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Targeted Professional Development Programs in Science Education and Teachers' Perception of the Programs' Impact

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ABSTRACT OF THE THESIS

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by

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Master of Arts, Graduate Program in Education
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The purpose of this study was to investigate teachers' experiences of the professional development program "Engaging Students in Learning about the Earth's Climate" offered by University of California San Diego Extension. It is a program that addresses the controversial issue of global climate change. I aimed to understand how the program was experienced by the participants (elementary- and middle school teachers) and how it impacted their commitment to cover climate change in their classrooms. The study also investigated how this particular program may have changed the teachers' classroom practice. Based on theory and prior research, I summarized characteristics of impactful professional development programs. Although the workshop did not respond to every single element for impactful professional development, my results revealed that overall it increased the participants' engagement to teach about global climate change.

Table of Contents

List of Figures

List of Tables

Chapter I: Introduction and Purpose

In July 2011, the National Research Council (NRC) of the National Academy of Science developed a Framework for K-12 Science Education. This framework served as a basis for the development of the Next Generation Science Standards (NGSS). The NGSS (National Academy of Science, 2013) are rich in content and practice, they are arranged in a coherent manner across disciplines and grades, and they are supposed to prepare students for college and careers. The NGSS are the first set of science standards that explicitly include global, man-made climate change (Hestness, McDonald, Breslyn, McGinnis, Mouza, 2014). Years later, practice and research show, however, that especially the standards on climate change are insufficiently covered – or even worse: Not covered at all - in U.S. public and private schools (e.g. Hestness et al., 2014; Penuel, Harris & Haydel DeBarger, 2015; Sosu, William & Gray, 2008).

There are several reasons for this unfortunate reality. For instance, scientific literacy among educators is often lacking (Hestness et al. 2014; National Research Council, 2012), and addressing climate change's moral dimensions is often perceived as outside of science teachers' roles (McGinnis, 2003, as cited in Hestness et al., 2014, p. 320). In addition, teachers face the challenge of lacking resources such as appropriate instructional materials for this sophisticated, interdisciplinary topic, or there is insufficient guidance on how to approach this element of the NGSS (Sosu et al., 2008, Hestness et al. 2014; Penuel et al., 2015). Another reason why teachers avoid teaching about climate change is the real or perceived lack of alignment between the topic and other content standards, such as standards in biology (National Research Council, 2012).

School districts sometimes do not act in favor of educating teachers in this regard, and their resources for professional development seem to be allocated elsewhere (e.g. Hestness et al., 2014). This is not only harmful for the individual student who wants to pursue a career in a science related field, it is also harmful for the society as a whole. Considering the current challenging political environment in the U.S., it is utterly important that engaged educators actively assist in raising responsible and critical citizens who are aware of controversial environmental issues and improve their decision-making in this regard (e.g. Hestness et al., 2014). In order to implement the vision of the NGSS, and the new standards on global climate change in particular, a big shift in teaching is needed. This shift requires extensive professional development (Penuel et al., 2015). Unfortunately, effective professional development opportunities on global climate change are still rare.

Prior qualitative and quantitative studies in K-12 education show that there are interrelations between teachers' subject matter knowledge, teachers' engagement, high quality professional development programs, teaching practices and students' achievement (e.g. DiEnno & Hilton, 2010; Sosu, William & Gray, 2008; Supovitz & Turner, 2000; Hart, 2003; Littledyke, 2008; Desimone, 2009; Heller, Daehler, Wong, Shinohara & Miratrix, 2012). Also, research has already been done on the development of guidelines and characteristics for effective and impactful professional development programs addressing teachers' content knowledge, teachers' beliefs, and engagement (e.g. Richardson, 2003 & 1994a, Anders & Richardson 1994; Allen & Lederman, 1998, Hawley & Valli, 1999).

In this study, I argue that K-12 teachers are insufficiently prepared to implement the NGSS. I see targeted, impactful professional development as a powerful tool to increase teachers' sense of preparedness. Impactful professional development is needed to increase teachers' content knowledge, to provide high quality teaching materials, and give instructional guidance. I claim that the more teachers feel prepared, the more they are engaged to cover the new standards on climate change in their classroom.

From a behavioral analysis perspective, this study reviews prior research and literature on teachers' engagement. The theoretical basis of this study is the constructivist and sociocultural learning theory which is rooted in the work of Jean Piaget, Lew S. Vygotzky, John Dewey, and Jerome S. Bruner. Much existing research addresses how the application of constructivist methods influences K-12 students' learning and engagement of the subject matter (e.g. Hua Liu & Matthews, 2005; Hoover, 1996). However, few studies investigate adult learners in a constructivist learning environment. In this research, the ideas of constructivism, sociocultural approaches, and professional development combined, and applied on a qualitative case study.

I conducted a qualitative case study in order to understand teachers' professional development experiences in the "Engaging Students in Learning About the Earth's Climate" program offered by UC San Diego Extension at the Birch Aquarium in San Diego.

Research Questions

The purpose of this thesis is to answer the following two research questions: What aspects of targeted professional development programs do teachers perceive as impactful, hence, influence their practice? How do targeted professional development programs shape K-12 teachers' perception of their engagement[1] in covering controversial environmental issues in their curriculum?

Chapter II: Literature Review

Teachers' Engagement in Environmental Education

In their study, Sosu et al. (2008) show the necessity of a holistic understanding of teachers' commitment to environmental education. The authors extend previous studies on teaching environmental education, as they apply theory to explain and measure actual teacher engagement. In applying the model of environmental education commitment (MEEC; further described in the forthcoming section) developed by Shuman and Ham (1997) the authors identify key variables that influence teachers' commitment on covering certain topics in their classrooms. They identified the predictors intentions, attitudes or beliefs, subjective norms (values, according to Hart, 2003), perceived behavioral control, and significant life experiences. These variables ought to serve as a basis for the development of strategies to increase teachers' commitment, i.e. in professional development programs.

[1] The teachers' action-oriented behavior and commitment related to teaching environmental education.

Sosu's et al. (2008) quantitative analysis revealed a complex relationship between the predictors and engagement. Although standardized Beta values show that the variable "perception of control" (autonomy) has the most significant influence on teachers' commitment to a certain topic, there are also moderately strong relationships between the other independent variables and the outcome. In addition, they emphasize the interrelations (covariances) between the predictors. Sosu et al. (2008) cite other studies (Hsu & Roth, 1999; Armitage & Conner, p. 201) which reported similar findings: perceived behavioral control, intention and perceived skills (background knowledge) are the most significant predictors of commitment. In order to increase commitment, the authors suggest to critically reflect teachers' attitudes and beliefs, enhance educators' control over the subject, but also increase their content knowledge (e.g. Cotton, 2006).

According to Green (1971, as cited in Richardson, 1994b, p. 91) beliefs are an individual's conscious or unconscious understandings of how the world works. He defines beliefs as a psychological concept that differs from knowledge, which implies some type of validation process external to the individual. Considering Richardson's (1994b) qualitative work and her literature review, it becomes obvious that teachers' beliefs (key influential variable "attitude" on teacher engagement according to Shuman and Ham, 1997) play an important role in terms of classroom practices. Beliefs affect the way teachers process new information and react to the possibilities of change (Richardson, 1996). As an example, Hestness et al. (2014, p. 321) cites other research (e.g. Wise, 2010) which indicates a belief among teachers that there is no scientific consensus on climate change. Therefore, attitudes and beliefs need to be addressed in

professional development programs designed to alter teachers' engagement and actions (Richardson, 1996; Mouza, 2009). Richardson (1994b) argues that Green's (1971) definition is applicable to teacher education: She cites Fenstermacher (1978, as cited in Richardson, 1994a, p. 92) who points out that one goal of a professional development program is to help teachers transform conscious or unconscious beliefs about content, teaching, learning, and the curriculum into objectively reasonable beliefs. In her research on teacher beliefs and technology, Mouza (2009) concluded that most of the teachers "adopted a new set of beliefs as a direct result of the knowledge and experience acquired through professional development" (p. 1224). In order to do so, teachers first have to identify and assess their beliefs in terms of their teaching (Green, 1971, as cited in Richardson, 1994b, p. 92). Richardson (1996) states that teacher education programs, socialization, and experience can help teachers to change their beliefs and practices. Research has shown that programs based on a constructivist approach are more successful in changing teacher beliefs than those which do not (e.g. Richardson, 1996).

In addition to a quantitative analysis, Sosu et al. (2008) conducted qualitative interviews to gain a deeper understanding of the complex construct "teacher commitment." The main results of this analysis was the identification and confirmation of motivating factors – such as favorable (positive) attitude – and the detection of barriers, such as missing background knowledge and an overly restrictive curriculum.

In terms of the barrier "restrictions in the curriculum," teachers mention a lack of legitimacy of covering environmental issues (Sosu et al, 2008). For instance, educators are forced to push children through standardized examinations and, therefore, focus on

mathematics and English language arts. This perceived challenge falls in line with the result of Sosu's et al. (2008) quantitative analysis which reveals perceived behavioral control, or autonomy, as an important influential factor on teachers' engagement. Hart (2003) asserts that reformers and policy makers repeatedly neglect teachers' values and interests regarding content and teaching practice. The teachers' perception of insufficient control and autonomy over content leads to important inferences for policy makers, educational authorities and people in charge of developing educational reforms. For instance, teachers should be involved in the process of the development of new standards in order to increase the perceived relevance. Sosu et al. (2008) suggest specific actions, such as creating a flexible curriculum or making resources, such as professional development programs, cross-curricular projects, or teaching materials, accessible. Sosu et al. (2008; p. 178) also refer to similar studies, for instance Cutter-Mackenzie & Smith (2003), which essentially came to the same conclusion: The lack of autonomy is, next to insufficient background knowledge, the main influential factors on teachers' engagement covering climate change in the classroom.

Missing background knowledge serves as a barrier for teachers to cover climate change in their classrooms (Sosu et al., 2008). Many teachers feel unprepared to fully address issues of global climate change, as few teachers took college-level courses related to climate science (Wise, 2010, as cited in Hestness et al., 2014, p. 321). As a result, teachers often derive their knowledge from media which is often not scientific enough (Michail et al., 2007, as cited in Hestness et al., 2014, p. 321), or climate change is portrayed as a controversial issue (Lambert et al., 2012, as cited in Hestness et al. 2014,

p. 321). In their research, Hestness et al. (2014) found out that targeted professional development activities can significantly improve teachers' sense of preparedness to teach about climate change.

In order to emphasize the complexity of studying teachers' commitment to covering controversial environmental issues, Sosu et al. (2008) mention that the analysis of the qualitative data revealed "significant life experience" (teacher background characteristics: Supovitz & Turner, 2000) as a powerful influential factor, whereas the quantitative analysis did not. Relatedly, the qualitative interviews central to Hart's work (2003) produced many instances of the importance of significant experiences in the middle childhood regarding developing an environmental consciousness. Hart (2003) also mentions teachers' social interactions as an important influential source.

The Model of Environmental Education Commitment

Based on the theory of planned behavior (Ajzen, 1985), Shuman and Ham (1997) developed the Model of Environmental Education Commitment (MEEC). It is a model that captures the potential for inclusion of life events in shaping teachers' commitment to teach environmental education despite the existence of certain barriers. In other words, it is an expansion of the theory of planned behavior, as it allows the incorporation of significant life experience in the stages of childhood, college, and adulthood. According to the authors of the model, the influential experience could be an outdoor experience, a professional development program or an environmental disaster in any stage stag of life. According to the model, significant life experience can have a direct impact on teachers'

commitment or indirect through the development of certain beliefs, attitudes, subjective norms, or perceived behavioral control (see figure 1)

I use the example of a hypothetical professional development program to explain the model, wherein teachers predisposed to environmental issues attend a professional development program on climate change (adult life experience). This hypothetical program increases their knowledge about the subject matter. After the program, they feel more confident to teach environmental education, therefore, their perceived behavioral control increases. Also, due to the new knowledge and the way the information was conveyed during the educational event, the teachers' beliefs about teaching environmental education changed: Their awareness about the importance of the knowledge about the environment for their students has grown. According to the model, the teachers' commitment to teach this content increased. The model predicts that the greater the teachers' commitment to teach a certain content, the higher the probability that they can overcome barriers, such as the lack of teaching materials, and show the behavior (teaching). This conclusion aligns with Hart's (2003) position on the relationship between teachers' involvement (engagement) and teaching practices (actual behavior).

The following figure envisions the relationships described in the model: The arrows indicate relationships based on the theory planned behavior (Ajzen, 1985), whereas the dashed arrows show the additions Shuman and Ham (1997) suggest. According to both Ajzen (1985) and Shuman & Ham (1997), commitment leads to actual behavior if there are no (external) barriers that prevent them from doing so. In the following section I conceptualize teacher commitment and impactful professional learning using the frameworks of constructivism and sociocultural theory.

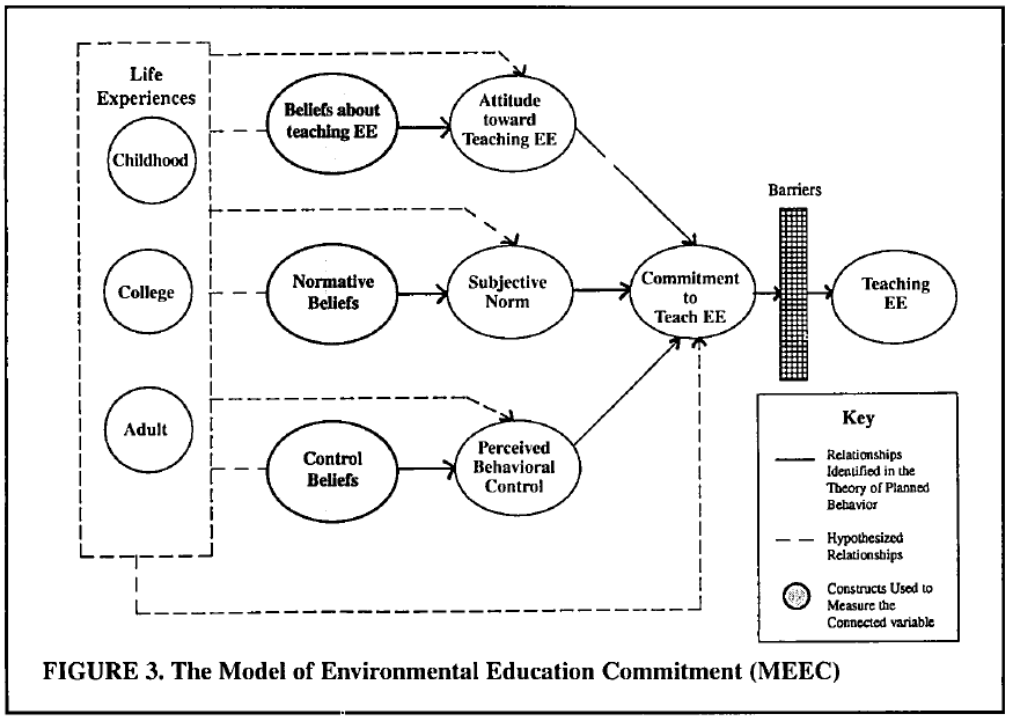

FIGURE 3. The Model of Environmental Education Commitment (MEEC)

Figure 1. The Model of Environmental Education Commitment (MEEC) according to Shuman and Ham (1997)

Constructivism and the Sociocultural Approach in Professional Development Programs

The learner-centered constructivist theory and the sociocultural learning philosophy is mainly rooted in work by scholars such as Jean Piaget, Lew S. Vygotzky, John Dewey, and Jerome S. Bruner (Hua Liu & Matthews, 2005; Hoover, 1996; DiEnno & Hilton, 2010; Galotti, 2011). According to Lord (2010), these philosophies are often applied on college level as well as in secondary education. According to Hoover (1996), the central idea of the theory is that all learning is constructed. All learners, regardless of age, build new knowledge upon the foundation of previous learning. The learning process itself is seen as an active one (active participation; Hua Liu & Matthews, 2005). Therefore, application and hands-on activities, such as experiments, play a major role for successful learning. Hoover (1996) mentions important implications for instructors, too: They must provide a learning environment (opportunities to construct knowledge) that creates new experiences, and they must note that every learner might need different experiences to construct knowledge (human subjectivity: Liu & Matthews, 2005). According to this learning theory, educators have to incorporate problems that are important for the individuals. Hoover (1996) emphasizes that learning experiences should be combined with group interactions. Indeed, group discussions in formal or informal settings or joint presentations of problem solving processes are examples of group interactions. Hua Liu and Matthews (2005) identify the learning environment and social interaction as major stimuli for the individual construction of knowledge. Borko (2004, p. 4) cites scholars such as Greeno (2003), Lave and Wenger (1991), or Cobb (1994) when

she states that learning effectively occurs in socially organized activities. Hence, learning can be viewed as both a process of active individual construction and as a process of enculturation into the society or context.

Research has shown (Lord, 2010; DiEnno & Hilton, 2010; Clover, 2011; Littledyke, 2008; Hestness, 2014) that constructivist and sociocultural approaches are more effective than traditional methods, such as lecturing. Research has taught us that in applying constructivist and sociocultural approaches, learners are more engaged in the subject matter. Learners show higher comprehension and an increased ability to use the new knowledge in various situations. In addition, test achievement scores are significantly higher for these learners (Lord, 2010). The cited research also shows a positive change in attitude towards the subject matter among learners who are exposed to constructivist teaching models.

According to prior research, models based on constructivism and sociocultural approaches can be applied in adult education. My extensive literature review revealed that many scholars use constructivism and/or the sociocultural theory as a basis for their recommendation for impactful professional development. For instance, there is Richardson's work on effective professional development programs ("Practical Inquiry" 1994a & 2003), Darling-Hammond, Hyler, and Gardner's (2017) seven widely shared features of effective teacher professional development, or Hawley and Valli's (1999) eight guiding principles for impactful professional development. The scholars' recommendations are very similar to each other, in that they each emphasize the importance of reflection, collaboration and continuous support.

As an example, Richardson's Practical Inquiry approach describes the teacher as a person who questions assumptions and is thoughtful about goals, practices, learners, and contexts (learning environments). The questioning of assumptions and constant reflection is also apparent in Hart's (2003) work on environmental education and Penuel's et al. (2015) study on professional development and the NGSS. Hart (2003) states that targeted professional development programs should address "some form of critique of environmental and educational values and assumptions that inform existing educational policies, curriculum activities, and school practices" (p. 29). Penuel et al. (2015) claim that in professional development programs, teachers need to be supported in analyzing their own practice. Hestness et al. (2014) found in their study that teachers benefited from reflective activities, such as journaling. Darling-Hammond et al. (2017) mention built-in time for teachers to think about their practice by facilitating reflection and soliciting feedback in order to move toward an expert vision of practice. In Lundeberg's and Levin's study (2003) on teachers' beliefs I found similar conclusions. Activities that offer opportunities for teachers to consider and articulate their own attitudes and values, or hear the perspectives of others, discuss, challenge and defend their own thinking, have the potential to change educators' beliefs. Hawley and Valli (1999, p. 143) cite Borko and Putnam (1995) when they discuss the importance of teachers being asked to reconsider fundamental beliefs, attitudes or practices. Continuous reflection on actions and reexamination of beliefs are also mentioned in Mouza's research (2009) on impactful professional development programs, or Darling-Hammond's work (2005) on professional development schools.

Sharing thoughts or perspectives is only possible in a collaborative setting (sociocultural perspective). Hawley and Valli (1999, p. 141) cite other scholars, for example Fullan (1991), Guskey (1995), or Bryk, Rollow, and Pinnell (1996), stating that collaboration does not only break down teacher isolation. Collaboration collectively empowers teachers, creates an environment of professional respect, and leads to the sharing of knowledge and expertise. Putnam and Borko (2000) emphasize that all knowledge is socially constructed, therefore, teacher learning should take place in a collaborative setting. According to Darling-Hammond et al. (2017), collaborative learning helps teachers to create communities (e.g. Hestness et al., 2014). that can increase teacher learning and practice. Richardson (1994a) and Hestness et al. (2014), too, mention the critical role of collaboration between the individuals (participants and trainers) and the active involvement of the learners (see also Garet, Porter, Desimone, Birman & Yoon., 2001; Hestness et al., 2014; Penuel et al., 2015; Penuel, Fishman, Yamaguchi & Gallagher, 2007).

The trainer's role in a collaborative setting is to facilitate action research.[2] According to Kazemi and Hubbard (2008) and Mouza (2009), the leaders of professional development activities should use artifacts of practice which allow teachers to discuss and negotiate their meaning and function across settings or contexts, and align with classroom practice. Hoover (1996) and Guskey and Yoon (2009) state that trainers in constructivist professional development programs should model learning activities that

[2] Richardson (1994a) refers to action research as a process in which teachers explore a curricular, instructional, or systemic problem or – a more narrower description – the examination of beliefs and assumptions related to certain contexts.

teachers can easily apply in their classrooms. The instructors have to engage the participants in activities that will lead to new actions in the classroom. In other terms, they have to provide them with materials, ideas, or lesson plans that excite and encourage them to modify and use them in their daily work with the students (e.g. Penuel et al., 2015).

According to Kazemi and Hubbard (2008), leaders of professional development have to ensure that the materials are flexible enough to be used in multiple settings, across multiple timescales, and at different times of the year. They have to ensure the connections between settings (teacher learning situation and classroom). According to Darling-Hammond et al. (2017) facilitators ideally show them models of effective practice, including lesson plans, or sample student work.

In K-12 education, teachers have little control over professional practice, certification policies, or personnel decisions (Darling-Hammond, 2005; Sosu et al., 2008: perception of control). Hence, teaching – or instruction - is often perceived as a pre-defined procedure, executed by teachers. Richardson (1994a) points out that in externally set professional development programs, in which the agenda is controlled by people external to the classroom, teacher inquiry is hard to find, because these teachers are unable to self-reflect or participate voluntarily. If the staff development initiative is teacher initiated, however, then teacher inquiry can take place easily. In other words, voluntariness and control of content and behavior, are essential components of an impactful professional development program.

According to Richardson (1994a), the providers of the professional development program should acknowledge the teachers' expertise and practical knowledge based on experience and reflection. According to Hawley and Valli's (1999) design principles of effective and impactful professional development teachers should be, whenever possible, involved in the development of the learning opportunity. A great degree of involvement empowers the participants, increases collaboration, and the content covered in the learning opportunity will be more relevant and meaningful for them. The researchers also point out, however, that teachers might need to be supported in articulating or understanding what their learning needs are, as there are so many opportunities to learn. Although professional development should be primarily school based and integral to school operations (Hawley & Valli, 1999), incorporating outside experts in the learning experience enriches it with new ideas and knowledge from sources beyond the school. The best case is, however, if outside consultants and teachers work as a joint team, for example in a research-practice partnership. An equitable partnership is especially important in order to create and maintain a nonthreatening environment (Hawley & Valli, 1999).

Literature on impactful professional development shows that continuous support during, coaching and follow-ups after the completion of the program is vital (e.g. Darling-Hammond et al., 2017; Garet et al., 2001, Penuel et al., 2015; Penuel et al., 2007). For instance, in an experimental design study, Kleickmann, Troebst, Jonen, Vehenmeyer, and Moeller (2016) compared four groups of teachers. A first group (18 teachers) received professional development with extensive scaffolding, a second group

(18 teachers) was provided with reduced expert scaffolding, and a third group (18 teachers) received no expert scaffolding. The third group was provided with the curriculum materials only (self-study group). A baseline group (19 teachers) did not participate in science related professional development at all and completed questionnaires only. Using ANOVA and effect sizes, the researchers showed that the group of teachers who received extensive expert scaffolding showed significant change in their beliefs, attitudes, and motivation. This finding goes in line with Spark's qualitative studies (1988) on teachers' attitudes and Luft's study (2001) on the impact of an inquiry-based professional development program: the program was more impactful in changing teachers' beliefs when it was accompanied by additional coaching. Continuous and ongoing support is also among Hawley and Valli's (1999) eight principles of impactful professional development. Hawley and Valli (1999, p. 142) refer to prior research, for instance Barr, Anderson, and Slaybaugh (1992) or Hodges (1996), when they state that ongoing support is necessary in particular during the first two years of implementation when the teachers are still practicing.

Providing continuous support and coaching means quick results are highly unlikely to be achieved. Training efforts need to be embedded in an overall improvement strategy (Heller et al., 2012), which also implies that effective, impactful professional development is not a short-term endeavor. Hestness et al. (2014, p. 322) draw on prior studies (e.g. Lester et al, 2016) showing that teachers clearly benefitted from an integrated workshop series that allowed them to practice their climate change education lessons over time. Therefore, professional development ideally is of sustained duration

(e.g. Richardson, 1994a, Darling-Hammond et al., 2017, Garet et al., 2001, Heller et al., 2012, Penuel et al. 2007). Guskey and Yoon (2009) agree on that finding, when they point out that fragmented "one shot workshops" are unlikely to be impactful.

In the next section I summarize researchers' recommendations for impactful professional development programs drawing on the constructivist and the sociocultural learning theories.

Summary of my Contribution to the Literature

In the following table I show those elements identified by the previously cited researchers as impactful and necessary to increase teachers' engagement in covering a topic in their classroom. I organize the elements using the categories participant, trainer, and program. Also, this table aims to emphasize the clear connection between the research question and the theoretical frameworks.

Table 1

Essential elements of impactful professional development programs drawing on the constructivist and sociocultural learning philosophy

Participant (Teacher)	Trainer	Program
Willingness to collaborate and reflect own behavior (teaching) and practices	Comprehensive knowledge	Teacher initiated or based on voluntary participation (perceived behavioral control)
Willingness to share significant life events in terms of teaching with other participants	Acknowledgement of teachers' expertise and prior experience (significant life events)	Incorporates teachers' experience
Willingness to change attitudes/beliefs	Provide challenging learning environment and opportunities to individualize learning environment	Engages teachers in concrete, assessment, and reflection; includes hands-on activities, i.e. experiments
Be comfortable in a collaborative environment and establish a professional network	Provide material that is immediately applicable in the classroom or easy to modify	Illuminates of the process of learning
Openness to receive support from internal and external sources	Ability to provide support after the program; ability to provide follow-up sessions	Flexible in terms of content covered; has clear connections to teachers' work and is derived from teachers' work;
	Ability to manage time effectively	Emphasizes usefulness and applicability of material
		The set-up fosters collaboration among teachers
		Covers cognitive and affective elements
		Sustained, ongoing and intensive
		Connected to other activities of school change
		Supported and valued by administration/principal

The Importance of Context

Context is beyond the teachers' and facilitators' influence, hence, I decided not to focus on it in table 1 (see elements "Connected to other activities of school change" and "Supported and valued by administration/principal"). However, context is vital for the success of the development program, therefore I discuss it in this section in order to give a more complete picture of the influential factors on impactful professional development. Also, keeping context in mind is also necessary for the practical application of my study, especially, when it comes to the explanation of why or why not a professional development activity was impactful. Lack of supportive context can be a barrier, a condition that hinders the sustainability of teachers' growth. For instance, when professional development activities are not embedded in a comprehensive improvement strategy, teachers will have a hard time accessing the necessary resources or learning opportunities. In this section, I focus on the school administration and the district, as my own research in this study revealed that both the school and district leadership can be a barrier to sustained teacher learning.

Scribner (1999) highlights in her article the great influence of the nested context on impactful professional development. She states that professional development has to become an integral part of teachers' work and the culture of schools. Penuel et al. (2007) mention the development of trust at a school site among teachers and administrators. They argue that teachers who get help from their colleagues gain important new information from that interactions (sociocultural perspective). These interactions extend what teachers learn from formal professional development experiences (Ball & Cohen,

1996, as cited in Penuel et al., 2007, p. 930). Penuel et al. (2007, p. 929) also recommend collective participation according to Garet et al. (2001) and Desimone (2002). That means, that teachers from their school and district attend professional development activities together and collaborate afterwards. Studies show, that this strategy builds trust, develops a school culture that is open to learning, and increases teachers' engagement (Frank, Zhao & Borman, 2004, as cited in Penuel et al. 2007, p. 929).

In her research, Mouza (2009) highlights the importance of the school administration in this regard, and Penuel et al. (2007, p. 931) is referring to school leadership as "local supports." School leaders have to create the organizational spaces to create, establish, and maintain collaborative relationships among colleagues. In addition, they have to ensure that the professional development efforts are embedded in an overall improvement strategy (Borko, 2004).

In the best case, this improvement strategy is not just school based, but also aligned with the state's and district's efforts on teacher development (e.g. Desimone, 2009): "In spite of unsteady support, teachers are being asked to teach in ways that promote critical thinking and problem-solving skills that require deeper subject matter knowledge" (Scribner, 1999, p. 240). Hence, in order to fulfill the requirements of new, rigorous standards, such as the NGSS, professional learning is needed that goes beyond fragmented, weakly supported events.

Also, in terms of content, a favorable attitude at the district level is necessary (Readon, 2011), in order to create an impact with professional development efforts. This is particularly true for teaching and learning about climate change. In his article, Readon

(2011) describes how teachers in one school district were required to demonstrate how they were handling the "controversial issue" global climate change. The district wanted to see the teachers approaching the phenomenon in a balanced fashion. A balanced fashion means that teachers teach "both sides." With the NGSS being so clear about the human activity leading to global climate change (National Academy of Science, 2013), following balanced approach seems to be highly questionable. In this context, teachers fear the repercussions of their pedagogical choices. According to Readon (2011) it is the school district's reaction in particular that is an area of teachers' concern. Hence, professional development programs aiming to increase teachers' engagement on covering global climate change according to the NGSS needs to be backed up by a support network.

Chapter III: Methodology

Introduction

In this study, I aimed to understand teachers' professional development experiences in the program "Engaging Students in Learning about the Earth's Climate." I investigated 1) what aspects of targeted professional development programs do teachers perceive as impactful, and 2) the influence of this professional development program on teachers' engagement to implement the new knowledge in their classrooms. I collected data from a variety of sources. In a first step, I read relevant literature in order to become familiar with current research and common theories in the field. Second, I observed the professional development program and conducted interviews with the participants. In a last step, I analyzed the gathered data. Borko (2004) refers to this type of set-up as Phase 1: "The goal of phase 1 activities is to create an existence proof: that is, to provide evidence that a professional development program can have a positive impact on teacher learning. Researchers study a single professional development program at a single site … They explore the nature of the professional development program, teachers as learners, and the relationship between teachers' participation in professional development and their learning" (p. 5).

Data

The Professional Development Program: The professional development "Engaging Students in Learning about the Earth's Climate" is regularly offered by University of California San Diego Extension in partnership with Sally Ride Science and the San Diego County Office of Education. It is usually held once a year at the Birch

Aquarium, San Diego. On the Aquarium's website, it is advertised as a collaborative event that provides educators with access to NGSS and Common Core aligned STEM modules. In addition, teachers are supposed to receive copies of Sally Ride Science books with teacher guides, as well as guidance on how to conduct hands-on activities (experiments). Sally Ride Science books, experiments, and workshops are known for their innovative approaches, for instance the 5E Model, and high instructional quality, i.e. collaboration among participants. I chose this case as a basis for my research because of my personal interest in science education professional development as well as the program's accessibility. Although the program description did not use the terms "constructivist" or "sociocultural," the description appeared to align with the underlying principles. Hence, I assumed that this reoccurring program is set out to use a constructivist and sociocultural approach. This was another reason why I chose "Engaging Students in Learning about the Earth's Climate."

In addition to the program on climate change, UC San Diego Extension regularly offers other in-person or online learning opportunities for K-12 teachers, such as "Explore the California Current Ecosystem" or "Exploring the Deep Ocean with the National Oceanic Atmospheric Administration's Office".

Participants: I chose the participants (four teachers; see table 2) mainly based on their interest of being part of the study. Each teacher is certified by an accredited university. In choosing the interviewees, however, I also kept in mind Luft's (2001) findings on the impact of an inquiry-based, short duration professional development program on teachers, as well as Sandholtz's (2002) study on in-service training versus

professional development and so I included teachers with different levels of experience, as the impact of professional development programs varies according to teacher experience (Luft, 2001; Sandholtz, 2002). In addition, I interviewed one teacher from a Charter school in order to see if there are any differences compared to public school teachers. I believe that the participants I chose are diverse enough to get a sense of multiple perspectives (Rudestam & Newton, 2007) and a variety of experiences to properly to answer my research questions.

The following table gives a brief overview over the teachers who voluntarily participated in the qualitative interviews:

Table 2

Interview participants

Name:	Andrea	Pamela	Vanessa	Daniela
School type	Charter	Public	Public	Public
Grades:	6th grade	6th grade	3rd grade	2nd grade
Demographics:	Female, 25-30 years	Female, 45-50 years	Female, 50-55 years	Female, 40-45 years
Notes:		School has a special focus on science Education		

After completing the professional development program, I contacted the volunteer teachers via e-mail and telephone for one-to-one, semi-structured interviews. Every participant was required to sign the consent form.

Methods

Howe and Eisenhart (1990) argue that in qualitative research it is the purpose that ought to drive the data collection and data analysis process – hence, the methods follow the research question. I purposefully chose the qualitative path to answer the research questions on important elements of professional development as well as the perceived change in teacher engagement. Given the purpose of my research and the research questions, a quantitative approach would not have been successful, as I am interested in teachers' experiences and narratives.

After a thorough literature review I began my qualitative data collection which mainly consisted of observational data, field notes, artifacts (books), and teacher interviews (audio recordings).

Observation: With the current research and theories in mind, I observed the professional development program at the Birch Aquarium. During the event, I collected all the learning materials, such as worksheets and books, and I took photographs of the activities, experiments, and structures on the whiteboard. During the program, I took notes on my laptop. For example, I recorded the layout of the room, how teachers were grouped for activities, or the time spent on the activities. The gathered observational data served to inform interview questions (Howe & Eisenhart, 1990).

Qualitative Interviews: The whole interview protocol is structured around the two research questions on aspects of professional development that are perceived impactful, and how the workshop shaped the teachers' engagement to cover global climate change in their classroom. For example, I asked questions addressing the overall experience of

the event, the teacher's reasoning why the training did or did not change their engagement and attitude, or I asked what characteristics educators are looking for in impactful professional development programs. The unabbreviated interview protocol can be found in the appendix of this study.

The semi-structured interview (Carspecken, 1996) protocol followed the structure Creswell (2014) proposes: Heading (date, place, interviewer, interviewee), Instructions for the interviewer (standard procedure), Questions (starting with an ice-breaker, followed by four to five questions, conclusion), and Probes for four to five questions. In order to answer the research questions, I kept the interview protocol flexible in order to probe for all the information I needed. The initial version of the interview protocol was reviewed by peers and professors, which lead to rewording or restructuring. Their comments informed further interview questions.

During the interview, I followed the characteristics Carspecken (1996) suggests for good qualitative interview conversations. In particular, I focused on guiding the participants through the interview, rather than influencing them too much with leading questions. The participants' responses were the basis of the interview.

In order to analyze the interviews properly, I recorded and transcribed them. In addition, I made notes, for instance when a participant hesitated in answering or emphasized a certain statement.

Data Analysis

For my data analysis, I followed Creswell's (2002) suggestions on qualitative data analysis. Guided by theory and prior research, I developed a general sense of my observational and interview data. The essential elements of impactful professional development programs I display in table 1 served as my coding categories. Table 3 serves as an example how I coded the interview transcripts, and table 4 shows how I coded the observational data. In the results section, I provide the results of my analysis in form of a summary.

Table 3

Three coding examples interviews

Participant (Teacher)	Quote from transcript:	Element
Andrea	"Talking about climate change itself was very cool, definitely the collaboration with other teachers too"	*Program:* The set-up fosters collaboration among teachers
Vanessa	"I was always excited about science, but I had very bad geology class as a kid, it was just textbook and reading. Then in Junior High we had to dissection a frog which was super exciting"	*Teacher:* Willingness to share significant life events in terms of teaching with other participants
Pamela	"I usually look for programs that provide things I can actually implement"	*Trainer:* Provide material that is immediately applicable in the classroom or easy to modify

An important aspect of impactful professional development programs is that they are structured to foster collaboration between participants, and so I coded interview transcripts for teacher references to instances of collaboration with others during the

professional development program (see example Andrea). In addition, in impactful professional development programs, teachers need to be willing to share their experience (see example Vanessa), and trainers provide applicable material (see example Pamela). As shown in table 3, I coded interview transcripts for participants' references to how they shared their experience during the workshop as well as references to the teaching materials they received.

Table 4

Three coding examples observational data

Field notes	Element(s)	Rationale/Comment
Introduction of 5E model (Engage, Explore, Explain, Elaborate, Evaluate) and relevance to CCSS and NGSS	clear connections to teachers' work, Illuminates of the process of learning	Teachers learned how to connect the science content with the standards
Lunch (provided by organization; many informal discussions about the topic & teaching in general; sharing of ideas)	The set-up fosters collaboration among teachers; Be comfortable in a collaborative environment and establish a professional network	In an informal setting the teachers shared ideas or best practices from their school site
Reflection on 5E model; experience today support student learning in the classroom?	Willingness to collaborate and reflect own behavior (teaching) and practices; Be comfortable in a collaborative environment and establish a professional network	Teachers shared their thoughts and professional knowledge on how to use the new method.

In table 4 I show how I coded my field notes for references to the elements of impactful professional development. As shown above, I matched my notes with the elements I expected to see in the program. To make my rationale transparent, I added the

column “Rationale/Comment.” During the introduction of the 5E model, for example, the clear connection to teachers’ work became palpable. The joint lunch contributed to additional opportunities for the teachers to collaborate and to the development of a comfortable environment. Reflections on the 5E model encouraged teachers to rethink their own teaching behavior and practices.

Trustworthiness

In order to assess if a research study is of high quality or not, the analysis of the design is not enough – it is also necessary to look at how the research was conducted. According to Freeman, deMarrais, Preissle, Roulston and St. Pierre (2007), the systematic and careful documentation of all procedures (account of practice) in a qualitative study is a good quality indicator: It makes a scholar’s work convincing. Freeman et al. (2007) state that a good researcher provides a record of ongoing contemplation and peer review. While collecting and analyzing data for my study, I always kept the criterion of account of practice in mind, and I thoroughly described how I conducted my research. In addition, I provide a variety of evidence, such as field notes (see appendix), or teachers’ direct quotes (see results section). Furthermore, I recognize my subjectivity and researcher bias in the section of the limitations.

In research, the term validity is used when it comes to assessing how researchers come to their conclusions: “Validating an argument or research process basically means showing that it is well founded and sound, whether or not the results generalize to a larger group” (Rudestam & Newton, 2007, p. 112). To ensure validity in my study, I handed the analyzed and interpreted data from the interviews back to the participants. In

doing so, I provided them with an opportunity to comment on the findings (member checking: Creswell, 2014). Furthermore, validity can be increased when a researcher's conclusions are based on multiple sources of data. In this study, my conclusions are based on both observations and interview data.

Reliability concerns the replication of the study under similar circumstances (Rudestam & Newton, 2007). According to Gerring (2012), reliability can be hard to test in qualitative research, as there is no opportunity to compare multiple iterations of a single research design. In this study, I explicitly show how I coded my qualitative data (table 3 and 4). In addition, I used peer debriefing according to Creswell (2014): After a fellow graduate student coded an excerpt of a teacher interview using my coding categories, I assessed the level of agreement between us both. Furthermore, peers and external auditors (professors) reviewed the entire project after completion. As my study is consistent with approaches and strategies prior scholars applied (Creswell, 2014), and I documented as many steps of the procedures as possible (Yin, 2009, as cited in Creswell, 2014, p. 203; Freeman et al., 2007), my study satisfies the criterion of reliability.

Chapter IV: Findings

Constructivism and the Sociocultural Approach in a Specific Professional Development Program

In this section of the study, I compare the criteria of impactful and high quality professional development listed in table 1 with the program "Engaging Students in Learning About Earth's Climate" offered by UC San Diego Extension at the Birch Aquarium San Diego. The program's schedule is part of my observational field notes, and it can be found in the appendix of this paper.

All the eighteen elementary and middle school teachers from San Diego County participated voluntarily in the program. However, it was externally organized (UC San Diego Extension with Sally Ride) and the content covered was completely set by the trainers. Although the connection between content and teachers' work was obvious throughout the training day, the schedule was set, hence, teachers could not add or modify content according to their individual needs (see schedule in the appendix).

To accommodate the teachers' different interests and backgrounds, such as different grade levels or special needs students, the trainers provided the participants with the opportunity to download additional and modified material (lesson plans, work-sheets, and factsheets for experiments) for their specific contexts. The facilitators delivered or referred to additional science background information upon teachers' request. During the experiment with the sea shells and the acid, for example, the participants raised a couple of questions about the pH-value and its interpretation. The instructors responded instantly with a quick refresher on the meaning of the pH-value and the acidity of water. An

additional help were the summaries of key concepts: For each section, the detailed lesson plans summarized the contents' key concepts and highlighted what content knowledge the teachers need to have or need to acquire before teaching the lesson.

Furthermore, the program leaders constantly pointed out ideas on how the covered science content according to NGSS can be linked and aligned with the Common Core Standards. With the "ACES Writing Activities,", for example, the facilitators creatively showed how science content can be covered in time slots for English language arts and mathematics (see appendix). In this activity, students learn writing strategies for essay writing while covering content on global climate change. Another example are the sentence structures and guiding questions to facilitate students' talking, as required in the NGSS. The trainers showed how to increase students' participation in whole and small group discussions using questions such as "What are some of the main ideas about ecosystems on this page?", "What is the purpose?", "How do you think living things may be affected by a changing climate? Why?", or "This section says that climate change is nothing new, and that there have been warmer and cooler periods as a result of natural shifts in the Earth's orbit or the amount of sunlight reaching the Earth. I have a question, though: Why isn't that the case today?"

The two trainers, who had a very thorough knowledge regarding content and pedagogy, used the available time to mix information sessions (lecturing), time slots for questions and discussions as well as sequences in which teachers were active. In general, they used the workshop time very efficiently. For instance, there was no time wasted for administrative matters.

As shown in the appendix of this paper, the teachers were actively involved in working through the provided material (e.g. lesson plans or books). For instance, the teachers were involved by participating in hands-on experiments, such as the investigation of temperature change in two different water bottles, or the exploration of how acid breaks down the carbonate in a seashell. Again, the trainers emphasized how to modify these activities for different grade levels or for learners with special needs.

The hands-on activities were held in small-group settings. During these small group sessions, the teachers collaborated and exchanged specific ideas for their classrooms and experiences in their school context. I could also observe these discussions in informal settings during the breaks. The teachers from various school sites seemed to be very comfortable in this collaborative environment and openly shared their experiences and concerns, for instance classroom management issues during experiments, such as appropriate reactions when students disturb the activity through misbehavior.

The two trainers covered facts on global climate change itself, as well as on how to convey it to students in different grade levels (cognitive components), such as concept maps. The videos shown on "How science works," the presentation of the guest speaker, as well as the raised issues with the new standards (insufficient coverage in K-12 education) was intended address areas of concern beyond content and teaching strategies. The latter could have been expanded in terms of time spent, as well as depth of discussion of these issues. For instance, the teachers could have collaboratively discussed how to solve structural or organizational issues by sharing their best practices and experiences.

At the end of the one-day training, the trainers suggested extended and additional programs on environmental education that are offered by UC San Diego Extension, for instance online courses and trainings, or conferences. All these programs are designed for teachers to attend on a voluntary basis. For teachers who did not wish to continue, their training was completed after the one-day-event at the Birch Aquarium. In order to gain in-service course credits, the teachers had to submit a lesson plan within two weeks after the completion of the program. In this lesson plan they were supposed to use the new knowledge acquired during the training. Although the facilitators offered additional training opportunities after the workshop "Engaging Students in Learning About the Earth's Climate," it is not intended to be a series of workshops that build on each other. In addition to further training opportunities, the trainers offered to answer open questions after the program via e-mail or phone. Unfortunately, there was no actual follow-up or structured coaching available for the participants. The day ended with a joint guided tour through the Birch Aquarium.

Looking at the comparison between the observed program and the criteria I expect to find in a professional development program based on constructivist and sociocultural ideas, i.e., a program that has the potential to change attitudes, beliefs, and engagement, I conclude that the observed program widely fits with the principles, although some criteria are not fully met. In particular, the program "Engaging Students in Learning About the Earth's Climate" is organized fully externally, hence, the participants cannot modify the pre-set schedule. In addition, it is a one-day event, hence, it is not of sustained duration. There is no extensive follow-up or coaching available.

My study and previous research (e.g. Darling-Hammond, 2017) revealed that very often professional development programs seldom incorporate all the recommendations for impactful teacher learning opportunities based on constructivist and sociocultural theories. However, facilitators and developers of professional development should combine as many of the suggested elements as possible.

In order to fully answer the research questions of this thesis, I present the results of the qualitative interviews using the criteria in table 1.

Interview Results

The interview coding resulted in a summary of the interviews, which I present in this section of my study. First, I provide some context to highlight the problems, barriers, and the concerns the participants have regarding teaching about global climate change. It becomes obvious that the issues the participants raise are the same ones as mentioned in prior studies, such as lacking scientific literacy (e.g. Hestness et al. 2014; National Research Council, 2012), inadequate resources, the existence of inappropriate instructional materials for this sophisticated, interdisciplinary topic, or the absence of guidance on how to approach this new element of the NGSS (e.g. Sosu et al., 2008, Hestness et al. 2014; Penuel et al., 2015).

Then, I show what aspects of the professional development program the teachers perceived as impactful, such as the availability of worksheets. In a next step, I present how the program shaped teachers' engagement in covering climate change in their classrooms. Lastly, I discuss what potential improvements for professional development programs the teachers see in order to increase their engagement further.

The interviews revealed that for elementary and middle school science teachers, resource access and appropriate training to fulfill the requirements of the NGSS were among the main issues. Pamela, a 7th and 8th grade middle school teacher in her 5th year of teaching, explained that science teachers from different school sites in her district created their own curriculum over the past two years. The school district offered a paid one-week-event during the summer ("Summer Institute") where teachers could collaborate, share, develop, and refine units they directly use in their classroom. Andrea,

a Charter School teacher who teaches science for all 6th grade classes at her school site, received no support or training from the district or the school site. She extracts most of her materials from internet platforms or from the professional development program offered by the Birch Aquarium. According to all of the interviewed teachers, the available textbooks are difficult to access for the students as the reading levels often do not align with the science standards for that grade level, or available textbooks are simply outdated. Vanessa, a 3rd grade teacher in her 39th year of teaching, mentioned that her district provides their teachers with outlines of lesson plans developed by a committee of teachers. She said that these materials are somewhat usable in the classroom. Her main criticism is that these plans are not detailed and comprehensive enough. Hence, the materials require a lot of modification, adaption, and additional research.

Probing more about the particular barriers and obstacles the teachers have to face in their schools, school districts, or on another level, Andrea mentioned that her Charter school doesn't have resources available and doesn't support teachers with training. However, the school reimbursed her when she ordered the necessary materials to carry out the lessons as proposed in the professional development program in San Diego. Daniela mentioned that her school administration is reluctant to spend money on materials teachers need for the experiments. Thinking more about the challenges, Daniela also mentioned structural issues. For instance, in California, a certain number of minutes is required for English language arts and mathematics. According to her, very often teachers don't know how to integrate science content into these two subjects and "kill two birds with one stone." Hence, teachers need more training in this regard.

In terms of training on how to implement the new standards on climate change, the teachers experienced different levels and a varying intensity and quality of preparation. Pamela and Vanessa mentioned that a district wide early training on NGSS two years ago was a more conceptual one, and less focused on content. Andrea, the Charter school teacher, did not receive any introduction into the new standards at her school. Vanessa explained that a one-day mandatory training "was not even close to sufficient," especially in her district where teachers receive release-time instead of paid-time. That means, that teachers are hesitant to leave the classroom and get a school site external training which is not aligned to their schedule. According to Pamela, in her school district there were numerous subsequent, paid trainings after the general introduction, which focused on the new standards' content. Also, Vanessa mentioned some follow-up trainings on the NGSS, which presented her with new ideas "but it's more work in progress stuff." In addition to the district-wide trainings on the NGSS, Pamela mentioned professional development events in the last couple of years regarding project based learning across all subjects organized by her school. This new knowledge, however, turned out to be very helpful for her to fulfill the requirements of the NGSS, especially in terms of students' learning strategies and conceptual learning.

All the interviewed teachers agreed on the importance of collaboration and professional networks. Unfortunately, it was just Pamela and Vanessa who experienced notable teamwork in terms of the implementation of the NGSS, or learning about the new standards on climate change. For Pamela, the district wide supported collaboration with other teachers were helpful to overcome the frustration of lacking materials and of

specific science knowledge[3]. Furthermore, Vanessa emphasized the district wide supported collaboration with teachers in the committee who were, and still are, developing lesson plans and sharing them.

All four interviewed teachers share a very positive experience when thinking back to the professional development program "Engaging Students in Learning About the Earth's Climate." Pamela pointed out that very often the initial description of the professional development program does not match with what it actually is – she mentioned prior trainings on the NGSS which appeared to be on a much higher level but turned out to be more like an introduction. Fortunately, this program met the initial description.

There are many aspects of the training the teachers enjoyed. The interviewed participants perceived the experiments as exceptionally positive. All the teachers enriched their science lessons with the two experiments (see appendix) demonstrated in the training. The collaboration among the participants, the materials, such as the worksheets and templates, as well as the books the trainers provided, were acknowledged as very good and helpful, too. The teachers highly appreciated that they could directly use the materials in their classroom: "The best trainings I attended were those when they used at least part of the time to give teachers a curriculum they can use right away," expressed Pamela. Both Andrea and Daniela, who is a 2nd and 5th grade teacher, did not adapt the materials. They perceived the work sheets, structure of the lesson plans, or readings as

[3] Most of the teachers have strong backgrounds in particular fields of science, such as life sciences; the NGSS require from the teachers that they have a more generalized knowledge and cover all the fields in their classroom.

directly applicable in their classrooms. They felt that all the material was very well aligned to the NGSS. However, depending on the difficulty of the texts, Andrea adjusted her teaching practice or time spent on explaining terms or vocabulary. Daniela also went online and added some additional resources to supplement the professional development program's materials. Pamela, for instance, adapted the materials from the program to fit them into her existing curriculum.

For a professional development program to be perceived impactful in general, the interviewed teachers agreed that showing applicable hands-on activities and providing materials is vital. Engaged, dynamic, and knowledgeable trainers are regarded as a prerequisite for an impactful professional development program. Andrea also mentioned the importance of the group sizes during the training, because she highly values the collaboration with the other teachers and being able to stop and ask questions. Pamela stated that instructors should show participants how to teach certain contents. For instance, she mentioned the difficult vocabulary in science. She stated that trainers should come up with ideas and strategies on how to include terms and vocabulary in teachers' instructional practices. Both Vanessa and Pamela emphasized the importance of ongoing training. Pamela noted that her principal was very supportive when it came to professional development activities on the NGSS, and he encouraged all teachers to go to every training possible. Hence, the principal supported a culture open to learning and improvement, and especially when it comes to science teaching.

According to Pamela and Vanessa, the professional development program at the Birch Aquarium increased their engagement regarding covering climate change in their classrooms, as the resources provided were so helpful, hands-on and very well thought through: “Having all these new ideas, my own excitement rose and I instantly knew that the kids will be more excited too, ” said Pamela. Daniela, for example, emphasized the controversial nature of climate change which, on its own, increased her engagement to teach these issues. The professional development program gave her more support, more knowledge, more confidence, and now she is able to express facts differently. Andrea mentioned in the interview that she was not very excited about teaching climate prior to the program. However, this changed after attending the one-day event, in particular because of the resources and templates, but also due to the collaboration with other teachers: “Talking about climate change itself was very cool.” She realized that students can relate to climate change issues when it is properly taught.

Looking at the perceived change in actual teaching practice after the professional development program, Andrea mentioned that she feels that the program had a great, positive impact on her instruction. She stated that she changed her teaching practice in general. Hence, she was able to generalize what she had learned in the training on climate change to other subjects. She told me that currently she is trying to focus on more conceptual and problem based instruction methods and incorporates hands-on activities. Before, she tended to be more lecture oriented: “Experiencing it first, then explaining it after, was a change in my teaching practice for sure. I kind of forgot how important it was.”

Considering other factors that may change a teacher's engagement covering controversial environmental issues in their classrooms, all four teachers mentioned that they generally enjoy science and they feel that students should be properly educated in that field: "Science blows my mind," said Vanessa. She referred to a remarkable class she took in junior high school when she was a kid and she had to dissect a frog. Also, she remembered very good chemistry classes in high school with meaningful experiments. But also on college level, she experienced fabulous science classes. All these experiences led to her being committed to covering science - environmental issues in particular - in her classroom. Daniela mentioned the daily living in California that motivates her to cover environmental issues in her classroom to increase students' awareness. For example, she mentioned the draught, mud slides, and wild fires. Pamela agreed on that statement, when she highlighted that teachers have to show kids how they can help, what the "depressing facts" are, but also that there are solutions, too. Pamela pointed out that teachers should show their students that they can make a difference when it comes to climate change.

The participants also mentioned potential improvements in order to further increase their engagement on teaching about global climate change. Daniela referred directly to the professional program at the Birch Aquarium when she stated that for her the inclusion of new technology is important. In the particular program, she was hoping to see more online activities for the students where they can work collaboratively on tasks. Vanessa perceived the books as too much "campaigning for science" and she was missing basic data in the reading tasks. According to her, even younger students are

capable of understanding numerical data if it is processed adequately. In addition, Vanessa emphasized the higher impact of ongoing training compared to one-time events like the program at the Birch Aquarium. She suggested that schools should use staff and grade-level team meetings for additional training purposes in order to expand the impact of one-day workshops.

Chapter V: Conclusion

My study showed that professional development on global climate change is complex and has its unique challenges (Hestness et al., 2014). The content is sophisticated, teachers' attitudes and beliefs play a major role, and the pedagogy can be demanding. Based on the MEEC, the constructivist and sociocultural learning theory, and empirical data, my study sheds light on elements that should be apparent in impactful professional development programs. Impactful professional development programs are able to increase educators' commitment to cover certain topics in their classrooms. A greater teacher commitment and engagement is supposed to result in increased student engagement and, in turn, student achievement. In my study, the theoretical framework, prior research, and the empirical analysis are closely linked, which leads to trustworthy findings and interpretations.

Research Questions and Main Findings in Relation to Prior Research

Based on evidence of prior research and theory, the objective of my study was to discover elements of effective and impactful professional development programs in science education. Using a qualitative case study, I also showed how a targeted professional development program shaped teachers' engagement to cover this topic in their classroom.

My first research question addressed aspects of targeted professional development programs that teachers perceive as impactful. One of the themes that emerged from my analysis was that programs that are based on constructivist and sociocultural approaches are more impactful than those using traditional methods, such as lecturing. Looking at my

literature review and table 1, scholars widely agree on the elements of impactful professional development programs.

In my qualitative case study I addressed my second research question on how targeted professional development programs shape K-12 teachers' perception of their engagement in covering controversial environmental issues in their classroom. I found out that in professional development programs it is mainly the collaboration, applicable and accessible materials, as well as hands-on activities that make teachers wanting to learn more about the topic and its pedagogy. As a result, their engagement regarding covering this topic in their classroom increases (see MEEC).

The findings of my qualitative case study support my hypothesis on the unpreparedness of teachers. The interviews indicated that teachers feel unprepared to cover global climate change in their classroom. The participants' engagement increased with their sense of preparedness. For instance, the participants of my study mentioned lacking teaching materials and insufficient professional development opportunities.

The program "Engaging Students in Learning About the Earth's Climate" responds to research-based recommendations on effective professional development, although it does not incorporate all the suggested elements. For instance, the program does only provide limited follow-up trainings and it is not following a long-term approach. Indeed, the program under investigation is designed as a one-day workshop. However, the facilitators and developers paid close attention to incorporating many of the recommended elements, such as collaboration and hands-on activities. The provided materials were fantastic. These findings are very positive, as prior research (e.g.

Sandholtz & Scribner, 2006) and my qualitative interviews in this study indicated that teachers are often exposed to professional development programs that do not follow the recommendations listed in table 1.

Limitations

In this section I discuss limitations of my study. First, I will acknowledge my own researcher bias and I will talk about the strategies I used to eliminate this bias. Next, I will discuss the extent of the study. Lastly, I address some validity and reliability concerns and possible limitations of the results.

Researcher bias: Gerring and Christenson (2012) and Anders and Richardson (1994) point out that the beliefs of a researcher can influence the process of data collection, the analysis and interpretation, as well as the conclusions. Peshkin (1988), who is an experienced qualitative researcher, points out that own biases and subjectivity need to be constantly addressed during the research process. As a former teacher and teacher educator, I can hardly fulfill the role as a completely detached researcher, as I am very familiar with the teachers' concerns. In addition, I was in charge of initiating, implementing, and evaluating professional development addressing educational reform and new standards at my school site. I am passionate about education, high quality instruction and student support. By involving third parties – professors as well as peers – I tried to reduce bias as much as possible. In addition, I regularly recorded my thoughts in a journal.

Extent of the study: I am aware that using only few participants as well as one professional development program (case) could lead to limited opportunities to generalize the findings. For subsequent studies, additional professional development programs could be added. Relatedly, the results are based on a group of female teachers who share a liberal mindset. Not only could the number of the participants be increased, the interviewees could also vary more regarding teaching experience, subject area, educational level, age, and gender (Sandholtz, 2002).

Validity and reliability: In a consecutive, larger study the validity of the data collection could be expanded as follows: 1) classroom observations (site visits) before and after the professional development experience, 2) document analysis (curriculum, syllabus, worksheets) before and after the professional development experience, and 3) students' interviews on how the overall teaching of the subject matter has changed after the professional development experience (triangulation). For a larger and externally funded study, cross-referencing to increase validity could be applicable. This larger study could compare different professional development programs and gather data using daily, weekly, or monthly surveys or logs, as well as video observations (e.g. Desimone, 2009).

Also, in a larger study, intercoder agreement (Creswell, 2014) could be applicable: A team of coders ensures the highest reliability possible. As mentioned above, in this study it was just one person who coded some of the interview excerpts with me.

Results: Based on the literature in this research area I am aware that capturing teachers' engagement and measuring impactful professional development is a very complex endeavor (e.g. Desimone, 2009). For example, prior research identified various,

interrelated influential factors on teachers' engagement or behavior. Especially when different methods (quantitative or qualitative) are applied, the magnitude of the variables' contribution to teachers' engagement is ambiguous (e.g. Sosu et al., 2008). The empirical findings of my study could be viewed as restricted to my qualitative case study, as my results are developed in a certain context and they are, therefore, very specific (Gerring & Christenson, 2012). Most of my empirical findings are based on teachers' self-reports as well as on how I experienced the professional development program. Hence, generalizations stemming from my empirical results are limited. Although the research question is fully answered with the selection of my approach, I am aware that there are some limitations.

Given the fact that in table 1 I organized the elements of effective professional development around the criteria participant, trainer, and program, I mentioned the importance of context more as a side note. I want to highlight, however, that a school districts' improvement strategy or a supportive environment at the school site is vital for the impactful professional development programs. This is true not only for science education, but also for all the other subjects, too.

Implications and Practical Application

One scholarly contribution of this study is to show what factors shape teachers' engagement to cover certain topics in their classroom, and what role professional development plays in this regard. A second contribution is to develop impactful or assess existing professional development programs addressing the NGSS or global climate change. The results of my research can be used by school districts, trainers, or teachers.

School districts can use the results of this study to overcome barriers that hinder teachers' commitment or actual teaching behavior by changing institutions' organizational structures and practices.

Currently, we witness increased public awareness of global climate change. The new set of rigorous standards (NGSS) can potentially catalyze climate change education efforts over the coming years (Hestness et al, 2014). However, without impactful, targeted professional development programs and high-quality research, the goals of the NGSS seem impossible to achieve.

Recommendations for Future Research

Given the results of the interviews and the problems with the implementation of the NGSS indicated in the introduction of this paper, there are various starting points for future research.

One avenue for a future study could be the investigation of additional factors influencing impact of professional development and teacher engagement (e.g. Desimone, 2009). For instance, the influence of the usage of technology or media, such as documentary films, in professional development could be investigated. Or in the light of the finding that some life events shape teachers' engagement, additional research could focus on what extent professional development programs produce significant life experiences which, in turn, affect teachers' commitment.

Based on this study, a follow-up study could be conducted. In particular, I am thinking about investigating in what additional, consecutive professional development the teachers participated, how they adapted and integrated the material, and what additional material they created.

Another possible area of future research could involve the school district, school administration, and the supportive or not supportive climate. Specifically, I am thinking about an experimental design study in which school districts are compared.

Further research could also be done on a broader basis. It might be useful to investigate discourse on ethics and morals in education, such as the importance of teaching or educating students on controversial topics, or conveying values and norms. In addition, this study focuses on formal learning in a classroom setting. Informal or implicit learning about the earths' climate could be part of a teachers' curriculum if they plan any field trips or excursions.

In adding global climate change to the new NGSS standards, I believe the National Research Council (NRC) made a clear statement on the importance of science education "in shaping a nation of citizens capable of understanding and making informed decisions about global climate change" (Hestness et al., 2014, p. 319). I believe, getting the teachers on the same page regarding content knowledge and favorable attitudes and believes is an important step we must immediately take. Impactful and targeted professional development is the vessel to push teaching about climate change from controversial towards a legitimate educational concern.

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Appendix A

Schedule

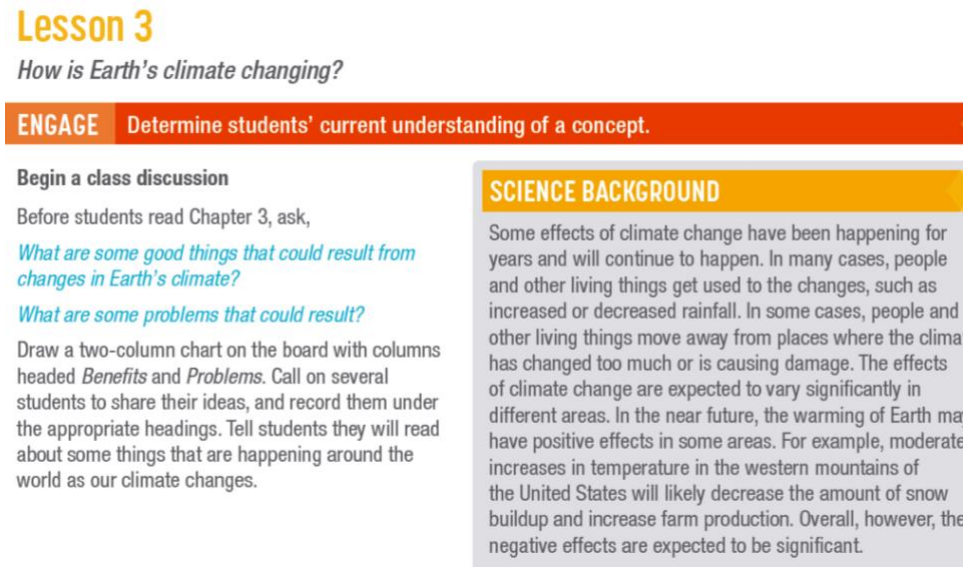
Professional Development Program: Engaging students in learning about earth's climate

8:00 am Check-in and continental breakfast

8:20 am Welcome & Introduction
Introduction of trainers (Karen and Chelsea) and participants (18 elementary and middle school teachers);

8:30 am Introduction to Sally Ride Science STEM Modules & books; Introduction of 5E model (Engage, Explore, Explain, Elaborate, Evaluate) and relevance to CCSS and NGSS

8:45 am Walked through the Earth's Climate module (How and why is Earth's atmosphere changing?), started off with Lesson 3; process exactly how teachers go through with students, but a little bit faster and with instructional advice and time for teachers' questions regarding instruction or content. Aim: To get a sense of the 5E model and how the modules work.
Engage: Benefits & Problems of warmer weather-> small group discussion, answers collected on white board;



Lesson 3

How is Earth's climate changing?

ENGAGE Determine students' current understanding of a concept.

Begin a class discussion

Before students read Chapter 3, ask,

What are some good things that could result from changes in Earth's climate?

What are some problems that could result?

Draw a two-column chart on the board with columns headed *Benefits* and *Problems*. Call on several students to share their ideas, and record them under the appropriate headings. Tell students they will read about some things that are happening around the world as our climate changes.

SCIENCE BACKGROUND

Some effects of climate change have been happening for years and will continue to happen. In many cases, people and other living things get used to the changes, such as increased or decreased rainfall. In some cases, people and other living things move away from places where the clima has changed too much or is causing damage. The effects of climate change are expected to vary significantly in different areas. In the near future, the warming of Earth ma have positive effects in some areas. For example, moderate increases in temperature in the western mountains of the United States will likely decrease the amount of snow buildup and increase farm production. Overall, however, the negative effects are expected to be significant.

Explore: Investigation: Hands on activity (simulating greenhouse effect with water bottles; small groups); alternative: video

EXPLORE Students observe, record, and describe data.

Watch video investigation: *Holding the Heat*

DOWNLOAD STUDENT VIDEO INVESTIGATION GUIDE

DOWNLOAD VIDEO INVESTIGATION GUIDE TEACHER EDITION

Give students the *Holding the Heat* Video Investigation Guide and have them watch the video *Holding the Heat*. In this investigation, students explore how extra carbon dioxide affects the temperature of air in a bottle placed under a heat source. Students add carbon dioxide to one bottle by dropping effervescent tablets in it, and then monitor the temperature in that bottle and in a control bottle.

The video has a place where you can pause to allow students to make a prediction on their investigation guides. After students watch the video, have them answer the interpretation questions about the investigation. Call on several students to share their answers with the class. See the teacher edition of the investigation guide for an answer key.

STANDARDS ALIGNMENT

NGSS
- *DCI* 3-ESS3.B: Natural Hazards
- *SEP* Engaging in Argument from Eviden
- *CCC* Cause and Effect

CCSS
- RI.3.2: Key Ideas and Details
- RI.3.4: Craft and Structure
- RI.3.10: Range of Reading and Level of Te Complexity
- W.3.10: Range of Writing
- SL.3.6: Presentation of Knowledge and Ideas
- L.3.1: Conventions of Standard English
- L.3.3: Knowledge of Language

HANDS-ON OPTION

To conduct the investigation in your classroom instead of watching the video, download the student and teacher *Holding the Heat* Investigation Guides, hands-on versions.

Explain: Reading in provided book (teachers' handbooks available)

EXPLAIN Provide time for students to explain concepts in their own words.

Model asking questions while reading

E-BOOK: *EARTH'S CLIMATE*

Tell students that asking questions while reading is a good way to improve their understanding. Use Chapter 3 of *Earth's Climate* to model asking questions while reading. Have students turn to page 16. Read aloud the title and subtitle of the chapter: Chapter 3: *Earth's Climate Is Changing—This Time, It's Us*. Say,

I wonder what that subtitle means: This Time It's Us. Has something else changed Earth's climate in the past? Write on the board, *What has changed Earth's climate in the past?*

STANDARDS ALIGNMENT

NGSS
- *DCI* 3-ESS2.D: Weather and Climate
- 3-ESS3.B: Natural Hazards
- *SEP* Obtaining, Evaluating, and Communicating Information
- Engaging in Argument from Evidence
- *CCC* Patterns
- Cause and Effect

CCSS
- RRI.3.1: Key Ideas and Details
- RI.3.7: Integration of Knowledge and Ideas
- RI.3.10: Range of Reading and Level of Text Complexity
- W.3.8: Research to Build and Present
- W.3.10: Range of Writing

Then say, *Good readers ask questions while they read. It helps them to better understand the text. They look for answers to their questions in the text or in other resources. Let's look for the answer to my question.*

Have a student read page 16 aloud. Say, *It says in the past, climate changes have been caused by variations in Earth's orbit or volcanic eruptions. That answers one of my questions. But what is changing the climate now? That's another question.*

Explain to students that asking themselves questions as they read will help focus their attention on important points of the reading.

Read Chapter 3: *Earth's Climate is Changing*

DOWNLOAD *EARTH'S CLIMATE* CHAPTER 3 STUDY GUIDE

Ask students to read Chapter 3 of *Earth's Climate: Earth's Climate is Changing*. (pages 16-23) and take notes on their Chapter 3 Study Guides. Tell them to write down any questions that occur to them as they read and to note any answers they find.

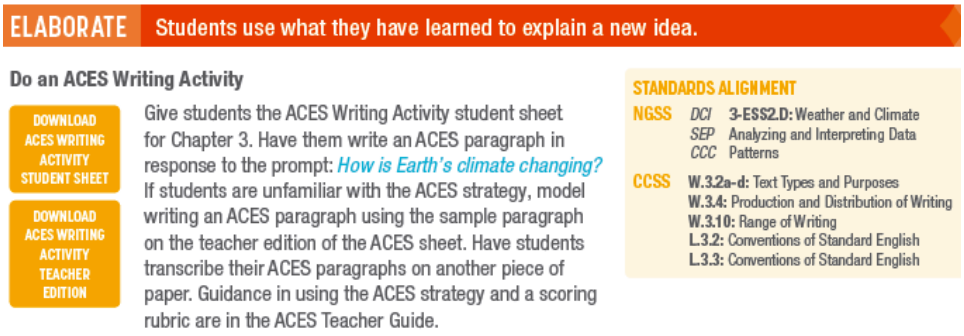
Read *Thinking Like a Scientist*

DOWNLOAD *THINKING LIKE A SCIENTIST* STUDENT SHEET

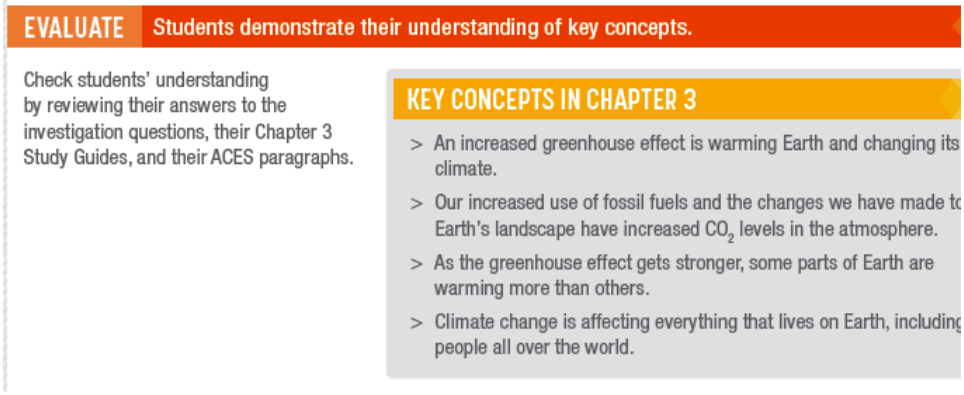
Ask students to go to page 24 in *Earth's Climate* and read *Thinking Like a Scientist*. Give them the *Thinkin Like a Scientist* student sheet and have them use it to answer the questions on page 25. Have students work in small groups to discuss the questions and come to agreement on the answers. Then ask each group to present one answer. Answers to the questions are in the *Earth's Climate Answer Key*.

DOWNLOAD *EARTH'S CLIMATE* ANSWER KEY

Elaborate: ACES (writing strategy) writing activity (-> links to language arts!)

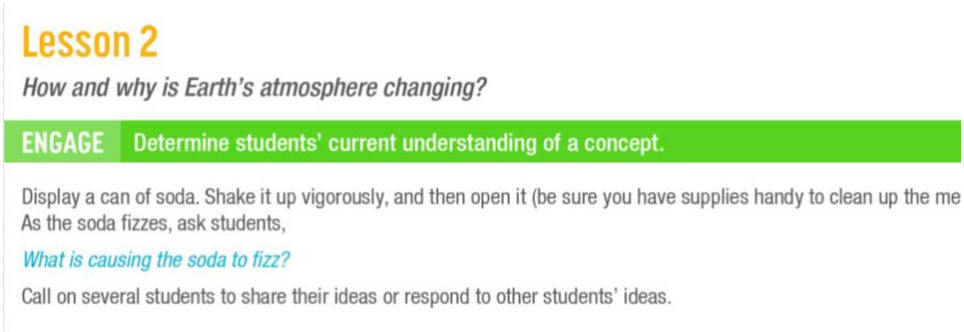


Evaluate: formative control; assessment



10:15 am Break

10:30 am Walked through lesson 3 Module "Climate Change Impacts"; 5 lesson plan; faster than before;
Engage: whole classroom discussion



Explore: Same hands down activity/video as before; was not repeated

EXPLORE Students observe, record, and describe data.

Watch video investigation: *Holding the Heat*

DOWNLOAD STUDENT VIDEO INVESTIGATION GUIDE

DOWNLOAD VIDEO INVESTIGATION GUIDE TEACHER EDITION

Give students the *Holding the Heat* Investigation Guide and have them watch the video *Holding the Heat*. In this investigation, students explore how extra carbon dioxide affects the temperature of air in a bottle placed under a heat source. Students add carbon dioxide to one bottle by dropping effervescent tablets in it, and then monitor the temperature in that bottle and in a control bottle.

The video has a place where you can pause to allow students to make a prediction on their investigation guides. After students watch the video, have them answer the interpretation questions about the investigation. Call on several students to share their answers with the class. See the teacher edition of the investigation guide for an answer key.

STANDARDS ALIGNMENT

NGSS *DCI* **MS-ESS3.D:** Global Climate Change
SEP Asking Questions and Defining Problem
CCC Stability and Change

CCSS **RST.6-8.3:** Key Ideas and Details
RST.6-8.9: Integration of Knowledge and Idea

HANDS-ON OPTION

To conduct the investigation in your classroom instead of watching the video, download the student and teacher *Holding the Heat* Investigation Guides, hands-on versions.

Explain: reading and writing activity (was not practiced with teachers; just shown)

EXPLAIN Provide time for students to explain concepts in their own words.

Model asking questions while reading

E-BOOK: *THE ATMOSPHERE*

Have students open to page 14 of *The Atmosphere*. Focus their attention on the paragraph titled "Back to the Future." Have a student volunteer read the section aloud.

Then say,

This section says that "climate change is nothing new" and that there have been warmer and cooler periods in Earth's history as a result of natural shifts in Earth's orbit or the amount of sunlight reaching Earth. I have a question, though: Why isn't that the case today?

Tell students that a good strategy to help them understand what they read is to ask questions as they read. Before they read Chapters 4 and 6 in *The Atmosphere*, go over these strategies of active reading.

STANDARDS ALIGNMENT

NGSS *DCI* **MS-ESS3.D:** Global Climate Change
MS-ESS2.D: Weather and Climate
MS-ESS3.A: Natural Resources
SEP Asking Questions and Defining Problems
Developing and Using Models
Planning and Carrying Out Investigations
Constructing Explanations and Designing Solutions
CCC Stability and Change
Cause and Effect
Systems and System Models

CCSS **RST.6-8.2:** Key Ideas and Details
RST.6-8.4: Craft and Structure
RST.6-8.10: Range of Reading and Level of Text Complexity
WHST.6-8.9: Research to Build and Present Knowledge
WHST.6-8.10: Range of Writing

During reading . . .

> ask questions as you read
> reread confusing passages at a slower pace or mark confusing passages to review later.
> jot down notes about the big ideas and how they connect to each other.

After reading . . .

> think about what you've read. What was most important? What was interesting, strange, or completely new to you?
> clarify your notes so they help you recall the big ideas and how they connect.

Read Chapters 4 and 6 in *The Atmosphere* (pages 14-23 and 26-29)

DOWNLOAD *THE ATMOSPHERE* CHAPTERS 4 AND 6 STUDY GUIDE

Ask students to read Chapters 4 and 6 in *The Atmosphere*. As they read, they should write down questions that occur to them on their study guides.

After students are done reading, call on several to share some of their questions about Earth's climate. Call on other students for ideas about how to find answers to the questions.

Explain: reading and writing activity (worksheets); sorting of cards (sinks or source)

EXPLAIN Provide time for students to explain concepts in their own words.

Model asking questions while reading

E-BOOK: *THE ATMOSPHERE*

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Tell students that a good strategy to help them understand what they read is to ask questions as they read. Before they read Chapters 4 and 6 in *The Atmosphere*, go over these strategies of active reading.

STANDARDS ALIGNMENT

NGSS
- *DCI* **MS-ESS3.D:** Global Climate Change
- **MS-ESS2.D:** Weather and Climate
- **MS-ESS3.A:** Natural Resources
- *SEP* Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Constructing Explanations and Designing Solutio
- *CCC* Stability and Change
- Cause and Effect
- Systems and System Models

CCSS
- **RST.6-8.2:** Key Ideas and Details
- **RST.6-8.4:** Craft and Structure
- **RST.6-8.10:** Range of Reading and Level of Text Complexity
- **WHST.6-8.9:** Research to Build and Present Knowledge
- **WHST.6-8.10:** Range of Writing

During reading . . .

> ask questions as you read
> reread confusing passages at a slower pace or mark confusing passages to review later.
> jot down notes about the big ideas and how they connect to each other.

After reading . . .

> think about what you've read. What was most important? What was interesting, strange, or completely new to you
> clarify your notes so they help you recall the big ideas and how they connect.

Read Chapters 4 and 6 in *The Atmosphere* (pages 14-23 and 26-29)

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After students are done reading, call on several to share some of their questions about Earth's climate Call on other students for ideas about how to find answers to the questions.

Evaluate: Evaluation of cards (sinks or sources)

EVALUATE Students demonstrate their understanding of key concepts.

Check students' understanding by looking over their answers to the *Holding the Heat* questions, listening as they take part in class discussions, and evaluating their *Source or Sink?* sheets.

KEY CONCEPTS FROM *THE ATMOSPHERE*, CHAPTERS 4 AND 6

- Climate change is a natural process. There have been warmer times and cooler times throughout Earth's history, for various reasons.
- Human activities are adding carbon dioxide and other greenhouse gases to the air.
- This is magnifying Earth's greenhouse effect and making our planet warmer.
- The amount of carbon dioxide in the air is higher now than it's been in at least 650,000 years.
- Earth's temperature and the amount of carbon dioxide in the air go up and down together.
- Over the past 100 years, Earth's average air temperature has warmed about 0.8°C (1.5°F).
- Global climate warming is causing oceans to warm, glaciers and ice caps to melt, weather patterns to change, and plants and animals to resettle in cooler lands or waters.
- The carbon cycle continuously moves carbon around Earth.
- Plants on land and phytoplankton in water remove carbon dioxide from the air to use in photosynthesis. As part of this process, oxygen is released into the air.
- When trees or other plants are cut down or die, much of the carbon dioxide they stored in their stems and leaves during photosynthesis is returned to the air.

11:15 am Brief overview 2 Module "Climate Change Impacts"; 3 lesson plan
Engage: Whole classroom discussion

Lesson 2

How are ecosystems changing in response to climate change?

ENGAGE Determine students' current understanding of a concept.

Begin a class discussion

Hold up a seashell. Ask students,

What is this?

What is its purpose?

How is it made?

Call on several students to share their ideas or respond to other students' ideas. Record students' answers on the b

Explore: Investigation/hands-down with eggshells and water/acid; alternative: video

EXPLORE Students observe, record, and describe data.

Watch video investigation: *A Slow Dissolve*

DOWNLOAD STUDENT VIDEO INVESTIGATION GUIDE

DOWNLOAD VIDEO INVESTIGATION GUIDE TEACHER EDITION

Give students the *A Slow Dissolve* Investigation Guide and have them watch the video *A Slow Dissolve*. In this investigation, students see how acid breaks down the carbonate in a seashell. They relate their findings to understanding that as more carbon dioxide dissolves into the oceans, the oceans become more acidic. This lower ocean pH can harm marine animals by neutralizing the carbonate in their exoskeletons and shells.

STANDARDS ALIGNMENT

NGSS *DCI* **MS-ESS2.C:** The Roles of Water in Earth's Surface Processes
MS-ESS3.D: Global Climate Change
SEP Planning and Carrying Out Investigatio
Asking Questions and Defining Proble
CCC Stability and Change
Systems and System Models

CCSS **RST.6-8.3:** Key Ideas and Details
RST.6-8.9: Integration of Knowledge and Ide
SL.6-8.1: Comprehension and Collaboration

The video has a place where you can pause to allow students to make a prediction on their investigation guides. After students watch the video, have them answer the interpretation questions about the investigation. Call on several students to share their answers with the class. See the teacher edition of the investigation guide for an answer key.

HANDS-ON OPTION

To conduct the investigation in your classroom instead of watching the video, download the student and teacher *A Slow Dissolve* Investigation Guides, hands-on versions.

Explain: Concept map with worksheets; individual work; then discussion

EXPLAIN Provide time for students to explain concepts in their own words.

Model making a concept map

E-BOOK: *ECOSYSTEMS*

DOWNLOAD *ECOSYSTEMS* CHAPTERS 3-4 STUDY GUIDE

Give students the Chapters 3-4 Study Guide for *Our Changing Climate: Ecosystems*. Point out that it has a place to draw a concept map summarizing the key points in the reading. Then draw a circle in the middle of the board. Write *Ecosystems* in the circle. Draw a second level of circles ringing the middle circle. Draw connecting lines from the middle circle to the new circles. Tell students that each level provides more detail for the previous level. Tell students to copy the concept map on their study guides.

STANDARDS ALIGNMENT

NGSS *DCI* **MS-LS1.C:** Organization for Matter and Energy Flo in Organisms
MS-LS2.A: Interdependent Relationships in Ecosystems
MS-LS2.B: Cycle of Matter and Energy Transfer in Ecosystems
MS-LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP Constructing Explanations and Designing Solutions
Engaging in Argument from Evidence
Analyzing and Interpreting Data
Developing and using models
CCC Energy and Matter
Cause and Effect
Stability and Change

CCSS **RST.6-8.2:** Key Ideas and Details
RST.6-8.4: Craft and Structure
RST.6-8.10: Range of Reading and Level of Text Complexity
WHST.6-8.9: Research to Build and Present Knowledge
WHST.6-8.10: Range of Writing

Have students turn to page 10 in *Ecosystems*. Call on a student to read aloud the text on page 10. Then ask,

What are some of the main ideas about ecosystems on this page?

In the second level of circles, write students' responses, such as *Ecosystems around the world are feeling the heat* and *As temperatures rise, animals and plants are expanding into new territories where it's cooler*.

Tell students that as they read, they should add to their concept maps.

Read Chapters 3-4 in *Ecosystems* (pages 10-27)

Ask students to read Chapters 3-4 in *Ecosystems*. As they read, they should take notes on their *Ecosystems*: Chapters 3 Study Guides and add to their concept maps. After students are done reading, call on several to share what they added t their concept maps.

Elaborate: Careers in science (separate book) & writing activity (worksheet)

ELABORATE Students use what they have learned to explain a new idea.

Read about a scientist whose work involves climate change

E-BOOK: *COOL CAREERS IN ENVIRONMENTAL SCIENCES* (MS)

DOWNLOAD *IS IT 4 U?* WRITING ACTIVITY STUDENT SHEET

Have students open *Cool Careers in Environmental Sciences* (Middle School) to page 20 and read about Patrick Gonzalez, a forest ecologist at the National Park Service who looks for signs of stress and disease in forests and tries to find ways to help. Ask,

What were some of Patrick Gonzalez's interests when he was young that led him to his career? [On family trips to national parks such as Yellowstone, he explored the forests. He loved the smell of the pine trees and the sound of the wind blowing. He liked being outdoors a lot, and became more interested in school. Today, he makes a living studying the outdoors he's always loved.]

What are some of your favorite activities? How could they lead to your career? [Sample answer: If a student likes to build things, she may consider a career in engineering.]

Call on several students to share their favorite activities and career ideas.

Next, have students read the *Is It 4 U?* activity on page 21. Give them the *Is It 4 U?* Writing Activity sheet and have them write a paragraph that explains whether they think they would make good forest ecologists.

Homework: Complete an *About Me* Questionnaire

DOWNLOAD *ABOUT ME* QUESTIONNAIRE

The more students know about themselves, the better they'll be able to plan their futures. Students should investigate their interests and scout out their skills and strengths by answering the questions on the *About Me* Questionnaire. They should staple the questionnaire into their science notebooks and revisit the questions a few times a year to see how they've changed and grown.

STANDARDS ALIGNMENT

NGSS
- *DCI* **MS-LS2.C:** Ecosystem Dynamics, Functioning, and Resilience
- *SEP* Engaging in Argument from Evidence
- *CCC* Stability and Change

CCSS
- **RST.6-8.10:** Range of Reading and Level of Text Complexity
- **WHST.6-8.2:** Text types and Purposes
- **WHST.6-8.4:** Production and Distribution of Writing

Evaluate: formative assessment: checking students' answers

EVALUATE Students demonstrate their understanding of key concepts.

Check students' understanding by checking their answers to the *A Slow Dissolve* questions, listening as they take part in class discussions, and evaluating their *Is It 4 U?* paragraphs.

KEY CONCEPTS FROM *ECOSYSTEMS*, CHAPTERS 3-4

- As Earth grows warmer, plants and animals are migrating to higher latitudes and to higher elevations where it's cooler.
- Trees are a carbon sink—trees take in carbon dioxide during photosynthesis and store some of the carbon in their leaves, stems, roots, and fruits.
- As Earth's air warms, its waters—oceans, rivers, and lakes—warm, too.
- The ultimate source of energy for life on Earth is the Sun. Some of the Sun's energy enters ecosystems when plants on land and in water carry out photosynthesis.
- In ecosystems, energy is passed along in food chains and food webs from producers to consumers.
- About one-half of the carbon dioxide people have added to the air has been absorbed by the oceans.
- When carbon dioxide dissolves in oceans, it combines with water molecules to form carbonic acid. This is making the oceans slightly more acidic.

Noon	Lunch (provided by organization; many informal discussions about the topic & teaching in general; sharing of ideas)
12:30 pm	How Science works handout (to show students methods)
12:45 pm / 1 pm	Video "How Science works" with Richard Norris: engage students for methods & guest speaker (how rocks and cores are collected in the Birch Aquarium; what technology is available and used at the Birch Aquarium; further offerings from Birch Aquarium for schools e.g. student cruises)
1:30 pm	Reflection on 5E model, SRS STEM modules and NGSS; How does the teachers' experience today support student learning in the classroom?

NGSS: Anatomy and Architecture: extension of common core

1. Level: Performance expectations (standards)
2. Level: 3 colored boxes: science, core ideas, cross cutting context

➔ 3 dimensionality; all 3 dimensions are equally important! Teaching not in isolation

3. Level: Bottom: interdisciplinary connections and connections with science (I know e.g. they already had some experience in it; quick check for my grade level)

2:00 pm Recap Curriculum, SRS Modules, Additional SRS Resources (teacher guidebooks, Teach STEM using 5E online course: online professional development program!), information on professional development credit (submission of individual tailored lesson plan to get the credit)

2:30 pm Evaluation, raffle, closing remarks

3:00 pm Tour the Expedition at Sea: R/V Sally Ride Gallery

Appendix B

Sally Ride Science @ UC San Diego
Dr. Karen Flammer
9500 Gilman Drive #0207
La Jolla, CA 92093-0207

May 23 2017

Office of Research Integrity
University of California, Riverside
900 University Ave.
216 University Office Building
Riverside, CA 92521
irb@ucr.edu

Dear Office of Research Integrity:

The purpose of this letter is to grant Anna-Lena Stift, a graduate student at the University of California, Riverside, permission to conduct research at our professional development program "Engaging Students in Learning About Earth's Climate" at the Birch Aquarium at UC San Diego. The project, "Targeted Professional Development Programs in Science Education and Teachers' perceptions of the Program's Impact on their Commitment Towards Addressing the Content in their Classrooms" entails the participation in the program as well as teacher interviews about how they perceived the program and how it impacted their commitment to teach about climate change. Sally Ride Science @ UC San Diego and Anna-Lena Stift will ensure that all information regarding participants will remain secure and strictly confidential at all times.

Sincerely,

Dr. Karen Flammer
Director of Education
Sally Ride Science at UC San Diego

Appendix C

RESEARCH INFORMED CONSENT

Title of research study: Targeted Professional Development Programs in Science Education and Teachers' Perceptions of the Program's Impact

Investigator: Anna-Lena Stift

Researcher:	Anna-Lena Stift, M.A. GSOE 562 269 63 86 agrue001@ucr.edu

Faculty Advisor:	Dr. Margaret Nash GSOE margaret.nash@ucr.edu

Introduction:

This is a research study about How targeted professional development programs on environmental education shape K-12 teachers' perceptions of their engagement in covering controversial environmental issues in their curriculum. The study researchers, Anna-Lena Gruendler and her faculty advisor Dr. Margaret Nash, from the UCR Department of Graduate School of Education, will explain this study to you.
Research studies include only those people who choose to participate in the study. Please take your time to make your decision about participating, and discuss your decision with your family or friends if you wish. If you have any questions at all, you may ask the researchers at any time.
You, as a teacher, are being asked to take part in this study because you have attended the professional development program "Engaging Students in Learning About Earth's Climate"

What happens if I say yes, I want to be in this research?

If you choose to participate in this study, you will participate in one 45-minute interview with me about the PROFESSIONAL DEVELOPMENT program you attended. I will ask you questions about your current teaching employment, how you perceived the program and how it impacted your commitment towards addressing the content in your classrooms. The interview will be audiotaped. I am asking you for permission to allow the audio recording. You do not have to agree to be audio recorded in order to participate in this study. I will transcribe the interview and remove any mention of names. The sound recording will then be destroyed.

Study location: All these procedures will be done at ☐ your office ☐ *local coffee place* ☐ *other location:* _____

Is there any way being in this study could be bad for me?

We do not anticipate any foreseeable risks or discomforts to you participating in this study other than those encountered in day-to-day life.

Will being in this study help me in any way?

We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits to you include your reflection on your own teaching practices as well as targeted professional development programs in the future.

This research may help others to develop impactful professional development programs.

What happens to the information collected for the research?

Confidentiality will be maintained. The data will be analyzed and incorporated in the study so that you won't be identifiable as pseudonyms are being used. You won't be linked to identifying information Your interview will be recorded, when the data analysis is complete the recording will be destroyed. The data (name, e-mail, phone number, transcripts, audio recording) will be stored on the researcher's laptop in a folder that requires a password to access. Identifying data will be stored separately from the interviews data. The researcher is the only person who will transcribe your interview. If you decide to withdraw from the study, the data will be deleted immediately.

Efforts will be made to limit use or disclosure of your personal information, including research study and medical records, to people who have a need to review this information. We cannot promise complete confidentiality. Organizations that may inspect and copy your information include the IRB and other University of California representatives responsible for the management or oversight of this study.

Will information about me be kept private?

We will do our best to make sure that the personal information gathered for this study is kept private. However, we cannot guarantee total privacy and if required by the law, your personal information may be disclosed. If information from this study is published or presented at scientific meetings, your name and other personal information will not be used.

- Authorized representatives from the following organizations may review your research data for the purpose of monitoring or managing the conduct of this study:
    - Representatives of the University of California
    - Representatives of the Office of Research Integrity. All information accessed by ORI will be held to the same level of confidentiality that has been stated by the research team.

Can I stop being in the study at any time?

You can stop taking part in the study at any time. Your data will be destroyed immediately. If you would like to stop, please contact the researcher (562) 269 6386 or agrue001@ucr.edu.

Will I receive payment for being in this study?

You will not be compensated for taking part in this study. However, after the interview you will receive a thank you gift (chocolate from a local coffee shop).

The results of this study may have commercial value to the sponsors, UC Riverside, and/or the researchers. Please know you will have no legal or financial interest in any commercial development resulting from the research or from the information or materials collected.

Whom can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, talk to the research team at Anna-Lena Stift, graduate student at the University of California, Riverside at (562) 269 6386 or agrue001@ucr.edu.

If you have questions about your rights or complaints as a research subject, please contact the IRB Chairperson at (951) 827 - 4802 during business hours, or to contact them by email at irb@ucr.edu.

CONSENT

You have been given a copy of this consent form to keep.

PARTICIPATION IN RESEARCH IS VOLUNTARY. The decision to participate, or not participate, is solely up to you. You have the right to decline to be in this study, or to withdraw from it at any point without penalty or loss of benefits to which you are otherwise entitled to or already have.

If you wish to participate in this study, you should sign below.

_____ _____

Date Participant's Signature for Consent

As the research study includes digital recordings (audio recording), please specify below if you wish to be recorded.

___ Yes, I consent to being audio recorded.
___ No, I do not consent to being audio recorded.

Appendix D

Protocol for Interviews with Teachers about PD Program

Time: Plan for 30 minutes; meet individually with each teacher.

Research Question: How do targeted professional development programs on environmental education shape K-12 teachers' perception of their engagement in covering controversial environmental issues in their curriculum?

Goals:

- Find out how the teacher experienced the particular PD program.
- Find out what the teacher found explicitly valuable.
- Find out how the particular PD program shaped the teachers' perceived engagement in environmental education.
- Find out whether or not the PD program changed their teaching practices.
- To better understand the context in which the teacher is working.
- Build a relationship for future research

Materials:

- Handouts and material from PD Program "Engaging Students in Learning About Earth's Climate"
- Blank copies of the surveys
- Audio-recording device
- "Thank you"-gift for teacher

Before turning the audio recorder on:
1. Explain the purpose of the interview.
SAY: My goal is to get some information about how you experienced the PD program "Engaging Students in Learning About Earth's Climate" and how it shaped your teaching practice. I appreciate so much your time and your support in helping me creating this paper.

2. **Consent Process.** I make sure to obtain consent from the participant if s/he has not consented before. SAY: Before we begin the interview, I want to remind you that participating in this study is voluntary and your responses are completely confidential. At any point during the interview, if you would like me to turn off the recorder, just tell me to do so. Do you have any questions about the study before we begin?

Turn the recorder on: It is (date) at (time). This is (interviewer's name) and I am interviewing (teacher's first name) at (school name).

Introductory Questions

1. How long have you been teaching science?
2. How long have you been teaching science at this school?
3. What classes do you teach (e.g., 6th grade)?
4. What grade levels do you teach?
5. Are the classes you are teaching grouped by skill level (e.g., honors, enrichment, inclusion, etc.)?
6. What are the primary resources you use to teach each class to fulfill the requirements of the California Next Generation Science Standards (e.g., Curriculum, texts, internet sources, textbooks)? (ask for concrete materials used)
7. Who decides on what materials are used in class?

Questions about how the teachers experienced the particular PROFESSIONAL DEVELOPMENT program

Pull out the material handed out at the PD program, hand it over to the teacher and give some time to remember the actual program.

Go through the survey question-by-question:

1) Thinking about the PD program you attended, how did you experienced the event overall?
2) Depending on what part/aspect, e.g. hands-on activities, worksheets, they emphasized: You mentioned xy (e.g. work-sheets, trainers knowledge,…). Is there any reason why you experienced this as exceptionally positive/negative?

a. To what extent were you able to incorporate the professional development/the material into your instruction? Why or why not?

Questions about how the teachers perceives the PD program changed their commitment to address environmental education in their classroom

1) Thinking about the PD program, do you think that it changed your engagement regarding covering climate change in your classroom? If yes, who? If no, why not?
2) If a PD program changed/did not change your attitude towards teaching environmental education, what other events/situations (“significant life experiences” according to theoretical model e.g. childhood events such as flooding) can you image that potentially alter your attitude towards covering these issues?

a. Do you have to face any challenges or are there any barriers at your school/school district that hinder or influence your commitment/ engagement in environmental education? (Depending on what the teacher says, probe regarding why/the source of the problems s/he describes)

3) If your teaching practice changed after the program, what exactly changed? (Ask for some evidence, e.g. what worksheets are used)
4) If material/ideas are used in the classroom: Why do you use this particular material (show) and not this (show)? In what way did you adapted it and why?

(e.g. adjusted because of the quality/usefulness of the material or the students capabilities)

Questions about what the teacher would change in the PD program to be more impactful

1) You mentioned that the PD program changed/did not change your overall engagement in covering environmental education in your classroom.
    a. In order to induce change in your engagement (improve engagement) what would you change in the particular PD program? (ask for concrete processes, material, instructors' behavior,…)
    b. What aspect of the PD program was exceptionally important for you to induce a change in your mindset/changed your attitude/increased your commitment towards/ to teaching environmental education/climate change?
2) Was there any other PD program you recently attended that had more/less impact on your teaching practices? If yes/no, why/why not? What was the difference between the program at the Birch Aquarium and the one you recently attended?
3) What would you look for in a PD program to perceive it as valuable/impactful? (ask for specific examples/evidence)

Closing Question

Is there anything we haven't discussed that you feel is important to me understanding your work as a science teacher in this school/district?