Marine Science, Climate Change, and the Next Generation Science Standards: Understanding the Knowledge and Perspectives of K-8 New Jersey Teachers

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ABSTRACT

Teachers must feel adequately prepared to teach about any topic. Research demonstrates that teachers at the K-8 level are often underprepared to teach about climate change (Plutzer et al., 2016). Understanding marine environments is essential for building a comprehensive perspective on climate change and climate systems. Although the Next Generation Science Standards (NGSS) have been widely used throughout the US and provide many opportunities to address marine science and climate change, many K-8 teachers are not comfortable implementing these standards (Haag & Megowan, 2015; Harris et al., 2017). Existing science curricula focus almost exclusively on the third of Earth's surface covered in land, rather than the two-thirds covered in water. To better understand the current state of teachers' knowledge of climate change, marine science, and effective use of the NGSS, we surveyed 164 preservice and practicing K-8 teachers and conducted a focus group discussion with 10 survey respondents. We used an explanatory sequential mixed-methods design approach (Creswell & Clark, 2017) to analyze data and describe K-8 teachers' understanding of these topics. Participants had mixed levels of comfort with their knowledge and ability to teach both climate change and marine science, but a high level of interest in learning more. They also shared strategies they were currently using to teach these topics. Participants reported mixed levels of confidence and comfort using the NGSS. Our findings revealed the range of current understandings of climate change, marine science and the NGSS held by teachers in New Jersey, and are instrumental for informing future curricular and professional development projects.

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Teachers and students must be well versed in ideas related to climate science and understand the role that marine environments play in regulating Earth's climate in order to create a scientifically literate populace as we enter the Anthropocene. Towards this goal, New Jersey (NJ) became the first state in the US to adopt climate change-specific learning standards across all grade levels and content areas K-12. The effects of climate change in NJ are more substantial than many other places, and include rising sea levels, increased incidence of severe weather events, increased average yearly temperature, and significant changes to plant and animal populations (NJ DEP, 2020). For example, the state's scientific report on climate change noted that New Jersey's increase in extreme storms over the past 50 years is occurring at a rate faster than anywhere else in the United States (NJ DEP, 2020: ix).

Our study used a mixed-methods approach to better understand current and future (undergraduate preservice) NJ K-8 teachers' knowledge and confidence in teaching about climate change, marine science, and their comfort in using the Next Generation Science Standards (NGSS) to plan and implement science lessons. Identifying teachers' baseline knowledge will guide the development of NGSS-aligned K-8 science curricular materials and professional development programs in New Jersey.

CONTEXTUAL FRAMEWORK

Climate change education began nearly a decade ago in New Jersey with the adoption of the NGSS. New Jersey was one of 44 states in the US adopting or modifying these standards as guidelines for structuring science education in K-12 schools (NGSS Lead States, 2013). One major innovation of the NGSS over prior learning standards is the direct and explicit inclusion of climate change as a disciplinary core idea that informs several performance expectations across the middle and high school grade span.

IMPLEMENTING THE NEXT GENERATION SCIENCE STANDARDS

The *National Science Education Standards* (NSES, 1996) were used as guidelines for individual states' standards documents and as the basis for science instructional materials across the US for more than two decades. In 2012, the National Research Council published a comprehensive *Framework for K-12 Science Education,* which offered a deep analysis and recommendations for important ideas related to science content and practice (NRC, 2012). The *Framework* moved away from teaching science as a rote and formulaic discipline, in favor of a more comprehensive and integrated approach. The framework introduced the idea of three-dimensional learning, in which science content (referred to as disciplinary core ideas) and process (referred to as science and engineering practices) are taught simultaneously, with explicit connections made to scientific concepts. These crosscutting concepts (such as form and function) connect across disciplines. The *Next Generation Science Standards* (NGSS) are based on this framework (NGSS Lead States, 2013). Aside from the three-dimensional aspect of these standards, the NGSS represents a major shift from previous standards based on the NSES in two ways. First, NGSS standards are written to particular grade levels rather than a range of grades (e.g., K-2). Second, the NGSS include ideas related to engineering, and require students to design solutions to a variety of problems, for the first time. The NGSS are recognized by the National Science Teaching Association (NSTA) as best practices for science instruction K-12 (NSTA, 2016). The NGSS adoption has been widespread and far reaching. The standards themselves and the aligned curricula, however, focus heavily on terrestrial systems, rather than the marine environment (Strang, 2012). Thus, there is a need for comprehensive NGSS-aligned instructional materials that includes marine science.

Teachers continue to express a lack of comfort and understanding of the NGSS, despite their widespread adoption and support from professional organizations. For example, in a survey of K-12 teachers in states that have adopted the NGSS, just 50% of respondents report familiarity with the standards. Teachers express a lack of certainty about the feasibility of adopting these standards due to time, communication, and materials, and lack of training on their use (Harris et al., 2017). Haag and Megowan (2015) conducted a nationwide survey of K-12 teachers related to their readiness to implement the NGSS. They found that teachers held mixed opinions about the NGSS and want professional development that modeled best practices using these standards. In a commentary on the roll out of the NGSS across the US, Penuel et al. (2015) commend the rigor and comprehensiveness of the standards, while emphasizing that teachers need access to both high-quality sustained professional development and high-quality instructional materials in order

to effectively implement the standards. In sum, although teachers and researchers widely agree that the adoption of the NGSS is a good innovation, more work is needed to better support teachers in adopting them as frameworks for teaching and learning within the space of K-12 classrooms.

MARINE SCIENCE EDUCATION

Seventy-one percent of the Earth's surface is covered in water and nearly 97% of that water can be found in oceans. Science curricular materials used in schools, favor terrestrial systems over marine environment (Strang, 2012). There is a need for comprehensive marine science NGSS-aligned instructional materials as many people hold misconceptions related to the ocean. For example, in his study of 10-11 year old children, Ballantyne (2004) found that they express numerous incorrect or partially correct conceptions related to the ocean. These ideas range from a misunderstanding of the reasons why the sea is salty (e.g., that people throw salt in it) to explanations for currents (e.g., whales and other large animals swimming could cause currents). However, these incomplete understandings are not just expressed by children. Guest, Lotze, and Wallace (2015) found similar results among Canadian teenagers. Fletcher et al. (2009) found that though the general public in the UK report an interest in marine environments, there is a lack of understanding about a variety of issues relating to marine science. These reports echo findings from earlier studies in the US (e.g., Steel et al., 2005) that show citizens have varied amounts of knowledge related to the oceans based on geography (distance from the coast) and socioeconomic status.

It is critical that teachers are knowledgeable and prepared to teach about marine environments in order to build a scientifically literate populace. Markos et al. (2015) used a quantitative survey instrument, the Survey of Ocean Literacy and Experience (SOLE) to study Greek preservice teachers' ocean literacy. This study revealed that teachers held a wide variety of conceptions and misconceptions related to marine science. Furthermore, the study shows that the instrument is useful for identifying teachers' conceptions and planning pre- and in-service teacher education accordingly. Payne and Zimmerman (2010) reported on the dearth of information in K-12 science textbooks, curricula, standards, and assessments related to marine environments while making a strong case for preparing current and future teachers to address the oceans in their instruction. These authors contrast this lack of coverage of marine science content with the systemic global environmental issues directly related to the oceans (e.g., global climate change, ozone depletion, decreasing biodiversity), and offer an instructional vision framework with direct connections to ocean and aquatic education. Over a decade later, Albuquerque and Zandvliet (2021), found a similar lack of representation of marine environments in curricular materials, despite widespread agreement that understanding of marine systems is necessary for teachers and students. The framework of Payne and Zimmerman (2010) builds off the guidelines created by the North American Association for Environmental Education (NAAEE 2004) that emphasize considering the cultural and relational factors that drive humans' understanding and interaction with the environment.

CLIMATE CHANGE EDUCATION

Climate change is one of Earth's greatest challenges, and teaching climate change demands rapid preparation for teachers. Studies show that climate change education is an effective and useful strategy for mitigating the effects of climate change through individual and collective action (Cordero et al., 2020; Turner et al., 2022). Climate change education in the United States varies tremendously: fewer than half of current K-12 science teachers report receiving formal education about climate change, yet many of them are personally motivated and impelled by NGSS standards to teach their students about the subject. For example, approximately 70% of middle school science teachers spend time teaching about climate change (Plutzer, 2016). A large proportion of these teachers report that they want to accurately represent the scientific consensus, and that they are motivated by strong student interest, their own passion for the environment, and by new NGSS standards that integrate climate change concepts (Wysession, 2013; McNeal et al., 2018). In an August 2022 nationwide survey conducted by Edge Research and the North American Association for Environmental Education (NAAEE), large majorities of teachers and administrators reported that teachers were responsible to teach about climate change, and that this was a topic many students bring up on their own (Edge Research & NAAEE, 2022).

Similarly, surveys targeting parents, teachers, and citizens across the US indicate that individuals across the political spectrum believe that climate change should be taught in schools (Kamenetz,

2019). However, despite excellent intentions, it is also clear that many teachers find teaching climate change daunting due to their limited knowledge of the science, and the (often misplaced) perception of controversy or threat to personal belief (e.g., Plutzer, 2018). The result is often that formal climate change instruction is severely limited in amount, scope, scientific accuracy, and utilizes ineffective communication strategies (Kahan, 2015; Breslyn et al., 2016; Liu et al., 2017; Monroe et al., 2017). Professional development (PD) for teaching about climate change shows important promise for conceptual changes in teachers and students alike (Drewes et al., 2018). Recent literature on professional development for climate change education emphasizes several pressing needs: a) more access to climate change PD opportunities that are thoroughly integrated with NGSS; b) PD that leverages regional, geographically specific observations and research in order to promote learning that is personally relevant to teachers and students; and c) PD grounded in up-to-date research-based climate science and pedagogy, including integration of advanced scientific and instructional technology (Edge Research & NAAEE, 2022; Drewes et al., 2018; Hestness et al., 2014; Shepardson et al., 2017).

Climate change education is an especially pressing concern in New Jersey. In June 2020, NJ became the first state to incorporate climate change across all content areas and grade levels (Murphy 2020). This commitment to interdisciplinary instruction on this complicated topic highlights the importance of preparing teachers of the youngest children, who might be least prepared to address the topic head-on and appropriately.

METHODOLOGY

We used an explanatory sequential mixed-methods design approach as per Cresswell & Clark (2017) to analyze our data, as depicted in Figure 1 below. Mixed-methods analyses allow for a balance between quantitative trends across a larger dataset and qualitative descriptions from a subset of the pool of respondents. We used a survey to collect initial quantitative data. Next, we followed up with a qualitative analysis of a focus group discussion to allow a subset of participants to elaborate on their responses. Finally, we interpreted our findings, both qualitative and quantitative together to ensure our findings included both depth and breadth.

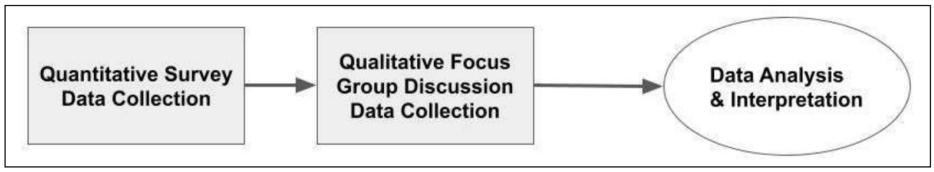

Figure 1 Explanatory sequential mixed-methods design (based on Creswell & Clark, 2017).

PARTICIPANTS

Survey participants were recruited via email and social media. The project team members shared the link to the survey within their professional networks over the course of three weeks. A total of 166 respondents took the survey; 164 agreed to participate in the study. Of the respondents, 44% were practicing K-8 teachers, 37% were preservice teachers, and 12% selected "other" indicating that they were either administrators, supervisors, or specialist teachers. Eleven percent of the participants did not respond to this question. Table 1 displays a detailed description of the survey respondents.

Table 1 Description of Survey Respondents' Professional Positions.

POSITION	NUMBER & PERCENTAGE	CATEGORY	NUMBER & PERCENTAGE BY CATEGORY
Classroom Teacher K-2	21 (13%)	Practicing Teachers	66 (44%)
Classroom Teacher 3–5	26 (16%)		
Classroom Teacher 6–8	15 (9%)		
Curriculum Coordinator/Facilitator	4 (2%)		
Preservice teacher- early childhood education	15 (9%)	Preservice Teachers	60 (37%)
Preservice teacher- elementary education	40 (23%)		
Preservice teacher- middle school specialization	5 (3%)		
Other	20 (12%)	Other	20 (12%)
Did not respond	18 (11%)		18 (11%)
Total	**164 Participants**		

DATA SOURCES

Survey Data

We developed a descriptive survey[1] to determine preservice and practicing K-8 teachers' understanding of the three foci of our project: climate change, marine science, and the NGSS. The survey began with questions about demographic information asking:

- if the respondent was a preservice or practicing teacher,
- number of years teaching experience, and
- grade level

Next, we asked respondents to identify the frequency with which they teach science in general, climate change, and marine science. Following each of these questions, we asked respondents to provide examples of lessons, units, or activities they used to teach these topics.

The survey also included a self-evaluation of their own understanding of, confidence in planning and teaching lessons, and interest in learning more about each of the three topics: the NGSS, marine science, and climate change. We also asked respondents if they would be interested in participating in a focus group discussion.

Focus Group Data

We held the focus group discussion via Zoom video conference with a subset of 10 survey participants recruited through their response to the item on the survey. These participants represented a convenience sample as they were available at the scheduled time for the focus group discussion. The project team facilitated the discussion guided by questions similar to those in the survey, with opportunities for participants to elaborate on their responses. The discussion lasted about an hour and was transcribed electronically.

Ten individuals participated in the focus group discussions. The focus group participants included two preservice teachers, seven practicing teachers, and one administrator. Nine of the participants were female; one was male. These included two preservice teachers, both pursuing licensure in elementary education and an additional endorsement to teach middle school science, two practicing middle school teachers, three practicing elementary school teachers, two STEM or science specialist teachers and one administrator. All focus group participants received a $25 gift card as an incentive for participating in the discussion.

FINDINGS

Prior research demonstrates that the amount of time and attention paid to science in elementary school classrooms varies considerably and is typically far less than the amount of time devoted to English-language arts and mathematics (Banilower et al., 2013). Thus, we explored the frequency in which our survey participants taught science before delving into climate change, marine science, or the NGSS. There were 105 responses to the question, "How often do you teach science?" and we received a range of responses, from once a week through daily, as displayed in Table 2.

Table 2 Frequency of Science Instruction.

HOW OFTEN SCIENCE IS TAUGHT	NUMBER AND PERCENTAGE
Every day	24 (23%)
A few times a week	14 (13%)
Once a week	2 (2%)
Every day but only during the part of the school year when teaching a science unit	17 (16%)
A few times a week but only during the part of the school year when teaching a science unit	14 (13%)
Once a week but only during the part of the school year when teaching a science unit	0 (0%)
Other	34 (32%)
Total	**105 (100%)**

1 Contact author for a copy of the full survey.

Respondents who answered "other" offered reasons related to being a preservice teacher such as "only when assigned to do so by a cooperating teacher or supervisor," or specific instances such as, "only when teaching a nonfiction science book." This context helps us to situate our understanding of teachers' responses with regard to climate change and marine science instruction as well.

CLIMATE CHANGE

When asked about the frequency with which they incorporated climate change into their classrooms, 88 participants responded and the survey responses ranged from "never" (22%) to "frequently" (15%), as shown in Table 3.

Table 3 Frequency of climate change instruction among survey respondents.

HOW OFTEN DO I INCORPORATE CLIMATE CHANGE IN MY CLASSROOM	NUMBER AND PERCENTAGE
Never	19 (22%)
Once in a while	22 (25%)
Sometimes	19 (22%)
Frequently	13 (15%)
A few times a week but only during the part of the school year when teaching a science unit	0 (0%)
Other	15 (17%)
Total	88 (100%)

Respondents who answered that they do teach climate were asked to provide examples of lessons, topics, activities, or units covered. Thirty-seven respondents provided these examples. These 37 responses fell into several large categories including:

- Integrating climate change into language arts through readings or video resources (10), or writing (2);
- Teaching climate change as a topic within social studies (2);
- Teaching about climate change through various Earth science topics including weather and climate (8), distribution of water on Earth's surface (9), Earth systems (1), atmospheric CO_2 (2), sea level rise (3);
- Teaching about climate change through life science instruction including biomes and ecosystems (5) or impact of climate change on animals (2); through discussion of energy broadly (3);
- Teaching about climate change through a variety of environmental science topics such as recycling and waste reduction (4), human impacts on Earth's systems (5), and environmental awareness (4).

Three of the 88 respondents described an entire instructional unit devoted to climate change. It should also be noted that for some of these responses that were tangential to climate change, such as "recycling" clarifying information connecting the response to climate change (e.g., recycling reduces plastic use which in turn reduces reliance on oil) was absent.

A number of respondents offered specific instructional strategies for teaching climate change such as problem-based learning (3); inviting expert guest lecturers or going on field trips (2); debate (1) and using artwork to raise awareness of climate change (1).

Participants were also asked to report their confidence with regard to teaching about climate change. Seventy-seven respondents reported on their confidence in teaching climate change content during NGSS units using a scale of 0–10 (0 indicating low confidence and 10 indicating high confidence). The mean score was 5.1 standard deviation was 2.3, and the distribution was fairly normal (Figure 2).

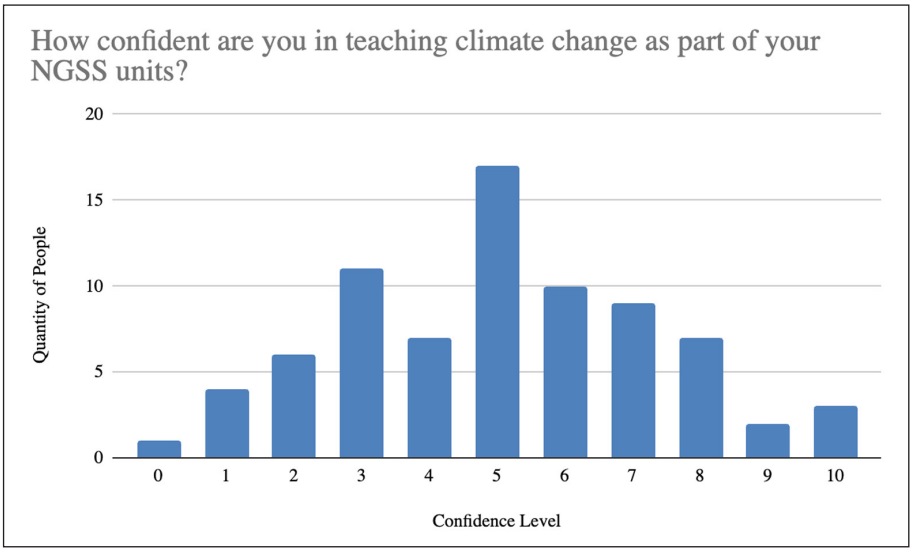

Figure 2 Respondents' confidence in teaching climate change during NGSS Units on a scale of 0–10.

When asked about interest in learning more about incorporating climate into science units, 71 participants responded, and these responses skewed toward the positive with 28 selecting 10 on a scale of 0–10. The mean was 7.8 and standard deviation was 2.5. These findings suggest that teachers are very interested in learning more about climate change and how to teach it effectively (Figure 3).

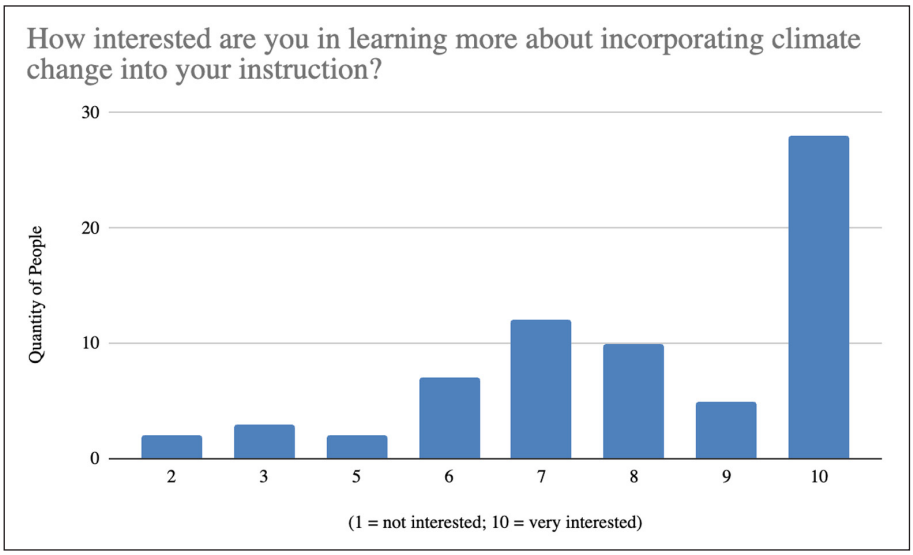

Figure 3 Respondents' interest in learning more about teaching climate change on a scale of 0–10.

The focus group discussions elaborated on some of these ideas. For example, one middle school STEM teacher described a project-based learning experience related to climate change:

> "We shut down all learning for about a week and we gave [the students] a topic. Some [examples] of topics were alternative energy and beach erosion…And they had to research this topic and come up with a feasible solution to it and then present it to a panel of judges, and they judge them on what their solution was like and how creative and innovative and all that stuff. So, I didn't necessarily teach directly into this topic, but they had to use their research skills and resources I gave them to learn about it."

The focus group discussion also revealed some topics that did not emerge on surveys including linking climate change to food deserts and discussion of climate change mitigation, suggesting that teachers employ a wide range of strategies to explore climate change with their students.

MARINE SCIENCE

When asked, "How often do you incorporate marine science into your classroom?" 104 participants responded. These responses ranged from never (27%) to frequently (3%), as displayed on Table 4 below.

HOW OFTEN DO I INCORPORATE MARINE SCIENCE IN MY CLASSROOM	NUMBER AND PERCENTAGE
Never	28 (27%)
Once in a while	30 (29%)
Sometimes	16 (15%)
Frequently	3 (3%)
A few times a week but only during the part of the school year when teaching a science unit	3 (3%)
Other	24 (23%)
Total	104 (100%)

Table 4 Frequency of Marine Science Instruction among survey respondents.

Many of the respondents who reported "other" indicated that they were preservice teachers. Several others in the other category qualified their response with specific lessons within a unit (e.g., during an ecosystems unit).

Respondents who answered that they teach marine science were asked to provide examples of lessons, topics, activities, or units. Forty respondents provided these examples. These 40 responses had several main themes, including:

- Through life science topics broadly, such as marine animals (17),
- During units on ecosystems, habitats, or food chains/webs (15);
- As part of instruction about general environmental issues related to the ocean such as:
  - Human impacts or pollution (7)
  - Clean oceans and marine conservation (5)
  - Climate change (5)
  - Ocean acidification (2)
- As part of instruction about on physical science ideas such as:
  - Currents (4)
  - Waves and tides (4)
  - Light (2)
  - Sonar (1)
- Integration of marine science discussions into language arts including:
  - Reading (7)
  - Writing (2)

Other specific instructional strategies were listed including field trips and guest lectures (4); using problem-based learning or research projects (4); arts-integration (2); and use of specific curricula (2).

During the focus group discussion, most participants stated that they rarely taught marine science, however, when they taught it, they integrated marine science in the ways listed above. For example, one fourth grade teacher shared her experiences introducing marine science during an ecosystems unit: "We touch on it a bit in our ecosystems unit, we do a little bit of different habitats and how food chains and food webs are impacted by changes in the habitat, but other than that, it doesn't come up very often."

Sixty-nine respondents reported on their confidence in teaching marine science content during NGSS units. The mean score was 4.1 on a scale of 0–10 and the standard deviation was 2.4, and the distribution was not normal, and skewed toward the low end of the scale as shown in Figure 4.

When asked about interest in learning more about incorporating marine science into science units, 79 participants responded, and these responses skewed toward the positive with 29 selecting 10 on a scale or 0–10. The mean was 7.8 and standard deviation was 2.3, suggesting that PD opportunities and curricular materials to aid teachers in this area would be well received. Figure 5 below displays this distribution.

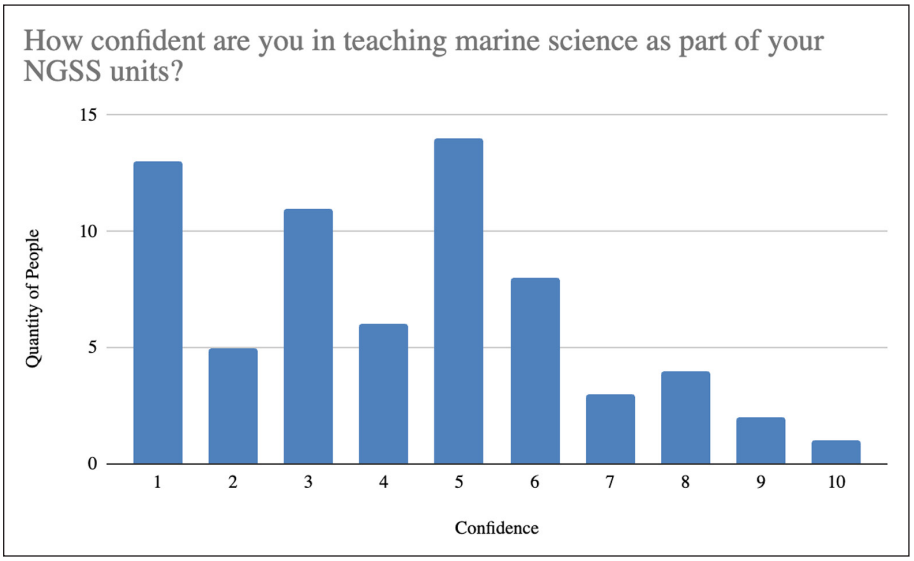

Figure 4 Survey respondents' confidence in teaching marine science on a scale of 0–10.

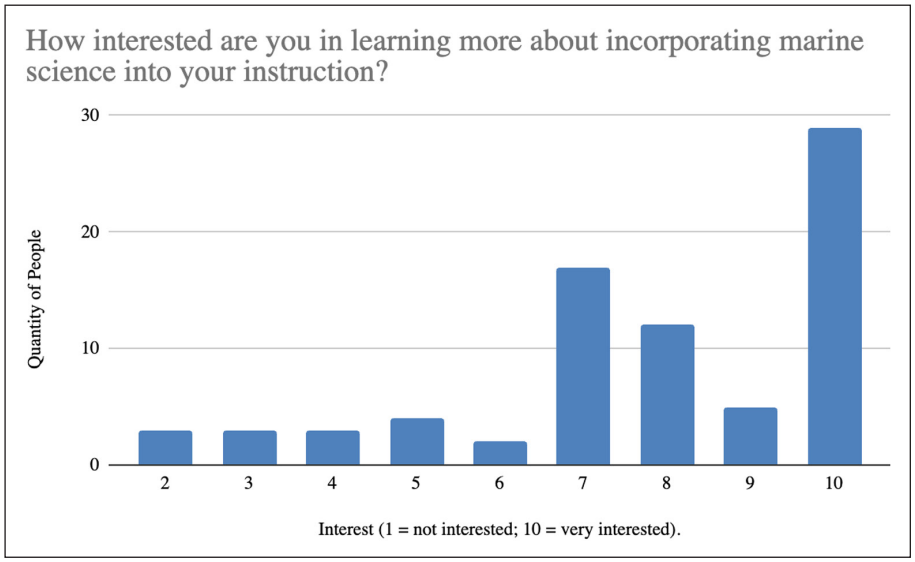

Figure 5 Survey respondents' interest in learning more about marine science on a scale of 0–10.

THE NGSS

Regarding their use of the NGSS, 125 respondents reported on their *knowledge* of the NGSS, and the mean score was 5.1 on a scale of 0–10 with a standard deviation of 2.3, and a fairly normal distribution, as shown in Figure 6.

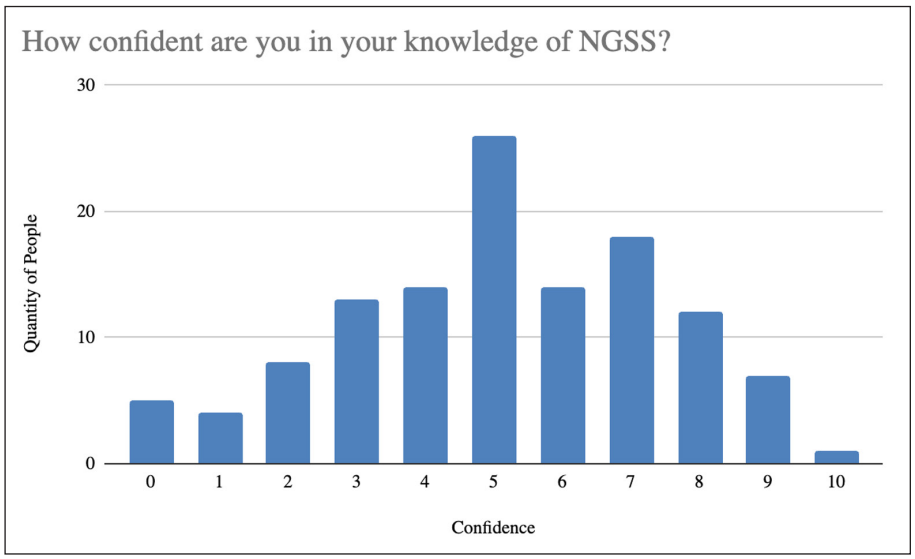

Figure 6 Survey respondents' knowledge of the NGSS on a scale of 0–10.

Similarly, 108 respondents reported on their confidence in the use of the NGSS, and the mean score was 5.1 on a scale of 0–10 with a standard deviation of 2.2, and a fairly normal distribution, as shown in Figure 7.

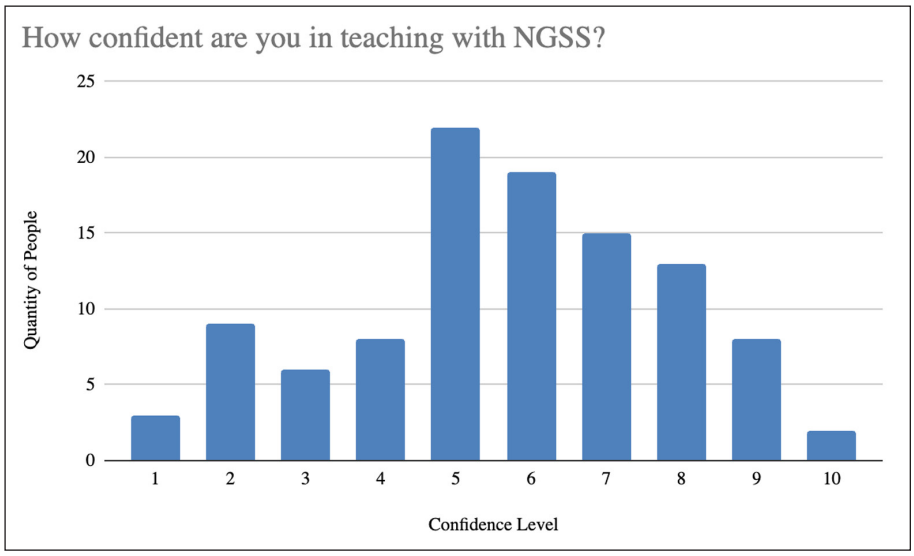

Figure 7 Survey respondents' confidence in using the NGSS on a scale of 0–10.

During the focus group, participants held mixed levels of knowledge, preparation and perspectives on using the NGSS. They also discussed the perceived misalignment between the NGSS and required state-wide standardized testing. For example, one third grade teacher shared, "I have never seen a professional development offered in my district that involves the Next Generation Science Standards." A K-5 STEM specialist in the focus group offered, "In the elementary schools, I think there is a huge disparity of comfort and fear and usage of NGSS in practices and in content. So, I think it is just all over the board." The school administrator in the focus group elaborated on this sentiment: "[There is a] huge disparity [in terms of NGSS instruction], depending on what class you're in... [if] 'Student A' has the luck to end up in one of those classes with those extraordinary learning experiences totally aligned with the standards but 'Student B' doesn't. And what happens if that happens for four or five years in a row. You know what happened to their science education. That's why we all have to have again, some consistency, some cohesion, with not only training, but curriculum as well." It is clear that there is a strong need for PD regarding the NGSS as well as well-aligned curricular materials based on the survey and focus group data.

OTHER FINDINGS

In the focus group discussion, there were four occasions where the intersection between climate change and marine science was made explicit. For example, an eighth-grade teacher shared, "We will use a lot of [examples referencing] marine animals and use changes in these animals as evidence for climate change, because I think that a lot of [times, animals] are canaries in coal mines. We have also done a bit when we're looking at topics like evolution and genetics, but we don't have any necessarily distinct units [on marine science]. We can see the huge changes in the fisheries, you can see huge changes and populations and huge changes and who's eating what it's really concrete evidence for a fast. Things are changing." This overlap in content emphasizes the need for future PD efforts focusing on the intersection between climate change and marine science within the context of the NGSS.

DISCUSSION AND CONCLUSIONS

This study found that K-8 teachers across New Jersey hold a wide range of knowledge, confidence, and comfort with climate change and marine science, even among a group of volunteer respondents. It should be noted that a large percentage of survey respondents (9%) were middle school teachers while several who responded "other" were science or STEM specialists. Teachers in each of these categories could potentially teach science every day and might account for the large percentage (23%) of respondents who reported teaching science every day. Our findings are very much in line with prior research in both marine science education (e.g., Markos et al., 2015) and climate change education (Payne and Zimmerman, 2010). In several instances, respondents also shared some misconceptions about climate change.

For example, participants sometimes provided general ideas about environmental issues (e.g., pollution or recycling) as topics related to climate change. Despite the mixed levels of teacher understanding, there was widespread interest in learning more about both marine science and climate change, suggesting that professional development in these areas would be well-received. The literature supports this notion as well (Drewes et al., 2018; Kamenetz, 2019; Edge Research & NAAEE, 2022). This information regarding interest in learning more about these areas is especially promising given New Jersey's adoption of climate change standards across grade levels and content areas beginning in September 2022.

Perhaps more surprising was participants' responses with regard to the NGSS. New Jersey adopted these standards as its science learning standards in 2014. Yet, teachers demonstrated a range of understanding of (and confidence in using) the standards, similar to our findings regarding marine science and climate change. There was significant variability among these teachers with regard to prior professional development on the use of the standards -- at least one teacher who participated in the focus group received no training at all. These findings are in line with previous work demonstrating a range in teachers' knowledge of the NGSS (e.g., Haag & Megowan, 2015). Furthermore, we echo the earlier call by Penuel et al. (2015) that more professional development is necessary to ensure the effective use of these learning standards across classrooms in New Jersey, and more broadly across the 44 US states currently using the NGSS or variants of these standards to guide their own state standards.

Given these responses, we have clear next steps for planning professional development and developing curricular materials to help mitigate teachers' gaps in understanding climate change, marine science, and the use of the NGSS. These include:

- Designing PD experiences to familiarize teachers with the mechanical use of the NGSS website and exploring all three components of each performance expectation (crosscutting concepts, science and engineering practices and disciplinary core ideas)
- Identifying clear examples where climate change and marine science are, or could be, addressed throughout the K-8 NGSS standards
- Providing clear descriptions of phenomena and science activities related to climate change and marine science

In sum, this research allowed us to identify the existing levels of K-8 teachers' understanding of marine science, climate change and the NGSS. As a result, we are well poised to create strategies for effective professional development activities and curricular materials to support teachers in their efforts to include climate change and marine science in NGSS-aligned lessons.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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