Title: Reconceptualizing teacher professional development for climate literacy using learning progressions and a regional observations approach

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Abstract
In the context of a summer professional development academy for formal and informal science educators, we investigated: (1) How do educators understand learning progressions and see the relevance of learning progressions to their teaching about climate change? and (2) How does a *regional observations* approach to climate change education inform educators' thinking about how they will address climate change in their own teaching? We report on the experiences of three focal participants—an informal science educator, a pre-service science teacher, and an experienced science teacher—using data from interviews, pre-academy questionnaires, and participant-developed learning segments. Results suggest that participants conceptualized learning progressions in a variety of ways and that teaching context may have informed participants' thinking about the use of a regional observations approach to climate change education.

Introduction

As global climate change becomes an increasingly salient topic in environmental education, there is a growing need to examine professional development practices that can prepare educators to address the topic in their teaching. The 2013 release of the Next Generation Science Standards (Achieve, 2013) marks the first set of U.S. national science standards to explicitly address climate change. The NGSS have garnered increased attention for climate change education and have the potential to catalyze climate change education efforts in the years to come. While the NGSS are founded upon learning progressions theory, limited attention has been afforded to engaging educators in examining the utility of learning progressions for gaining insight into student understanding.

Our study investigates a model of professional development for informal and formal science educators. Specifically, we focus on the inclusion of learning progressions in a professional development academy on climate change and its regionally-relevant impacts.

Background

Learning progressions. Learning progressions (LPs) provide a rich framework for understanding when and how students can learn about climate change at various levels (Mohan, Chen, & Anderson, 2009). Smith, Wiser, Anderson, Krajcik, and Coppola (2004) describe LP pedagogy as where "big ideas can be understood in progressively more sophisticated ways as students gain in cognitive abilities and experiences with phenomena and representations" (p.5). The LP starts with a Lower Anchor (representing the understanding of a typical fourth grade school student) and ends with an Upper Anchor (representing the standards that society would want a high school student to meet upon graduation). In the climate science academy, the idea of

learning progressions was presented to participants using the metaphor of the progressively more difficult stages of learning to ride a bike (Figure 1).

Figure 1. "Learning to ride a bike" as a metaphor for explaining to participants the progressively more sophisticated levels of understanding represented in learning progressions.

In our project, we are developing and empirically testing three hypothetical LPs derived from our analysis of the NGSS: sea level rise, extreme weather, and urban heat island effect. We selected these three observable phenomena in the environment as particularly relevant for the diverse geographical regions within the two states in which our work is focused. In developing these LPs, and collaborating with teachers to use them to inform instruction, we seek new insights into the ways in which a regional observations approach to climate change education may influence student learning.

Regional observations. Our project addresses climate change education through the lens of regional observations (National Climate Assessment and Development Advisory Committee, 2013), with the goal of supporting learners in constructing explanations about climate change relevant to their own lives and communities. The National Climate Assessment highlights the following regional observations of climate change as significant for our region and coastlines:

- Northeast: Heat waves, coastal flooding due to sea level rise and storm surge, and river flooding due to more extreme precipitation events
- Coastal areas: Coastal lifelines, such as water supply infrastructure and evacuation routes, are increasingly vulnerable to higher sea levels and storm surges, inland flooding, and other climate-related changes

This assessment informed our decision-making related to the focal impacts we would present to teachers through our project's professional development efforts.

Research Questions

In investigating the inclusion of learning progressions in a professional development academy on climate change and its regionally-relevant impacts, we focused on two key questions: (1) How do educators understand learning progressions and see the relevance of learning progressions to their teaching about climate change? and (2) How does a *regional observations* approach to climate change education inform educators' thinking about how they will address climate change in their own teaching?

Context and Participants

Our study context was a weeklong professional development Climate Science Academy that took place in early summer 2013. The workshop was a component of a larger NSF-funded project, Maryland and Delaware Climate Education, Assessment and Research (MADE CLEAR), which focuses on the implementation of a comprehensive climate change education

plan for our region. Participants (N=28) in the academy were middle school (n=16), high school (n=6), higher education (n=2), and informal science educators (n=4) from Delaware and Maryland. Throughout the week, climate change content experts and experts in learning theory delivered presentations. Participants engaged with vetted classroom resources related to climate change education, examined NGSS components relevant to climate change, and developed their own climate science learning segments to be implemented in their teaching contexts during the 2013-2014 school year.

Participants were presented with a draft hypothesized learning progression on sea level rise, which is a locally-relevant climate change impact. They utilized the sea level rise learning progression as they developed their learning segments, and were asked to consider collecting information during the coming year about their students' understanding of sea level rise. In this way, teachers would take the role of co-researchers in helping to test and validate the draft hypothesized learning progression.

Methods

Our primary methods for gaining insight into the research questions entailed the use of a pre-academy and post-academy questionnaire, individual audiotaped interviews with each participant, and analysis of participant-created learning segments developed during the professional development experience.

Interviews. We interviewed each participant to gain insight into their understandings of learning progressions and their applicability to climate change education. During the interviews, participants watched two brief video clips, recorded during two of the academy sessions. The purpose of the video clips was to place participants' thinking back into the context of the sessions. Participants then responded to questions regarding their thinking about how learning

progressions could inform their teaching about climate change and its impacts, particularly sea level rise. A sample question was:

In the videotape selection from the Climate Science Academy:

- *(video clip from Sea Level Rise learning progression presentation) What did you learn about how learning progressions can guide your teaching about sea level rise, an example of a locally relevant effect of climate change?*

Questionnaires. Before and after the academy, participants completed questionnaires with items related to their perceptions of the climate change topics most relevant to learners in their teaching contexts. These items provided additional insight into our *regional observations* research question. Sample questions included:

- *Does your geographic location influence how you approach teaching about climate change? For example, are certain topics more relevant or interesting for your students based on where they live? Please explain.*
- *Please rank the following three climate change topics according to their relevance to your students (1: most relevant, 3: least relevant).*
    - *Sea level rise*
    - *Extreme weather events*
    - *Urban heat island effect*
- *Which other climate change topics do you see as relevant to your students? Check all that apply.*
    - *Impacts on water systems*
    - *Impacts on agriculture*
    - *Impacts on fishing*

- *Loss of biodiversity*
- *Impacts on human health*
- *Other (please list)*

Learning segments. The key deliverable for participants in the climate science academy was a 3-5 hour learning segment to be implemented in participants' science teaching context during the coming year. Participants had the option to collaborate with others or to work individually on the learning segment. The parameters around the learning segments were flexible, however participants were asked to incorporate the topic of sea level rise and to use the draft hypothesized sea level rise learning progression to inform their learning segment development.

Data

We report data from three focal participants – an informal science educator, a middle school (formal) science educator, and a pre-service (formal) high school science teacher. We believe these participants' voices are illustrative of diverse science educator perspectives on the utility of learning progressions for informing approaches to climate change education, and on the use of a regional observations approach to framing the topic in their teaching. We note that the participants presented here all provide fairly clear ideas about how learning progressions could inform their teaching. However, because we did ask participants how they each defined "learning progressions", it is difficult to discern whether their ideas about the utility of LPs were based upon conceptions of learning progressions that were similar to one another's and ours.

Focal participant 1: Marcia (informal science educator). Marcia is an experienced informal science educator who teaches in an urban park system. She decided to participate in the

professional development academy to improve her own climate science knowledge and learn about current climate change education initiatives for formal and informal science educators. Though the informal science education programs that Marcia was already teaching were focused primarily on water and energy (not specifically on climate change), she believed that the programs could provide a context for students to better understand the issue of climate change.

When asked about the utility of learning progressions for her work, Marcia stated that she envisioned herself using learning progressions to identify "targets for learning" in the informal science education programs she develops. She saw linkages between learning progressions and assessment, and emphasized the importance of connecting her programs to science standards (participants had engaged in a session that demonstrated the connections between the draft hypothesized learning progression on sea level rise and the Next Generation Science Standards). She also reflected on her role as a learner in the Climate Science Academy, and her own level of climate change content understanding in terms of learning progressions:

> *"I would say that was pretty 'Level 2' when I started in terms of a lot of the science of it. There's a lot of content knowledge in this academy that gave us direct, focused time to build some skills… So [I'm] getting an idea of what this learning progression process is all about."* (Interview)

Marcia felt that, having gained new content understandings herself, it would take time to process the information before she could fully apply it to her science teaching, stating "It may take more than the last couple of days for me to internalize it or understand it enough to implement it" (Interview).

In response to teaching climate change with a focus on regional observations, Marcia expressed support, stating, "I'm teaching about my [local park], it's kind of like the fundamentals

of what I do… Locally is always how I do my education" (Interview). She also saw highlighting the local impacts of climate change as a way to make a case for the importance of teaching about the topic. Marcia believed that impacts on water systems and fishing, as well as loss of biodiversity, were climate change topics especially relevant to her teaching context. She viewed public understanding of climate change in her state as primarily focused on sea level rise, although she believed that some people might not fully recognize the connection between sea level rise and the urban community where she worked.

Marcia hoped that she would be able to create successful and positive climate change education experiences through collaboration with other formal and informal science educators. At the academy, she developed her learning segment in partnership with two high school science teachers from her state, Christine (a pre-service teacher) and Patricia (an experienced teacher). Marcia planned to visit these teachers and co-teach a classroom-based program on the properties of water, including thermal expansion, and implications for sea level rise. This experience would be followed up with a field-based experience in which students would complete a GPS scavenger hunt to investigate the impact of sea level rise on local ecological systems. Students would also complete a mapping activity to predict sea level rise in the next 50 and 100 years. Marcia stated,

> *"My hope was that… I would be in on the ground floor of creating a climate change program that involved both in-school and in-field experiences. The amazing part of this short week is that not only do I have that for the future, I have that for now"* (Interview).

Focal participant 2: Christine (pre-service high school science teacher). Christine is a recent graduate of a teacher preparation program in secondary science education. She had received a job offer to teach high school chemistry at an urban independent school, which she

would begin at the end of the summer in which the climate science academy took place. Christine had decided to attend the academy to gain ideas she could use in the classroom, especially since her school offered great flexibility in how she planned the courses she would teach.

When asked about the utility of learning progressions for her teaching, Christine stated,

> *"Personally, I don't think there's a way to teach science without having learning progressions. Especially in my area where everything builds on itself… in order to go on to the next topic you have to have that learning progression, you have to have gained that knowledge. So I'm always seeing my kids grow from level to level as we go through the topics"* (Interview).

She believed that in science, students needed to establish a "baseline" understanding of certain fundamental concepts, which they could continuously build upon and expand. Christine emphasized the use of questions "to help them progress through" and the importance of making connections between abstract topics (e.g., thermal expansion) and the real world (e.g., local environment).

Christine appeared to see value in teaching about climate change through a regional observations approach, stating,

> *"Having it as something where they can go out and see it and map it… is really just going to solidify that. They get to that final level of thinking and it hits home for them. Especially going out and seeing it and playing with any of the simulations and seeing like, wow, I go to Bethany Beach every summer, like that's where I stay…"* (Interview).

She talked about the importance of making science personal for students and helping them to see the relevance of topics, such as sea level rise, to their own lives. She lamented her prior teaching experiences in which students had not seen science learning as relevant:

> *"At the end of the year they're like, we don't understand why we learn this, this, and this, and it kills me, but I was always like "Because we have to.' But if they came at the end and they linked everything together and realized why we did it? I just I think that would be awesome"* (Interview).

She emphasized the importance of seeing climate change impacts firsthand through field experiences in order to get the concepts to "hit home" for students. In addition to sea level rise, she saw impacts on water systems and fishing, as well as impacts on human health as aspects of climate change especially relevant to her students.

In developing her learning segment, Christine collaborated with Marcia (an informal science educator) and Patricia (an experienced high school science teacher from a different part of her state). Among the activities they designed were opportunities for students from two different areas of the state to share predictions and findings with one another related to water chemistry tests, as well as potential implications of sea level rise for local bodies of water. In describing the chemistry content infused in her learning segment, Christine stated,

> *"The second that they start learning about how everything gets excited when it's warming… if they know that thermal expansion does this to water, they connect that with global warming, they are going to [understand that] sea level is going to rise. It's amazing how much that they can put stuff together"* (Interview).

Focal participant 3: Michael (experienced middle school science teacher). Michael is an experienced middle school science teacher working in a suburban public school. He was interested in the climate science academy because he sees climate change as an issue that is "likely to impact our world and our students for the foreseeable future" and because he wanted to "be part of the planning for changing how we (teachers) approach it" (Interview).

Michael viewed learning progressions as a way to think about where "students are at", emphasizing that "we have to be cognizant that students come from a variety of levels". He suggested that learning progressions allow teachers to look at students "more as individual learners, or a group of learners, at a place" and then try to "move them along" to a higher level of understanding. He noted that initially, many students can be expected to "be lower on that scale of progression", and at higher levels, he would expect to see fewer students. Michael cautioned that "your 'Level 4's, the kids that have already made it through the progression" are often the students who are most vocal and participatory in class. Therefore, it is important for the teacher to recognize that "there may be very many students at that much lower level". Michael appeared to think about the idea of learning progressions using the metaphor presented in the academy of the progressive stages of learning to ride a bike (Figure 1). When students come to the classroom with limited prior knowledge or experience with a topic, he saw value in

> *"Slowing down and focusing on bringing that level on that tricycle up to the training wheels, up to the exploration, and then finally being the leader… You really have to be careful about pushing that tricycle too fast, or taking the training wheels off and forgetting your helmet, and those different subtleties about riding a bike."* (Interview).

In response to the idea of the regional observations approach to teaching about climate change, Michael questioned whether his students would have much personal connection or prior experiences related to the topic. He stated that,

> *"In talking about global climate change, you really have to keep that in mind… many students may not have had much interaction with that. And what little interaction they had may have been very highly directed. And it could have been directed through several different ways, it could have been directed through media, their own personal experiences and conversations with people, lay people, scientists, whoever it is… You can't assume that the kids have a strong background in climate science. We can't assume that they understand what global climate change means. We can't necessarily assume that they've heard anything about it. Or that they understand the process at all."* (Interview)

Michael also noted that the suburban environment in which he taught did not "lend itself well to field experiences that could enhance the way students look at the impacts of climate change" (Interview). With that said, he did view extreme weather events, impacts on water systems, loss of biodiversity, and impacts on human health as aspects of climate change that were relevant to his students.

Michael developed a learning segment that involved students in investigations of the connection between carbon emissions and global warming, thermal expansion of ocean water and ice melt as results of global warming leading to sea level rise, and sea level rise predictions for the East Coast of the U.S. The culminating activity would involve students using maps they created showing their coastline under varying sea level rise scenarios. They would use this

information as they worked to design solutions that address the impacts of sea level rise on human populations and ecosystems in their region.

Discussion

We are engaged in ongoing analysis of data provided by the full cohort of participants in the professional development academy, including the three focal participants. Here we discuss some preliminary findings gleaned from the data presented here. We note that analysis of the full set of data collected may impact our final report of the study. The three focal participants illustrate two key points related to our research questions. First, participants, by specialization (e.g., informal and formal) and experience, conceptualized learning progressions in a variety of ways. Second, teaching context (e.g. urban, suburban) may inform participants' thinking about the use of a regional observations approach to climate change education.

We observed that integrating learning progressions into professional development on climate change afforded a number of benefits and challenges. While many participants stated that they viewed learning progressions as useful to their thinking about how they could address climate change, as suggested by our focal participants' responses, it appeared that participants may have had a range of ideas about the definition and purpose of a learning progression. For example, Marcia's conception of learning progressions included some ideas related to curriculum planning ("targets for learning"), which may suggest a view of a learning progression as serving a similar purpose to science standards. Christine's statements about learning progressions sometimes suggested that she saw them as offering a way to represent students' processes of building on prior knowledge, and at other times suggested that she saw them as similar to a science unit plan (for example, she stated that the culminating activity in her learning segment

would take students “back to the [location] where they began this learning progression”). In Michael’s view, learning progressions offered a way to assess individual students’ conceptual understandings, providing teachers with information about how to approach instruction. Other participants, not discussed in detail here, likened learning progressions to other familiar pedagogical concepts such as scaffolding student learning, or “breaking things down into simple steps” (Interview). These differing conceptions of learning progressions emphasize that participants each appeared to interpret learning progressions theory in their own ways and for their own purposes, and raise questions about how best to present learning progressions theory to science educators.

Benefits of including learning progressions in this professional development experience included introducing science educators to a current learning theory of interest to their field. With the Next Generation Science Standards developed from a learning progressions perspective, a better understanding of this theoretical perspective may help both formal and informal science educators participate in current conversations within the wider science education community. The idea of learning progressions may encourage teachers to engage in formative assessment to understand students’ thinking, and may lead to better analysis of student data for instructional design and decision-making. This notion was evident in responses like Michael’s, when he stated that teachers needed to be highly cognizant of where “students were at”. Finally, learning progressions provided a new lens through which some participants were able to reflect on their own understandings. This was evident in comments like Marcia’s, when she stated that she was “pretty Level 2” when she started the climate science academy.

The infusion of a learning progressions perspective into the climate science academy also presented a number of challenges. As stated previously, participants took up the concept in

different ways, some of which conflated learning progressions with other educational or pedagogical notions such as scope and sequence, spiral curriculum, and curriculum standards. We believe this could be a product of teachers' efforts to assimilate a new idea into their diverse existing conceptions of their own science teaching practices, as well as our own decision-making about how to present the concept. Another challenging area was the emphasis of learning progressions theory on formative assessment, in contrast to the emphasis of many teaching contexts on summative assessment. Teaching with learning progressions in mind would require educators to be continuously seeking to understand their students' thinking throughout their engagement with a topic. This raises a final challenge of moving from a learning progressions theory of learning to a teaching progressions approach to participants' classroom practice. Many questions remain related to how participants will be able to use their conceptions of learning progressions to inform their science teaching pedagogy.

Related to the regional observations approach to teaching about climate change, we also observed variation in participants' responses. Notably, for our informal science educator focal participant (Marcia), a regional observations approach was well aligned to the ways in which she was already teaching. Through engaging students in field experiences in the park environment, she was already accustomed to encouraging learners to make observations about their surroundings. While these types of experiences may be more challenging to facilitate in formal science education settings, the partnership between Marcia and Christine exemplifies the potential value of collaboration between formal and informal science educators in teaching climate change using a regional observations approach. We also noted participants' use of technology in engaging students in making sense of regional observations of climate change. An example of this was the dimension of Michael's learning segment that had students creating

maps of future sea level rise based upon their learning through web-based simulations (similar to an online sea level rise activity[1] modeled at the academy).

We noted that although participants were teaching in the same geographic region of the U.S., they did not all view the same regional observations of climate change as relevant for their learners. For example, in ranking the issues of sea level rise, extreme weather events, and urban heat island effect according to their relevance to students, each focal participant selected a different order. Marcia (urban setting) and Michael (suburban setting) both chose extreme weather events as most relevant, while Christine (urban setting) chose sea level rise as most relevant. They had many similarities in terms of the other climate change impacts they viewed as relevant to their students, however, with all three focal participants selecting "impacts on water systems" and two selecting "impacts on fishing", "loss of biodiversity", and "impacts on human health". This raises the point that as teachers in the same region engage in professional development highlighting regional observations relevant to their geographic region of the U.S., they may prioritize varying regional observations of climate change differently. This may potentially relate to differences in the specific contexts in which they work, or simply differences in teachers' perceptions of which issues would be viewed as most pressing in their communities.

Future Directions

In the future, our project will build on these preliminary understandings of the ways in which educators understand learning progressions and see the relevance of learning progressions to their teaching about climate change, and how a *regional observations* approach to climate change education informs educators' thinking about how they will address climate change. We

[1] http://www.climateedresearch.org/EDCI372/

will engage in further analysis of data collected from participants during the summer climate academy, as well as study the implementation of participants' learning segments in their teaching contexts. We will also continue work on the draft hypothesized sea level rise learning progression presented in the academy, with the goal of collecting student data that will help us to validate and refine it. In addition to the sea level rise learning progression, we will begin to develop two additional learning progressions. These learning progressions will be on the urban heat island effect and extreme weather. Finally, we will implement a revised version of the climate science academy in future summers, mindful of lessons learned from our initial climate change academy regarding the inclusion of learning progressions and regional observations in professional development related to climate change education.

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