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Does Teacher Epistemic Cognition Relate to Their Ability to Promote Investigable Next Generation Science Standards Aligned Questions?

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Abstract

The foundation of science is based on the premise that humans make observations and ask questions about the natural world and then attempt to make sense of it by evaluating available evidence. These scientific practices became aspects of expected instruction when the Next Generation Science Standards (NGSS) were created. A key aspect of the NGSS is that science begins when a question about the natural world is raised. For teachers to meet the expectations of the NGSS, they should allow students to explore phenomena, raise authentic questions, and explore them through inquiry. However, giving students autonomy to raise their questions poses potential issues, primarily what if their questions don't align with the concepts teachers are required to teach. In this study, the researchers focused on Science and Engineering Practice (SEP), Asking Questions and Designing Problems, by asking a group of teachers with divergent epistemic orientations toward science what they would do in a situation where students raised questions that do not align with the concepts they are required to teach. Participants were presented with vignettes depicting a classroom scenario in which a teacher facilitated a lesson, allowing students to explore a phenomenon. Within these vignettes, students generated questions that were untestable and did not align with the targeted concepts and disciplinary core ideas outlined in NGSS. The researchers found that the two groups of teachers have different suggestions on what to do in this situation.

Keywords: Epistemic Cognition, Argumentation, Dialogic Feedback

Introduction

The value of students' questions has been a focus of many science education scholars for decades (Alexander, 2017; Chin & Kayalvizhi, 2002; Hackling & Murica, 2010; Kuhn, 2010;

Osborne, et al., 2004). Allowing students to ask authentic questions helps students connect their observations to their prior knowledge and engage in a critical aspect of scientific literacy (Chin & Osborne, 2008; Herranen & Aksela, 2019). The practice of questioning the unknown, or not well understood, is the beginning of any scientific endeavor. It is an aspect of all contemporary science standards (see UK Department for Children, Schools and Families [DCSF], Australian Curriculum, Assessment and Reporting Authority [ACARA], Promoting Inquiry in Mathematics and Science Education across Europe project [PRIMAS], Next Generation Science Standards [NGSS]). In the United States, the Science and engineering practices (SEPs) are essential components of the NGSS and assist in helping teachers understand that their students' role in learning science is to engage in practices that professional scientists and engineers use to reach their conclusions (NGSS, Lead States, 2013). Asking Questions and Defining Problems is a SEP, and the National Research Council (NRC, 2012) of the standards expects students to be involved in the process. The National Research Council (NRC, 2012) described the first SEP as:

> Students at any grade level should be able to ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations. For engineering, they should ask questions to define the problem to be solved and to elicit ideas that lead to the constraints and specifications for its solution. (NRC Framework 2012, p. 56).

Allowing students to engage in scientific practices like making observations and developing questions to investigate is highlighted in the Association for Science Education (ASE, 2018) list of best practices for science teachers. The ASE (2018) cited benefits like developing problem-solving skills, working independently, and developing skills to think like a scientist. The National Research Council (2012) has argued that "from the earliest grades, students should have opportunities to carry out careful and systematic investigations, with appropriately supported prior experiences that develop their ability to observe and measure and to record data using appropriate tools and instruments" (p. 60-61). Science teachers who aim to embrace expectations of the NGSS should embrace a pedagogy that promotes creativity and curiosity, which includes having students develop investigable questions after exploring phenomenon (Lee et al., 2000; Like et al., 2019; Like, Morgan, Escalada & Burns, 2019).

However, asking students to develop questions to investigate is typically omitted from school science (Alexander, 2017; Flup, 2002; NRC, 2012). Traditional science classrooms often rely on a one-way flow of information, with teachers acting as knowledge distributors and students as passive receivers (National Research Council, 2012; Osborne et al., 2004). This approach can paint science as a static body of facts, neglecting the debate and questioning that are hallmarks of scientific progress. Packer (2001) argued that schools have a responsibility to equip students with the ability to "transform themselves" (p. 74) rather than be passive observers who are expected to memorize and repeat what they are taught. Therefore, if the goal is to prepare students to think and act like scientists, a pedagogical approach that encourages questioning and debate, not a static view of knowledge, is essential. Research in questioning has found that elementary-aged students can generate insightful investigable questions. However, many struggle to pose these types of questions due to the lack of opportunities presented to them in the classroom (Bismack et al., 2022; Chin & Kayalvizhi, 2002; Hackling & Murica, 2010; Kuhn, 2010; Suh et al., 2022).

For students to fully comprehend the scope of science content, they must be proficient in questioning phenomena, understanding the nature of scientific inquiry, and interpreting data and evidence through a scientific lens (Vincent-Lancrin et al., 2019). Students must grasp scientific knowledge and the epistemic goals and processes underpinning science. Developing more scientifically literate students requires an integrated understanding of content knowledge, procedural knowledge, and the epistemic foundations of science (Crawford & Capps, 2013).

Effectively implementing the NGSS requires a significant change in science teachers' understanding of science. This includes their views on the nature of scientific knowledge, how science is practiced, and the core scientific concepts (Kite et al., 2021; Vincent-Lancrin et al., 2019). Since implementing these practices requires a shift in teachers' beliefs and knowledge, research is crucial to understand what motivates teachers to integrate science practices into their classrooms (Suh et al., 2022). However, growing evidence shows that teachers may not be fully equipped to implement these ambitious goals (Chinn & Duncan, 2021).

Several scholars have highlighted the challenges in aligning the expectations of the NGSS with teachers' instructional practices (Osborne, 2014; Richmond et al. 2016; Smith & Nadelson, 2017). In classroom investigations, students spontaneously generate questions; however, these questions can be off target, challenging to manage, and unsuitable for scientific inquiry (Chin & Kayalvizhi, 2002). Frequently, these questions focus on straightforward concepts rather than exploring complex ideas or uncovering causal mechanisms behind phenomena (Touchet et al. 2024). This underscores the need for improved instructional practices where teachers still allow students autonomy to raise questions about what they are curious about, but keep the inquiry aligned with the required content. However, simply telling the teacher to change their instructional practice is a strategy with mixed results, at best (Danielson et al., 2025; Hewson & Hewson, 1984; Khort, 2025). Recent literature has indicated that teachers who use pedagogical practices that align with reform-based standards have common epistemological viewpoints about science (Braten, et al., 2017; Ford & Forman, 2015). The following section will explore the correlation between teacher epistemic cognition and instructional practices.

Literature Review

A common definition of Epistemic Cognition (EC) is the cognitive processes that include "all kinds of explicit or tacit cognitions related to epistemic or epistemological matters" (Chinn et al. 2011, p.141). Science has a unique epistemology where fundamental issues of knowledge are socially justified through argumentation (Alexander, 2017; Berland & Reiser, 2009; Ford, 2015). There are clear connections between the philosophies of science education and EC because both are primarily social (Greene, et al., 2008). Furthermore, scientific knowledge is considered tentative but durable (NRC, 2012), in that claims are based on the best available evidence at the time. This interpretation of knowledge correlates with Kuhn, Cheney, and Wienstock's (2000) view that sophisticated epistemological beliefs consider knowledge as tentative rather than certain, constructed by learners rather than transferred from authority.

However, contemporary views of EC consider situations when governing knowledge rather than a static, *one-size-fits-all approach*. For example, scientists attempting to develop a vaccine rely on vigorous argumentation and critique of presented claims. For those claims to become scientific knowledge, they must be certified by the community of experts in the field. The source of that claim may be initiated from a single source, but for it to become accepted, the author must internalize the critiques of peers. Some of those critiques may be accepted, but the original claim may need to be amended. Other critiques are rejected, but engaging in the uncertainty requires the author to self-evaluate their ideas. This exercise emphasizes the epistemology of science that: "individuals don't construct scientific knowledge, communities do" (Ford & Forman, 2015, p. 143).

Numerous studies have claimed that teachers' beliefs and practices are related (Brownlee & Berthelsen, 2006; Fishmen et. al, 2017; Hayes & Trexler, 2015; Kelly, 2016). However, few studies have examined the relationship between teachers' epistemic cognition (EC) and their ability to support students in developing investigable questions, although the connection appears theoretically sound. For instance, if a teacher held a view that knowledge is static and their role is to give students the facts, then simply providing the students with the question, providing the steps of the instruction, and telling them what happened in the investigation would be the most effective way to instruct. Bakhtin (1981) described teachers with these beliefs as someone who "pretends to possess a ready-made truth" (p.10) and "someone who knows and possesses the truth and instructs someone ignorant of it and in error" (Bakhtin, 1981, p.81). These teachers may fail to recognize the value of using dialogic feedback to support students in developing questions. When students struggle to formulate answers or express misconceptions, such teachers are likely to perceive providing the correct information as the most appropriate course of action.

Consequently, teachers who view knowledge as a constructed social process would view classroom resources spent on students wading through the murkiness of knowledge construction as a priority. The potential to promote engagement with the process of science with students outweighs the urge to end the conversation by interjecting with the *correct* question. Kuhn (2016) supported this perspective, emphasizing that mastering scientific practices requires students to understand procedural knowledge and the epistemic principles inherent in these practices. Only when students recognize "the purposes and ends of the practices they engage in" (Kuhn, 2016, p. 2) can they fully appreciate how scientific knowledge is constructed and apply this understanding to other domains. Therefore, teachers should encourage active participation in essential scientific practices—such as generating questions, planning and conducting investigations, and analyzing and interpreting data—that enhance students' comprehension of science's processes and epistemic nature (NRC, 2012).

Achieving this goal, however, requires teaching approaches that differ fundamentally from traditional methods focused on knowledge transmission. Instead, teachers must create generative learning environments that foster the simultaneous development of scientific concepts and an understanding of the epistemology of science (Windschitl, 2002). This shift necessitates that teachers adopt epistemic orientations aligned with student-centered, knowledge-generation approaches rather than teacher-centered, knowledge-replication models (Duschl, 2008; Fiorella & Mayer, 2015; Jiménez-Aleixandre & Crujeiras, 2017; Yaman & Hand, 2024).

Moreover, educators must navigate the dual responsibility of facilitating students' understanding of scientific inquiry while adhering to state-mandated science curriculum requirements. On the one hand, educators are accountable to these standards and often emphasize attaining conventional understandings of specific scientific concepts (Ahtee et al., 2011; Duschl, et al., 2007). Some educators may lean towards employing monological teaching approaches excessively. On the other hand, a contemporary approach to science education promotes students' active construction of knowledge through questioning phenomena and engaging in the process of argumentation to understand the scientific principles behind the observation (Bråten, et al., 2017; Duschl & Osborne, 2002; Windschitl & Stroupe, 2017). Thus, educators face a dilemma regarding when to assert control over certain aspects of knowledge development in classroom discourse and when to encourage students to engage in knowledge construction amid epistemic uncertainty. The researchers hypothesize that educators' epistemic cognition concerning science instruction may partially influence their approach to addressing student questions that are not amenable to investigation.

One of the key roles of educators is to guide students in formulating questions suitable for investigation. Although it was recognized that all student questions have value and non-investigable questions could be researched to help students understand the phenomenon, this study focuses on situations where teachers want investigable queries but don't receive them from their students. These questions must align with the opportunities and limitations within the educational setting. According to Chin and Kayalvizhi (2002), students often struggle to formulate such questions. An *investigable question* enables practical inquiries, allowing students to gather firsthand data or evidence to address the query. While the importance of utilizing second-hand information in the classroom is not overlooked, the primary focus of this discourse is on assisting students in developing questions that are feasible to investigate and gather data within their educational environment. This study examines the correlation between teachers' epistemic orientations toward science and how they respond when students raise non-investigable questions.

Although the NGSS position questions, as the entry point into scientific inquiry, classroom realities often complicate this ideal. Teachers are expected to let students explore phenomena, surface their own curiosities, and generate investigable questions—yet the questions students produce frequently fall outside the scope of the targeted disciplinary core ideas or are not testable within classroom constraints. This tension is not merely pedagogical; it reflects deeper differences in how teachers understand the nature of scientific knowledge and the role of students in constructing it. Prior research suggests that teachers' epistemic cognition shapes how they interpret uncertainty, how they respond to students' ideas, and how they position learners within the inquiry process. Still, little is known about how these epistemic orientations influence teachers' decisions in the specific moment when student-generated questions do not align with the intended learning goals. This dilemma—balancing student autonomy with curricular expectations—became the central problem guiding the present study.

Research Question

What strategies do teachers with different epistemic orientations use when students fail to develop investigable/testable questions aligned with targeted concepts?

Methods

The researchers used purposeful sampling by selecting 20 teachers from a previous study (see Rinehart et al., 2020), where teachers were interviewed using the Teacher Belief Interview (TBI; Luft & Roehrig, 2007). The interview transcripts were coded using Luft and Roehrig's (2007) rubric, which has categories from teacher-centered to student-centered beliefs. The Teacher Belief Interview (TBI) tool is a semi-structured, seven-question interview with coding maps to identify a subject's epistemic orientation toward teaching science. In prior research, the TBI was employed to collect qualitative data, which was then coded and assigned categorical values for quantitative analysis (Enderle et al., 2014). To qualify for a specific category, teachers must provide responses aligned with at least five of the seven characteristics defining that category. The authors randomly selected 10 teachers who scored traditional on the TBI and 10 who scored reform-based. Some time has passed since the original interviews, so we contacted the teachers and re-interviewed them. The 10 teachers who scored reform-based scored the same in the second interview.

Of the ten teachers who initially received a traditional score, nine maintained that classification during the second interview, whereas one teacher shifted to a transitional score. That teacher was excluded from the study, and another participant who had received a traditional score in the original research was re-interviewed; their score remained consistent with the initial interview. That teacher was removed from this study, and another teacher who scored traditional from the original research was re-interviewed, and their score was the same as their first interview.

Next, all participating teachers were presented with a vignette depicting a classroom scenario in which a teacher designed a lesson that allowed students to explore a phenomenon aligned with a bundle of Next Generation Science Standards (NGSS). The teacher allowed students to explore four stations and write observations and questions. In the vignette (see below), students engaged with the learning stations and recorded their questions; however, none of the questions generated would have led to an investigation aligned with the Next Generation Science Standards (NGSS). The participants in the study were asked what they would do next if this happened in their classroom. This station type of setup is a common phenomenon exploration lesson teachers use when starting an NGSS-aligned unit. (Deverel-Rico & Heredia, 2018).

Vignette:

A 4th-grade teacher set up a phenomenon exploration for an energy unit. The bundle of standards are:

- *4–PS3–1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.*
- *4–PS3–2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.*
- *4–PS3–3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.*
- *4–PS3–4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*

The teacher set up four stations, put four to five students in a group, gave them 12 minutes at each station, and then asked them to write down their observations and questions. The four stations were:

- **A station of iPads with a National Geographic video of big horn rams colliding**
    - *To elicit prior knowledge about:*
        - 4–PS3–1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.
        - 4–PS3–3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.
- **A station of toy cars of various sizes and weights. The students are encouraged to pick a partner and observe what happens when the cars collide.**
    - *To elicit prior knowledge about:*
        - 4–PS3–3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.

- **A Newton's cradle.**
    - *To elicit prior knowledge about:*
        - 4–PS3–3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.
        - 4–PS3–4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
- **An area with batteries, wires, small light bulbs and light bulb holders to complete the circuit.**
- *To elicit prior knowledge about:*
        - 4–PS3–2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

For the lesson, students were given the following instructions: Please observe the video at the iPad stations and carefully play with the materials at the other stations. You will have eight minutes to make observations and then four minutes to write down your observations and questions in your journal. After each group of students interacted with the stations, the teacher instructed them to record their questions on sticky notes.

<u>Below is a list of questions that the students came up with:</u>

1. Why is it called a Newton's cradle?
2. Why did the light turn on?
3. Did the ram get hurt?
4. Are red cars faster than others?

The interview audio recordings were transcribed; the data were coded and organized into smaller components for data interpretation and analysis. A constant comparison method, based on Glaser and Strauss' (2017) grounded theory, was used, and after multiple rounds of coding, themes emerged. The researchers coded the data independently and calculated a correlation of r = .91, indicating a high level of agreement (Cohen, 1988). The responses from teachers with a reform-based epistemic orientation can be found in Table 1, and responses from teachers with a traditional epistemic orientation can be found in Table 2.

Results

Table 1
Orientation-Reform-Based

Code	%	Definition	Example
Reframe the question	48%	Ask the students to take their questions and make it testable.	I would tell the students that their questions and ideas are great, but now we need to investigate them. Sometimes I show them how to use SMART goals and ask them to rewrite the questions in small groups.
Establish a Conceptual Framework	37%	Teacher discusses the general topic of the phenomenon before the students ask questions.	After the students played with the toy cars I would make a comment like "I noticed that some of you made the cars move fast and some of you made the cars move slow. What do you think moved them? Oh, force, What do you know about force? Let's figure that out and then create a question to investigate.
Reflective Toss	22%	The teacher identifies a key component in need of further reflection and asks deeper questions.	I would ask them to explain more about a specific aspect of their question. For example, the question about the rams. I would say "Well, I don't know if they got hurt, but what do you think they would hurt themselves if they were moving faster?
Augmented Autonomy	15%	When the teacher lists all of the student's questions, they include some of their own.	I have some questions too. I am going to write one on the board. However, I still want you to select the question to investigate.
Provide the Question	5%	The teacher tells the students the driving question.	If we get to a certain point, I would tell the student we would have to investigate a question that aligned to the standard.

Note - A teacher's response to a question could receive more than one code and the percentages reflect how many teachers within that category had the same coded response.

Table 2
Orientation - Traditional

Code	%	Definition	Example
Provide the Question	82%	The teacher tells the students the driving question.	If we reach a certain point, I would tell the student we would have to investigate a question that aligned with the standard.
Deception	20%	Use a method to manipulate students	I would have the students write down questions on sticky notes and put them in a hat. Then, I would pick out one question, but I would ensure it was the one I wanted.
Choice	12%	The teacher provides the students a few options of questions to select from.	I would give them two or three options of questions that I made up. I would ensure they align with the standards and then let them vote on which one.

Note - A teacher's response to a question could receive more than one code and the percentages reflect how many teachers within that category had the same coded response.

Discussion

The primary finding of this study indicated that teachers' epistemic beliefs about teaching science were aligned with the instructional moves they would use after students raised non-investigable questions. According to the Teacher Belief Interview (TBI), reform-based teachers "focus on mediating student knowledge or interactions" (Luft & Roehrig, 2007, P. 54). One of the teachers who scored reform-based on the TBI noted that their responsibility as a science teacher was to: "offer students opportunities that enable me to comprehend both their understanding of the content and how they are interpreting scientific practices." These teachers' suggestions aligned with the second most common response to our interview, where they suggested reframing the question by setting expectations and then asking students to develop a question that aligned with the predetermined framework. Nearly all responses from teachers with a reform-based epistemic orientation emphasized maintaining students' questions as the central focus of instruction, with only 5% of the responses suggesting that they give the students the questions to investigate.

For example, the reflective toss move was a common response for the reform-based teachers. This instructional move involves the teacher "catching" the meaning of the student's observations or thoughts and "throwing" the responsibility for developing the question back to the students. Table 3 offers an example of what a reflective toss might look like in a 4th-grade classroom. A teacher with a reform-based EC would understand that scientific questions require an opportunity to develop questions based on their observations. As stated throughout this paper, helping students achieve scientific literacy is a goal for the NGSS and most science education literature. To achieve this goal, students must be involved in developing questions to investigate. Professional scientists do not have questions delivered to them. Instead, they observe natural phenomena, look for patterns in data, and raise questions about unresolved issues. If a science teacher provides the question to the student, it robs them of the opportunity to begin an inquiry.

The authors took the information from Tables 1 and 2 and created practical examples aligned to specific NGSS phenomena. Suggestions from teachers with a traditional epistemic orientation were excluded from the analysis because they did not align with the expectations outlined in the NGSS. Luft and Roehrig (2007) described these beliefs as focusing on information, transmission, structure, or sources, and their role is delivering information to the teachers. The teachers in the study suggested simply providing the students with the question or using a form of deception to land on the desired question (see Table 2).

The patterns in Tables 1 and 2 show clear differences in how teachers respond when students generate non-investigable questions. Reform-based teachers tended to preserve student agency by reframing questions or using dialogic moves that guided students toward testable ideas, while traditional-oriented teachers were more likely to replace student questions with predetermined ones. These differences suggest that supporting NGSS-aligned inquiry requires more than instructional tools—it requires helping teachers develop epistemic beliefs that value uncertainty, student thinking, and the iterative nature of scientific questioning. Professional learning that emphasizes these orientations may better prepare teachers to help students generate authentic, investigable questions that anchor meaningful scientific inquiry.

Table 3
Suggestions of how to help students develop authentic questions aligned to an NGSS standard and phenomenon.

Code	NGSS	Phenomenon	Practical Example

Reframe the question	3–PS2–1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.	Students watch a video of people playing tug-of-war with an unexpected winner.	S: Why did the side with the smaller kids win? T: Does that seem strange? S: Yes, I thought the big kids would win. T: How do you think the smaller kids won? S: They must be super strong. T: Could we think of a question that tests this idea? Could we design a test where we could control how strong the force is on each side?
Establish a Conceptual Framework	4-ESS1-1. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.	Students observe fossils of water-dwelling animals found in a desert area.	S: Why did people put those fish fossils in the desert? T: Well, do you think this area has always been a desert, or has it changed over time? S: I don't know T: Well, can you think of examples of how the Earth has changed over time?
Reflective Toss	2-PS1-4. Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.	Students observe a piece of chocolate melting into liquid and a piece of paper burning to ash.	S: I don't think either one can go back. T: Look at the pictures of the chocolate after it melted and the paper after it burned. What is different about them? S: The chocolate is a liquid, and the paper is smoke. T: Do you think we could design a test to see if we could change them back?
Augmented Autonomy	K-PS2-2. Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.	Students observe small, cut-up pieces of paper blown by a fan at high and low speeds.	S: Why does paper fly? S: Can paper fly like birds? T: These are all good questions, let's write them on the board. We can figure out the answer to those questions. Let's write down some more. T: I'm going to add a question that I have: Can a fan move paper faster than blowing it?

Note - The code “Provide the Question” from the qualitative analysis was removed from this table since it was not a reform-based suggestion that aligns with the NGSS.

Conclusions

Science comprises a series of interconnected practices (Jiménez-Aleixandre & Crujeiras, 2017; Suh et al., 2022). These practices are inherently linked to conceptual work and unified into a coherent system by their underlying epistemic goals (Berland et al., 2016; Windschitl et al., 2012). Therefore, to thoroughly understand both the epistemic foundations of science and its conceptual knowledge, students must have opportunities to participate actively in the core practices of science (Davis & Smithey, 2009; Duschl & Grandy, 2013).

Kuhn et al. (2017) highlighted that students who deeply engage in authentic scientific practices develop “superior epistemological understanding regarding science as entailing the evaluation of claims about available evidence” (p. 1). This study provides insight into teachers’ challenges as they implement practices aligned with the expectations of the NGSS. For teachers to meet these expectations, they will need to adopt instructional practices that are more collaborative and inclusive, rather than direct instruction, where the teacher’s questions are the only ones investigated. An emerging principle in science education research is that students should encounter ambiguities, complexities, and inconsistencies (Engle, 2011; Engle & Conant, 2002; Manz, 2015; Reiser, 2004; Hammer, et. al., 2012).

For students to fully understand “what we know, how we know, and the epistemic and procedural constructs that guide the practice of science” (Osborne, 2014, p. 183), they must engage in science practices as part of a coherent network of purposeful scientific actions aimed at achieving epistemic goals (Berland et al., 2016; Krajcik et al., 2014). This engagement requires students to comprehend the purpose, role, and significance of their scientific actions in constructing scientific knowledge (Osborne, 2014). However, facilitating such meaningful engagement where students approach science practices as a unified effort aligned with epistemic objectives requires teachers to engage in sophisticated planning and instruction. This level of teaching demands a deep understanding of the epistemic, procedural, and conceptual aspects of science practices (Fiorella & Mayer, 2015).

While the finding of a correlation between epistemic beliefs and instructional practices is not novel, the teachers’ responses to how they would handle non-investigable questions would be of interest to those who prepare science teachers. A crucial step in shifting the focus from simply understanding *what we know* to actively engaging learners in science involves having them explore the relationships between evidence and explanation. In classrooms, this engagement is fostered when students plan and carry out investigations that require navigating the complex steps of moving from questions to measurements, to data, to evidence, and finally to explanation. A significant drawback arises if students and teachers are limited to preplanned, confirmatory investigations with predictable, step-by-step procedures to ensure anticipated outcomes. This approach strips away the cognitive and material challenges essential to the authentic process of doing science. One of the core practices of scientists is systematically planning and executing investigations. This practice involves identifying what data to record and determining which variables are dependent, independent, or controlled. Observations and data collected through such investigations are critical for testing existing theories and explanations or for revising and developing new ones.

Science education scholars have identified that encouraging change in instructional practice is a challenge and should be a focus of teacher professional development. This study focused on one SEP of the NGSS, but the authors feel it is an underserved aspect of quality science instruction. With the rise of standardized curricula that simply provide questions to students, teachers mustn't ignore this critical aspect of the scientific process. Encouraging students to refine and evaluate their own questions underscores that developing meaningful and investigable scientific questions is a skill that demands thoughtful consideration and revision. Science educators and practitioners who provide professional development to teachers should consider including students in developing investigable questions. This paper provided a theoretical framework for including students in this endeavor and some practical examples of achieving this goal.

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