take a view that epistemic relations and social relations are important. In some cases, only one element is referred to (e.g., just the "epistemic relations" are important), in other cases, both are discussed together. The responses, overall, represent a view of science as either an elite or knowledge code, with strong social relations and strong epistemic relations being represented (Figure 4).

This indicates that they have a strong conception that science is empirical, that it relies on tangible data gathered about the natural and physical world. Some of these ideas included views that science was *only* about these "facts," or that it was somewhat subjective (ER+, SR-), though others acknowledged that there might be some social and cultural influences (ER+, SR+).

Table 2. Illustrative examples of preservice teachers' responses coded to the three categories of "Informed," "Mixed" and "Naïve."

	Examples
Informed	Science is infused with social & cultural values. Historically our ideas of science have changed with changes in society, influencing the research that takes place. The church preventing scientific research into astronomy, the creation of atomic energy & atomic bomb during world war 2, creation of ammoniom for use. in explosives WWI (Q9)
Mixed	I believe when the social & cultural aspects of people were completely orientated around religion & the bible, science was infused with social & cultural values, however, now that society is more open to other possibilities, theories & concepts, science has (or is becoming more) become universal. (Q9)
Naïve	Science is uneffected by cultural and societal norms. This can be seen by the accepting of similar concepts worldwide. For example, USA, Australia and Germany are all very different countries, yet none of them dispute the influence of DNA on an organism. (Q9) Science is the explanation and study of the world around us. Science is different from other studies as it consists of observable laws etc. and is non-subjective. Unlike other areas of study such as religion, its content does not vary according to each person, and is not shaped by culture, sex, social context etc. Science is a non-man made subject, the study of science is. Without the existance of Humans, science continues to exist. Humans do not create science, we can only use it. (Q1)

Table 3. Illustrative examples of preservice teachers' responses coded along two dimensions representing strengths of epistemic relations and social relations on a 3 point scale (−1, 0, +1).

Strengths of Epistemic and social relations	Example responses
ER+ (SR_0)	Science is an objective view on how things work, that is analytical in nature and bases knowledge on research and data. It's different because it has only an answer based on testable truths. (Q1)
SR+ (ER_0)	Science is subjective. Science is what cultural belief we give it as fact is not (Q9)
SR- (ER_0)	Science is uneffected by cultural and societal norms. This can be seen by the accepting of similar concepts worldwide. For example, USA, Australia and Germany are all very different countries, yet none of them dispute the influence of DNA on an organism. (Q9)
ER+, SR-	Science is the explanation and study of the world around us. Science is different from other studies as it consists of observable laws etc. and is non-subjective. Unlike other areas of study such as religion, its content does not vary according to each person, and is not shaped by culture, sex, social context etc. Science is a non-man made subject, the study of science is. Without the existance of Humans, science continues to exist. Humans do not create science, we can only use it. (Q1)
ER+, SR+	Most Science is universal. It is governed by laws that hold true in 100% of the observable universe (e.g., gravity). Some science may be influenced by society/cultue, such as education psychology (e.g., most IQ testing favors westernized cultures). (Q9)

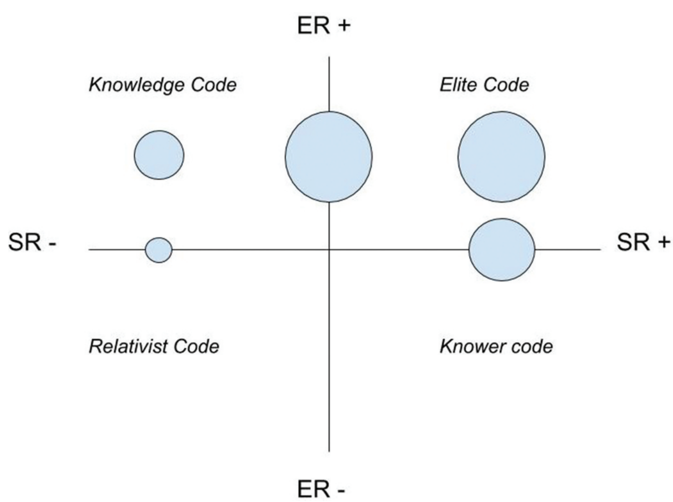

Figure 4. Preservice teachers' Nature of Science views on the "social embeddedness" tenet on the specialization plane.

The following three excerpts act as illustrative examples of the comparisons between the two cycles. The first response was coded as "Informed" in cycle one, and (ER-, SR+) in cycle two and would be considered a fairly typical and therefore straightforward response to assign to the three cycle one categories.

> Science is a reflection of social and cultural values of the time, as each theory is starred by someones idea about a specific thing, which is influenced by there context (includes social and cultural values), for example, when catholicism was the main religious belief many scientists based their theories on the bible, such as the earth was the centre of the universe. (ER-, SR+), Informed

The second response was coded as naïve in cycle one, and (ER+, SR_0) in cycle two. For cycle one, the coding scheme clearly articulates that science is not "universal," as it defines universal in the question stem as "not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced." However, one might argue that the universality discussed here is appropriately and validly discussed.

> Science is universal, as it is drawn from tangible/reproducable results with collaboration on projects crossing boarders & continents. For example, the Hadron Collider a multinational facility open to numerous countries. (ER+, SR0), Naïve

Finally, the third example was coded as Mixed in cycle one, and (ER+, SR+) in cycle two. Here, the student is expressing the view that science is universal *and* that it is influenced by social and historical values. As with Tsybulsky et al. (2018), the student is expressing the social and cultural influences as present, but undesirable.

> I believe science is universal. That it should transcend national/cultural boundaries. Certain laws are widely accepted by the world such as Newton's Laws. Research into our bodies, DNA, and our systems should be widely accepted, in both treatment and prevention of health problems. However, barriers are present across cultural beliefs. Particularly in biology and viewing animal bodies and systems along with evolution, largely due to religion beliefs. This supports that science is infused with social and cultural values. (ER+, SR+), Mixed

Both cycles were also supported by interview data, to support interpretations of meaning. Three interviews were conducted for this purpose, with responses to the question of social embeddedness ranging from between 300 and 2000 transcribed words. The interviews were used to validate assignments. An example is provided below. This example was chosen because it was similar to other responses to this question (Question 9):

> I believe in both as both are true in my opinion. science for centries has been infused with many things like the catholic church, phylosiphes & politics e.g., Gaelio? was told he couldn't do his maths for the case of that the earth was not the centre of the solar system. & Einstien helping to create nuclear bombs due to politics. it's only really now that its universal & not truly infused with outside things as they are trying to be as objective as possible.

This response was coded as Mixed in cycle one, because it contains both the ideas that science is influenced by social and cultural factors *and* that it is not. Similarly, for the same reasons, it was coded as ER+, SR+ for cycle two, acknowledging that science is "both" universal and influenced by social and cultural factors. In the interview, this participant further explained that:

> I probably more sit that it's embedded but just not as much as it was before, like before, it was so embedded, but now . . . scientists are a bit more independent . . . but I still think that, well, there's always, you know, other political or something that hovers over them

The cycle two analysis thus provides us with the potential for further analysis. As way of demonstration, we could further represent the above response on the specialization plane to reflect the nuances in the response. The preservice teacher expresses that in the past (B), science is considered to have weaker epistemic relations and stronger social relations (ER-, SR+), reflecting a "knower code." Today, science exhibits, stronger epistemic relations and weaker social relations (A) (See, Figure 5)

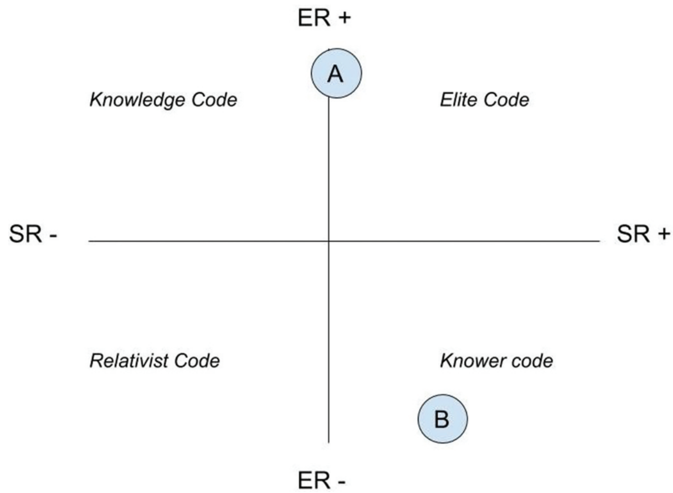

Figure 5. Examples of placements on the specialization plane. The student believes scientific practices now (A) differ from how science was practiced in the past (B).

There were similar nuances that could be explored further within the Specialization plane. For instance, many students considered the knowledge code as the "ideal," the way science should be: universal and free of social influences (ER+, SR-) but acknowledged that it is unavoidably affected by social factors (ER+, SR+). In another response, Physics is considered as having stronger epistemic relations and weaker social relations (ER+, SR–) when compared to the field of Biology (ER+, SR 0/+).

One student expressed different ideas across the two questions. Take one student's response to how science is different to other areas, like religion (question one):

> Science is a discipline of knowledge and belief that bases itself on research and evidence-based findings. I believe it differs from religion and philosophy, as these are more faith based and driven from individual ideas, not fact.

This student's answer to question nine is:

> Science is a reflection of social and cultural values of the time, as each theory is started by someones idea about a specific thing, which is influenced by their context (includes social and cultural values), for example, when catholicism was the main religious belief many scientists based their theories on the bible, such as the earth was the centre of the universe.

This student is expressing both a Sophisticated view, that science is influenced by social context and a Naïve view, that science is based on "fact," rather than a collection of individual's ideas. In the first instance, however, they seem to be comparing science to other disciplines: they are comparing relative values of epistemic relations and social relations. Compared to religion or philosophy science does exhibit a knowledge code (ER +, SR-), where "possession of specialised knowledge, skills or procedures is emphasised as the basis of achievement and the dispositions of authors or actors are downplayed." However, in question nine, the student is asked specifically about whether social factors play a role. In this case, they provide a response that indicates stronger social relations (SR +), allowing for a judgment around appropriateness to context, rather than Naïve or Sophisticated.

Discussion

The two analyses presented above provide us with different perspectives. In cycle one, we observe that conceptions relating to the "social embeddedness" of science are predominantly Mixed, in that they include a variety of views. Such analysis provides a good first step in assessing NOS views and how they change, however, there is significant detail that remains not captured, as the Mixed views are considerably varied. These results are consistent with critiques focused on the over-simplistic nature of the NOS consensus view and the associated tenets (e.g., Alters, 1997; Hodson & Wong, 2017).

In order to better capture the varied meaning in the students' responses, a second analysis, cycle two, was undertaken. In this approach, the "social embeddedness" tenet was further explored using LCT (Specialization) to analyze the same set of the preservice teachers' responses. We find that most responses either expressed the notion that "knowledge" was what mattered (ER+) in isolation or that they acknowledged that both knowledge and knowers were important (ER+, SR+). These essentially reflect "knowledge" and "elite code" views: "what you are is important," and in some cases, "who you are" is also valued (Maton, 2014). There were a smaller group who only discussed the importance of the social element in terms of knowledge (SR+) and there was a group who explicitly rejected the relevance of any social or cultural influences (ER+, SR-).

This analysis is a launching pad for further consideration. Science has typically been characterized in LCT as a knowledge code, it matters "what you know," not "who you are" (Maton, 2014), reflective of a broader conception of science as "objective," but this is not the whole story, and only generally true when considering science *relative to* other disciplines. Research, practitioners and scientists have rejected the notion that "knowledge" or "facts" are *all* that matters in science. There is an element of "social embeddedness" that is inherent and unavoidable (indeed necessary) in scientific practice (Lederman, 2007). In the consensus view, in terms of the "social embeddedness" tenet, traditional analyses code positivist views as Naïve, thus implying they must be changed. However, this approach has been criticized for being over-simplistic. The question then becomes about which views are appropriate and when. Clough (2007) explains that this "does not mean that esoteric philosophical distinctions are sought, but that the nature of science is understood" (p. 39). Indeed, the embrace of positions too close to either end of the spectrum seem unhelpful. For instance, it is well known that school science often presents too strong a "positivist" view of science, a view that gives students the impression that everything is known and facts are there to discover (Sin, 2014). At the other end of the scale, recognition that science is inherently a social and historical construction might give the impression that this is all that matters, and thus personal views are just as good as "facts" (Good & Shymansky, 2001; Russ, 2014). The key, Clough (2007) points out, is rather than assigning certain ideas right or wrong, or "black or white," it is more appropriate to consider these ideas as existing on a spectrum. Holding one view might have utility in one context but not another. LCT(Specialization) allows for this cline to be more explicitly realized, with more nuance, and free of judgment, thus offering a more sophisticated way of exploring these differences. For example, we can trace preservice teachers' views on the specialization plane as reflective of different contexts (Figure 5, the past, the present), or for different subjects. We could also trace the epistemic views of NOS themselves (Figure 2). We might ask, for example: in which codes do we want students to be operating in specific contexts (disciplinary contexts, conducting an experiment, completing a project, answering a question)? What sort of changes do we want to encourage? How do we measure and track these changes? This is particularly important when assessing students' NOS views in context. For example, in the burgeoning research on socio-scientific issues, it is insufficient to assess students views within just the one context (i.e., the VNOS-C), rather, views should be considered within the context they arise (Irez et al., 2018). We know that practicing teachers do not hold sophisticated or nuanced views of NOS, even today (Kite et al., 2021), and it is clear that we require a significantly sophisticated understanding of NOS concepts in order to help encourage their development (Valente et al., 2018). Because the social embeddedness tenet has been shown to be particularly troublesome, and with ideological controversies becoming increasingly common in NOS discussions, it is important to find ways to increase precision around this tenet—and others—to ensure PST, teachers, and of course students, develop an holistic—and accurate- view of the nature of science.

Limitations and future research

In this paper, it is argued that a new method of analyzing student responses using LCT(Specialization) has utility in terms of understanding NOS views. As such, it has a place amongst the catalog of NOS assessment McComas et al. (2020) argues is necessary to capture its different elements and characteristics. Nevertheless, the approach is limited in scope. It considers only one aspect of the Nature of Science and has been tested with only one NOS instrument. Future research might use the LCT(Specialization) analysis in different contexts, such as in the design and analysis of NOS questionnaire items, or in analyzing classroom discourse, to track how views change over time. In addition, the utility of this analysis could be tested in actual teaching and learning contexts. Teachers might find the tool a useful one to both come to terms with, and address with students, the complexities and nuances of this otherwise abstract but important idea in science education.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

Akerson, V. L., Morrison, J. A., & McDuffie, A. R. (2006). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching*, *43*(2), 194–213. https://doi.org/10.1002/tea.20099

Alters, B. J. (1997). Whose nature of science? *Journal of Research in Science Teaching*, *34*(1), 39–55. https://doi.org/10.1002/(SICI)1098-2736(199701)34:1<39::AID-TEA4>3.0.CO;2-P

Bell, R., Abd-El-Khalick, F., Lederman, N. G., McComas, W. F., & Matthews, M. R. (2001). The nature of science and science education: A bibliography. *Science & Education*, *10*(1–2), 187–204. https://doi.org/10.1023/A:1008712616090

Burke, L. E. C. A., Wessels, A., & McAvella, A. (2018). Using theater and drama to expose and expand the epistemic insights of youth regarding the nature of science. *Research in Science Education*, *48*(6), 1151–1169. https://doi.org/10.1007/s11165-018-9782-z

Clough, M. P. (2007). Teaching the nature of science to secondary and post-secondary students: Questions rather than tenets. *The Pantaneto Forum*, *25*(1), 31–40. http://pantaneto.co.uk/teaching-the-nature-of-science-to-secondary-and-post-secondary-students-questions-rather-than-tenets-michael-clough/

Cofre, H., Nunez, P., Santibanez, D., Pavez, J. M., Valencia, M., & Vergara, C. (2019). A critical review of students' and teachers' understandings of nature of science. *Science & Education*, *3–5*(3–5), 205. https://doi.org/10.1007/s11191-019-00051-3

Dagher, Z. R., & Erduran, S. (2016). Reconceptualizing the nature of science for science education. *Science & Education*, *25*(1–2), 147–164. https://doi.org/10.1007/s11191-015-9800-8

Ellery, K. (2019). Congruence in knowledge and knower codes: The challenge of enabling learner autonomy in a science foundation course. *Alternation*, *26*(2), 213–239. https://doi.org/10.29086/2519-5476/2019/v26n2a10

Erduran, S., & Dagher, Z. R. (2014). Reconceptualizing nature of science for science education. In S. Erduran & Z. R. Dagher (Eds.), *Reconceptualizing the nature of science for science education* (pp. 1–18). Springer.

Georgiou, H. (2020). Characterising communication of scientific concepts in student-generated digital products. *Education Sciences*, *10*(1), 18.

Georgiou, H., Maton, K., & Sharma, M. (2014). Recovering knowledge for science education research: Exploring the "Icarus effect" in student work. *Canadian Journal of Science, Mathematics and Technology Education*, *14*(3), 252–268.

Good, R., & Shymansky, J. (2001). Nature-of-science literacy in benchmarks and standards: Post-modern/relativist or modern/realist? In F. Bevilacqua, E. Giannetto, & M. R. Matthews (Eds.), *Science education and culture* (pp. 53–65). Springer, Dordrecht. https://doi.org/10.1007/978-94-010-0730-6_5

Hodson, D., & Wong, S. L. (2017). Going beyond the consensus view: Broadening and enriching the scope of NOS-oriented curricula. *Canadian Journal of Science, Mathematics and Technology Education*, *17*(1), 3–17. https://doi.org/10.1080/14926156.2016.1271919

Howard, S., & Maton, K. (2011). Theorising knowledge practices: A missing piece of the educational technology puzzle. *Research in Learning Technology*, *19*(3), 191–206. https://doi.org/10.3402/rlt.v19i3.17109

Irez, S., Han-Tosunoglu, C., Dogan, N., Cakmakci, G., Yalaki, Y., & Erdas-Kartal, E. (2018). Assessing teachers' competencies in identifying aspects of nature of science in educational critical scenarios. *Science Education International*, *29*(4), 274–283. https://doi.org/10.33828/sei.v31.i4.10

Kaya, E., Erduran, S., Aksoz, B., & Akgun, S. (2019). Reconceptualised family resemblance approach to nature of science in pre-service science teacher education. *International Journal of Science Education*, *41*(1), 21–47. https://doi.org/10.1080/09500693.2018.1529447

Kinchin, I. M., Möllits, A., & Reiska, P. (2019). Uncovering types of knowledge in concept maps. *Education Sciences*, *9*(2), 131. https://doi.org/10.3390/educsci9020131

Kite, V., Park, S., McCance, K., & Seung, E. (2021). Secondary science teachers' understandings of the epistemic nature of science practices. *Journal of Science Teacher Education*, *32*(3), 243–264. https://doi.org/10.1080/1046560X.2020.1808757

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331–359. https://doi.org/10.1002/tea.3660290404

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell, K. Appleton, & D. L. Hanuscin (Eds.), *Handbook of research on science education* (Vol. 2, pp. 831–879). Routledge.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497–521. https://doi.org/10.1002/tea.10034

Lederman, N. G., & Lederman, J. S. (2019). Teaching and learning nature of scientific knowledge: Is it Déjà vu all over again? *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 6. https://doi.org/10.1186/s43031-019-0002-0

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry—The views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching*, *51*(1), 65–83. https://doi.org/10.1002/tea.21125

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Pre-service teachers' understanding and teaching of nature of science: An intervention study. *Canadian Journal of Science, Mathematics and Technology Education*, *1*(2), 135–160. https://doi.org/10.1080/14926150109556458

Lee, Y.-J., & Wan, D. (2022). How complex or abstract are science learning outcomes? A novel coding scheme based on semantic density and gravity. *Research in Science Education*, *52*, 493–509. https://doi.org/10.1007/s11165-020-09955-5

Luckett, K. (2012). Disciplinarity in question: Comparing knowledge and knower codes in sociology. *Research Papers in Education*, *27*(1), 19–40. https://doi.org/10.1080/02671521003592655

Maeng, J. L., Bell, R. L., St.Clair, T., Gonczi, A. L., & Whitworth, B. A. (2018). Supporting elementary teachers' enactment of nature of science instruction: A randomized controlled trial. *International Journal of Science Education*, *40*(18), 2245–2264. https://doi.org/10.1080/09500693.2018.1528643

Maton, K. (2014). *Knowledge and knowers: Towards a realist sociology of education*. Routledge.

Maton, K., Martin, J. R., & Doran, Y. J. (Eds.). (2021). *Teaching science: Knowledge, language, pedagogy*. Routledge.

Maton, K., & Chen, R. T. H. (2020). Specialization codes: Knowledge, knowers and student success. In J. R. Martin, K. Maton, & Y. J. Doran (Eds.), *Accessing academic discourse: Systemic functional linguistics and legitimation code theory* (pp. 35–58). Routledge.

McComas, W. F. (Ed). (1998). *The nature of science in science education*. Springer.

McComas, W. F. (2020a). Considering a consensus view of nature of science content for school science purposes. In W. F. McComas (Ed.), *Nature of science in science instruction* (pp. 23–34). Springer. https://doi.org/10.1007/978-3-030-57239-6

McComas, W. F. (Ed.). (2020b). *Nature of science in science instruction: Rationales and strategies*. Springer Nature.

McComas, W. F. (2020c). Principal elements of nature of science: Informing science teaching while dispelling the myths. In W. F. McComas (Ed.), *Nature of science in science instruction* (pp. 35–65). Springer. https://doi.org/10.1007/978-3-030-57239-6

McComas, W. F., Almazroa, H., & Clough, M. P. (1998). The nature of science in science education: An introduction. *Science & Education*, *7*(6), 511–532.

McComas, W. F., & Clough, M. P. (2020). Nature of science in science instruction: Meaning, advocacy, rationales, and recommendations. In W. F. McComas (Ed.), *Nature of science in science instruction* (pp. 3–22). Springer. https://doi.org/10.1007/978-3-030-57239-6

McComas, W. F., Clough, M. P., & Nouri, N. (2020). Nature of science and classroom practice: A review of the literature with implications for effective NOS instruction. In McComas (Ed.), *Nature of science in science instruction* (pp. 67–111). Springer.

Mesci, G., & Schwartz, R. (2017). Changing preservice science teachers' views of nature of science: Why some conceptions may be more easily altered than others. *Research in Science Education*, *47*(2), 329–351. https://doi.org/10.1007/s11165-015-9503-9

Romero-Maltrana, D., Benitez, F., Vera, F., & Rivera, R. (2017). The 'nature of science' and the perils of epistemic relativism. *Research in Science Education*, *49*(6), 1735–1757. https://doi.org/10.1007/s11165-017-9673-8

Rudge, D. W., & Howe, E. M. (2013). Whither the VNOS? In C. C. Silva & M. E. B. Prestes (Eds.), *Aprendendo ciência e sobre sua natureza: Abordagens históricas e filosóficas (Proceedings of the First Latin American Conference of the International History, Philosophy, and Science Teaching Group)* (pp. 219–228). Tipographia Editora Expressa.

Russ, R. S. (2014). Epistemology of science vs. epistemology for science. *Science Education*, *98*(3), 388–396. https://doi.org/10.1002/sce.21106

Sin, C. (2014). Epistemology, sociology, and learning and teaching in physics. *Science Education*, *98*(2), 342–365. https://doi.org/10.1002/sce.21100

Summers, R., Abd-El-Khalick, F., & Brunner, J. (2020). Evidence and rationale for expanding the views of nature of science questionnaire. *Teaching, Leadership & Professional Practice Faculty Publications*. https://commons.und.edu/tlpp-fac/7

Tsybulsky, D., Dodick, J., & Camhi, J. (2018). The effect of field trips to university research labs on Israeli high school students' NOS understanding. *Research in Science Education*, *48*(6), 1247–1272. https://doi.org/10.1007/s11165-016-9601-3

Valente, B., Maurício, P., & Faria, C. (2018). Understanding the process and conditions that improve preservice teachers' conceptions of nature of science in real contexts. *Journal of Science Teacher Education*, *29*(7), 620–643. https://doi.org/10.1080/1046560X.2018.1485399