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Teacher Sensemaking and Implementation Fidelity:
How Do I Know What I Do Until I See What I Did

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Teacher Sensemaking and Implementation Fidelity:
How Do I Know What I Do Until I See What I Did

by

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Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctoral of Philosophy

The University of Texas at Austin

May 2018

Dedication

To my husband, TzeYang Ng, who gets the worst of me and still loves me first; my children, Jesslynn and William, who always inspire me; my parents Lim Peng and Tan Lee Kiang, who always give their best to me and help me be my best; PeiTi, YinShan, QiuShan, WeiZhuang, who have always been the sources of my motivation and role models.

Acknowledgements

I would like to express my utmost and deepest appreciation to my supervisor. Without his guidance and help, this dissertation would not have been possible. I thank Dr. Petrosino wholeheartedly, not only for his tremendous academic support, but also for giving me so many wonderful opportunities.

Similar, profound gratitude goes to my committee members, Dr. Barufaldi, Dr. Fletcher, Dr. Marshall, and Dr. Sampson. Who connect me with the right resources and wonderful educators that without their help, none of this would be in the picture.

Special mention goes to Welly and Ferry Chahaya, Eik Siang Mar and James Laughlin. For cheering me on, baby-sitting, and many more. All the fun and food, you guys help me through. Cheers.

Finally, but by no means least, thanks go to mama, papa, Tze for almost unbelievable support. Also, my sweetness in life, Jesslynn and William. All of this is because of you; I hope it shows you how I value education.

Abstract

Teacher Sensemaking and Implementation Fidelity:
How Do I Know What I Do Until I See What I Did

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The University of Texas at Austin, 2018

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The teacher, as the implementer of a program's core components, is the most crucial factor that influences the process of educational implementation of any professional development (PD) program. Focusing on how teachers resolve their ambiguity and uncertainties will provide insight regarding how teachers' participation in PD can influence their decision about implementing the program's core components (Allen & Penuel, 2015). The purpose of this research is to explore how science teachers' sensemaking processes influence implementation fidelity of a PD program that emphasizes reform-oriented instructional approaches. The main research question is, how does science teacher sense-making influence implementation fidelity?

Using qualitative case study and numerous data resources (observation of PD, survey, classroom observation and rating, interview, self-report, and artifacts collection) the research revealed six common triggers of teacher sensemaking instances of the program's core components shared by all teacher participants. They are: the value of PD in their classroom, their emotion regarding the implementation of the core components, the

relevance of the PD program to students' needs, the relevance of PD to state standards, the implementation network that operates within school, and time constraints. The triggers of teacher sensemaking instances that arise only on the low fidelity implementers are: the abundance of information gained from professional learning experiences, lack of clarity about roles and responsibilities to implement the core components, lack of clarity in the setting and environment for implementation, and lack of success measures for implementation. On the other hand, sensemaking of the high-fidelity implementers is focusing on: availability and accessibility to instructional resources, accessibility of the experts, their current progression toward establishing a student-centered classroom, and availability of planning time during the PD.

The research also identifies four types of teachers' implementation orientation as they make sense of the PD program. They are, (i) passive distributive, (ii) critical evaluative, (iii) creative emergent, and (iv) transformative. The research found that teacher sensemaking of PD is interconnected with their implementation. Thus, to study teacher sensemaking is not only to focus on how teachers make sense of the PD program, but also to study how they implement the reform-oriented program in the classroom.

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Chapter One: Introduction

Aware of the tension between fidelity to professional development program suggestions and the necessity of adaptations in the classroom, the U.S Department of Education (2009) suggested that program modifications or adaptations are acceptable as long as a program's active ingredients, or its core components, are delivered as planned and originally designed. Thus, the teacher, as the implementing agent of these core components is the most crucial factor that influences the process of educational implementation of any professional development program. This includes policy implementation, curriculum implementation, intervention implementation, or any kind of educational initiative implementation. Dewey's notion of education informs us that teaching in a democratic society, with all the turbulence and complexity that it entails, is predicated on processes that evoke reasoning and problem solving, not just the efficiency of providing information (Lin & Cooney, 2001). Thus, teacher education from such a process-oriented perspective is fraught with complexity—where a teacher's thought process and sensemaking of his or her professional learning is influenced by many internal and external factors.

Hence, it is crucial to consider the thought processeses of teachers regarding their implementation of professional development programs' core components. Questions to consider include: What do they consider important, and what do they take to be problematic (Tzur, Simon, Heinz, & Kinzel, 2001)? How do teachers interpret, understand, and implement the professional development programs' core components in the classroom?

The purpose of this research is to explore how teachers' sensemaking processes influence their fidelity of implementation in science classrooms from a constructivism perspective. The main research question is, do teachers' sensemaking processes influence

their implementation fidelity in the classroom? If so, how? By answering the research questions, the theoretical accomplishment of this research is to make connections between teachers' sensemaking processes and implementation fidelity. Teacher surveys, observation of professional development programs, classroom observations, teacher interviews, and teacher self-reports will be used and analyzed to explore teacher fidelity of implementation.

BACKGROUND OF THE PROBLEM

We are living in an age of accountability where students and teachers are expected to meet higher standards (Guskey, 2000; Shaha, Lewis, O'Donnell, & Brown, 2004). Professional development is considered a fundamental mechanism for deepening teachers' content knowledge and improving their instructional practice in the classroom (Desimone, Porter, Garet, Yoon, & Birman, 2002; Desimone, Smith, & Ueno, 2006; Loucks-Horsley, Hewson, Love, & Stiles, 1998). As teachers are held accountable for student achievement, professional development programs are asked to show that "what they really do matters" (Guskey, 2000, p. 67). Thus, teacher professional development programs are asked to plan, design, and implement "state-of-the-art" efforts to transform teachers and school administrators into "reflective, team building, global thinking, creative, risk takers" (Guskey, 2000, p. 67). Ideally, teacher professional development should provide teachers with learning processes that will improve the quality of their teaching and ultimately increase student achievement (Desimone et al., 2002; Kutner, Sherman, Tibbetts, & Condelli, 1997).

Many teachers in the United States are required to participate in a certain number of professional development hours each year in order to sustain their teacher certification

(Kutner et al., 1997). With the presence of these requirements, the potential impact of professional development programs on the quality of classroom instruction and student achievement is extremely valuable, especially since these programs demand a sizeable amount of financial and physical resources (Kutner et al., 1997; Desimone et al., 2002).

Studies have been conducted over the past several decades to evaluate the effectiveness of various teacher professional development programs (Cohen, 1990; Desimone et al., 2002; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2010). Scholars have learned that, despite the emphasis on the importance of teachers' professional development, the available professional development for teachers is woefully inadequate (Garet, Porter, Birman, Yoon, & Desimone, 2001; Gaible & Burns, 2005; Wei, Darling-Hammond, Andrea, Richardson, & Orphanos, 2009). The professional development programs studied include in-service seminars for teachers and other forms of professional development that were often found to be fragmented, intellectually superficial, disconnected from teachers' practices and—most importantly—they did not take into account how teachers learn (Ball & Cohen, 1999; Borko, 2004; Putnam & Borko, 1997; DeMonte, 2013; Garet et al., 2001; Wei et al., 2009). Sykes (1996) argued that the inadequacy of these traditional professional development programs is "the most serious unsolved problem for policy and practice in American education" (p. 465).

As research elucidated the inadequacy of teachers' professional development training, studies also started to identify and suggest the characteristics of effective professional development. These characteristics include that programs should focus on content and how students learn the content (Cohen & Hill, 2000; Desimone et al., 2002; Smith, Desimone, Zeidner, Dunn, Bhatt, & Rumyantseva, 2007), teacher incentives (Loucks-Horsley et al., 2010; Kutner et al., 1997), opportunities to practice (Desimone et al., 2002; Loucks-Horsley et al., 2010), strategies for planning and better integration into

normal school activities (Payne, Gottfredson, D., & Gottfredson, G., 2006), and collective participation of teachers' supportive networks (Desimone et al., 2002; Loucks-Horsley et al., 2010). Effective programs also lasted for an extended duration and required the collective participation of groups of teachers from same school or grade (Desimone et al., 2002). Supported by much educational research, these program characteristics can have a substantial and positive influence on teachers' classroom instruction and student achievement (Birman, Desimone, Garet, & Porter, 2000; Garet et al., 2001; Loucks-Horsley et al., 2010).

Grounded within the context of research on teacher change as well as a rich wisdom of "best practices" research, Penuel, Fishman, Yamaguchi, and Gallagher (2007) redefined key constructs of effective professional development that directly inform implementation concerns. Penuel et al. (2007) stressed characteristics such as (i) a focus on content and how students learn the content and (ii) ways to support teachers in order to foster student inquiry in the classroom (Fishman & Krajcik, 2003). These two elements can have a substantial and positive influence on teacher implementation in the classroom as well as student achievement (Birman et al., 2000; Desimone et al., 2002; Garet et al., 2001; Loucks-Horsley et al., 2010; Putnam & Burko, 2000).

Evaluating the effectiveness of teachers' professional development can provide evidence of whether an intervention works and whether the intervention can improve teacher practices (Rogers & Smith, 2006). However, the current focus on student outcomes does not show the whole picture of the effectiveness of professional development programs and implementation (Hanusein, Rebello, Sinha, Cheng, Muslu, & Chandrasekhar, 2014). It does not clearly indicate how or whether teachers implement the training.

Emerging from these studies of effective professional development is the question of implementation fidelity. Factors such as students' opportunity to learn and the way

teachers present content in the classroom (as intended from the professional development) can influence what students learn and how they learn it (Hanusein et al., 2014). After all, the question of whether a professional development program is effective and replicable by teachers in the classroom can inform how much to invest in such programs. Plus, as teachers and facilitators are trained to undertake new subjects such as Science, Technology, Engineering, and Mathematics (STEM) education-focused programs in the United States, teacher implementation becomes imperative. Subsequently, educational leaders have sought to examine the alignment between how a professional development program is designed to be implemented and how that program is actually implemented in the field (Barker, Nugent, & Grandgenett, 2013).

Under the umbrella of evaluating the effectiveness of teachers' professional development, implementation research is relatively young. There is no journal focused solely on its implementation in education, nor are there consistent methods of inquiry (Century & Cassata, 2016). One of the premier journals for implementation research in health care, "Implementation Science," has been in circulation only since 2006. Whilst the research of implementation in education has evolved, different philosophical, theoretical, and practical orientations have emerged, which makes shared learning fairly challenging (Century & Cassata, 2016).

Reflections on educational trends toward accountability, monetary inputs, and student performance become vital in the discussion about the American education system (Kutner, et al, 1997). Consequently, the fidelity of teachers' professional development has received increased attention, especially the need to find out whether the teachers and students will receive what was intended from the professional development training. Carroll, Patterson, Wood, Booth, Rick, and Blain (2007) emphasized that "only by understanding and measuring whether an intervention has been implemented with fidelity

can researchers and practitioners gain a better understanding of how and why an intervention works, and the extent to which outcomes can be improved" (p. 1).

However, implementation is not just how the teacher complies with the program's prescribed contents and directions. The implementation involves many processes that occur within the implementer. This brings us to the next point of discussion, perhaps the most important one. The quality of teaching practices and implementation in the classroom is filtered through each individual teacher's mind. Thus, they are not implemented in the same way or in a standardized manner. Although individual differences among students receive much attention, individual differences in teacher sensemaking are often ignored (Quinn, 2009). In order to understand how a professional development program finds its way into teachers' instructional practices and implementation, an understanding of how teachers make sense of their professional learning is essential.

Similar to students' sensemaking processes in their learning, teachers' sensemaking processes of their professional learning experiences cannot be taken for granted. Indeed, teachers' implementation practice involves the process of sensemaking (Coburn, 2001; Coburn, 2005; Spillane, Reiser, & Reimer, 2002). Without a proper understanding of how teachers make sense of their professional development, new and complex learning theories, knowledge and skills, and improved practices are less likely to find their way into teacher implementation (Loucks-Horsley et al., 2010; Kutner et al., 1997; Roehrig, Kruse, & Kern, 2007; Payne et al., 2006). Research is needed on how the professional developers can better provide teacher professional learning experiences that can support teachers' sensemaking processes and implementation.

The challenge is that each teacher has unique thoughts, interpretations, reasoning, and reflections. Because teachers' thought processes are implicit or happen in the mind, they cannot be measured or standardized. But this does not mean that teachers' thought

process should be ignored (Quinn, 2009). Instead, this research argues that it should be investigated and taken seriously. The reason is twofold. First, "Not everything that can be counted counts, and not everything that counts can be counted" (Cameron, 1963). Second, Dewey's notion of education in a democratic society is predicated on processes that evoke reasoning and problem solving, not just efficiency of providing transformation (Lin & Cooney, 2001). Ignoring teacher thinking and reasoning processes disregards the most important variable in educational implementation (Quinn, 2009; Schimidt & Datnow, 2005).

This research argues that teacher sensemaking of professional development impacts a teacher's classroom implementation. Spillane et al. (2002) claimed that, "to better understand the influences on the implementation, we must explore the mechanisms by which teachers understand and construct the meaning of their professional development and attempt to connect understanding with practice." Coburn (2001) asserted that rather than professional development mainly influencing a teacher's practice, it is more likely that teachers play a more influential role when it comes to classroom implementation. After all, teachers interpret, adapt, and even transform what they learn and how they learn as they put teaching strategies into place. In summary, gaining a better understanding of how teachers make sense and reconstruct the meaning of professional development in their professional practice (such as making sense of intervention strategies) is crucial if the implementation is to be successful, i.e., replicated with high fidelity and sustained over time.

STATEMENT OF PROBLEM

Due to educational trends toward accountability, professional development programs have, in recent years, been bound to evidence-based practices (Carroll et al., 2007). These evidence-based practices seek to understand the effectiveness of the teacher's professional development program as well as the teacher's fidelity of implementation after receiving professional development.

About four decades ago, Van Mater and Van Horn (1975) argued that the study of implementation fidelity was lacking due to the complexity of implementation. While there is still much to understand about the complexity of implementation (Century & Cassata, 2016) research has suggested some factors that affect the complexities of implementation. Fullan (2001) argued that implementation is affected by internal characteristics (teacher), local characteristics (district, community and principal), as well as external factors (government and other agencies).

Failure to anticipate and control the complexities and variability of real-world contextual factors aside, researchers recognize that a program can never be fully implemented by teachers exactly as it was designed (Fixsen, Naoom, Blasé, Friedman, & Wallace, 2005; Kelly & Perkins, 2005; Ringwalt, Ennett, Johnson, Rohrbach, Rudolph, Vincas, & Thorne, 2003). Thus, as the study of fidelity of implementation began to move beyond the traditional view of fidelity as adherence, the tension between fidelity and adaptation was raised and questioned (Dusenbury, Brannigan, Falco, & Hansen, 2003; Elliott & Mihalic, 2004; Fagan & Mihalic, 2003; Fixsen et al., 2005; Mihalic & Irwin, 2003).

About three decades ago, Carlgren (1987) discussed that for educational initiatives to change the core of teaching and learning in actual classrooms, the sensemaking processes of teachers should not be taken for granted. Weick (1995) discussed that "sense

making is about the placement of items into a framework, comprehending, redressing surprises, constructing meaning, interacting in pursuit of mutual understanding, and patterning. It is grounded in both individual and social activity" (p. 6). Sensemaking according to Weick (1995) is a process grounded in identity formation and the maintenance of a consistent positive self-conception—retrospective and social as one's own actions, interpretations, and expectations take shape vis-à-vis the actions, interpretations, and expectations of others; enactive of sensible environments; ongoing and focused on and by extracted cues; and driven by plausibility rather than accuracy.

More recently and more closely related to the education setting, Spillane et al. (2002) added that the processes by which the implementer (teacher) comes to understand his or her professional development are rarely analyzed explicitly in conventional implementation models. Spillane et al. (2002) then created a cognitive framework of teacher sensemaking as it related to policy implementation. The framework was designed to unpack teacher sensemaking from and about the policy. They claimed that teacher sensemaking is influenced by basic information processing, as well as the complexities and influences of motivation and affect, and the social context and social interaction of the teacher. The Spillane et al. (2002) framework consists of three main aspects: a teacher's individual cognition, the teacher's situated cognition, and their roles of representation.

Evolving from Spillane et al. (2002), Coburn (2005) later added that sensemaking is influenced by the sense-giving, or the shaping action, of school administrators and by education policies from the larger context of the district. Later, Coburn and Russell (2008) suggested that teachers' social networks in and outside of campus play an important role in teachers' sensemaking processes, and thus their implementation in the classroom. They explained that collaborative communities of teachers create trusting environments that promote risk-taking and situations where teachers are more willing, enthusiastic, and

prepared to experience the discomfort and uncertainties that may accompany making changes in the classroom. These communities also promote teacher access to expertise that supports their professional learning and opportunities for teachers to negotiate the meaning and implications of education reform.

Though not extensive, there is some literature that examines the critical role of teachers' sensemaking of their professional development and their subsequent implementation practices. For example, Coburn and Stein (2006) and Quinn (2009) discussed what teachers understand and interpret about their professional learning as they attempt to link their understanding to implementation. Rajala and Kumpulainen (2017) discussed that for educational change to take place and be sustained, there is a need for collective teacher sensemaking. Their research suggested that it is important to facilitate collective sensemaking among teachers in school communities through deliberative reflections on their practice and agency orientation.

Nevertheless, there still exists a big knowledge gap about the relationship between teacher sensemaking patterns and their implementation fidelity, especially in the field of STEM education. The gap in knowledge is problematic because it leaves school districts and curriculum developers with little insight into how they can shape ideas, instruction, strategies, activities, and learning experiences into programs that will enable teacher sensemaking and create high implementation fidelity.

Subsequently, considering the critical yet limited research on teachers' sensemaking and its impact on teachers' implementation in the classroom, this research aims to explore how teachers' sensemaking is shaping teachers' implementation in the classroom. When teachers are introduced to new educational initiatives—such as school reform, new standards, curriculum, or intervention strategies—during their professional

development, teachers' sensemaking of the content, context, and process of professional development can impact the program's successful implementation in the classroom.

PURPOSE

Although increasing attention has been paid to the rise of STEM education and teachers' fidelity of implementation after teachers receive professional development in education courses, there is very little research on fidelity of teacher implementation in STEM education (Borrego, Cutler, Prince, Handerson, & Froyd, 2013; Century & Cassata, 2016). More critically, understanding how to structure a teacher's learning experiences in order to promote fidelity of implementation is often overlooked and (worse) ignored. There are very few studies on how teachers construct an interpretation of what they learn into their own behavior and then implement it in the classroom.

The purpose of this research is to explore how teachers' sensemaking processes influence fidelity of implementation in the classroom from a constructivism perspective. While keeping in mind that any program will inevitably be changed and adapted by teachers, this research would like to uncover how teachers construct their interpretation and meaning regarding professional development programs, and how this process governs what adaptation or modifications are suitable during their implementation in the classroom. Since the object is to pursue insight, discovery, and holistic interpretation (Merriam, 1998), a qualitative case study approach will be used. The participants in this research are purposefully chosen, and they are all science teachers who participated in the professional development course called Planet Earth from Making Sense of SCIENCE ™ (MSS) program. They are: Alan and Julia (eighth-grade science teachers) who are expected to teach the content of the course, and Kelly (fifth-grade science teacher) and Lily (seventh-

grade science teacher), who are not expected to teach the content of the course based on their grade level's state standards.

SIGNIFICANCE OF THE RESEARCH

Recent reform efforts, such as the Next Generation Science Standards (NGSS), expand expectations for students to learn science-as-practice. This means that students, in addition to learning concepts and methods, should become legitimate participants in the social, epistemic, and material dimensions of science (Stroupe, 2014; Lehrer & Schauble, 2006). Aligning with the emergence of various reform in K–12 education, new themes of teaching and learning in the classroom emerged—ambitious science pedagogy. Ambitious science pedagogy stresses the importance of classroom practice that provides students with various opportunities to connect to their communities, agencies and engage in authentic practices of various disciplines (Stroupe, DeBarger, & Warner, 2017; Stroupe, 2014; Kang, Windschitl, Stroup,e & Thompson, 2016). Ultimately it stresses that learning is best anchored by a puzzling phenomenon or problem that students (and the teacher) work to solve over time (NRC, 2007). Teachers enacting the ambitious instruction frame their instructional practice differently than teachers who view teaching as information delivery and the assessment of students' conceptual understanding.

The professional development program in this research—the MSS program—uses a reform-oriented curriculum approach to professional learning that connects hands-on science with integrated teaching and literacy supports. It challenges teacher teaching and learning experiences with periods of disequilibrium and encourages participants to confront their preconceived ideas about science, teaching, learning, and literacy. The primary goal of the program is to develop a community of inquiry to support teachers doing

the most important job—making sense. It argued that the conservative or traditional classroom practice does not align with literature about the teacher and student learning, learning sciences, disciplinary practices, and teacher education (Heller, 2012). Drawing on sources such as research in learning science, teacher learning, equity studies, and evidence-based practice, the professional development in this research emphasizes science teachers' classroom practices that support students' sensemaking of science activities, connect observation and everyday experiences with science ideas, and use various literacy (reading, writing, productive science conversation) modalities to deepen students' understanding about the natural world (Heller, 2012).

Teacher participants of this reform-oriented curriculum approach are trained and expected to implement the pedagogical practices and reasoning that are evidenced in the core intervention components (also known as four critical dimensions). These core intervention components are, (A) focus on conceptual understanding of learners, (B) emphasis of collaborative inquiry and sensemaking of learners, (C) focus on learners' thinking, and (D) reflection on teaching (teacher) and learning (students).

This paper intends to elaborate how teacher sensemaking processes of a professional development's reform-oriented curriculum approach unfold, particularly in the science classroom. In doing so, this paper aims to, first, answer the critical call for understanding how to create teachers' learning opportunities from which teachers are able to construct the meaning of their professional development and its implications of reform-oriented pedagogy in the classroom. Secondly, it aims to respond to the need for teachers' professional development to engage teachers in sustained sensemaking activities around issues of perceived incoherence to bolster teacher understanding of reform-oriented intervention strategies or any new education initiatives and increase the likelihood of implementing instructional practices aligned to its core.

Ideally, professional development program creators would like teachers to implement their programs with high fidelity, if not total adherence. To address this desire, this research will begin to explore the relationship between high fidelity implementation by teachers and the sensemaking of their own professional development. Last but not least, this research anticipates to provide insight and suggestions to principals, districts, professional development program developers and curriculum developers regarding how they can shape teacher ideas, instruction, strategies, activities, and learning experiences in order to enable teacher sensemaking that leads to high implementation fidelity of reform-oriented instructional practices.

RESEARCH QUESTIONS

This research seeks to discover what sense science teachers make of their professional development programs and how it influences in their instructional practice and implementation in the classroom. The primary research question in this research is, does teacher sensemaking influences implementation fidelity? If so, how? The exploration of this main research question is guided by four sub-questions. They are:

- What are the triggers of teacher sensemaking instances during and after teacher professional development?
- What are the triggers of teacher sensemaking instances that relate to teachers' rejection of implementation?
- What are the triggers of teacher sensemaking instances that relate to science teachers' additive learning or assimilation?

- What are the triggers of teacher sensemaking instances that relate to teacher transformation in classroom practices to implement the program with high fidelity?

RESEARCH DESIGN AND OVERVIEW

The research framework of this research focuses on qualitative, interpretive case study (Creswell 1998; 2007) to pursue insight, discovery and holistic interpretation (Merriam, 1998). The important issue is that the case studies are located within a broader perspective on the teachers' sensemaking and implementation of a professional development program, and in this sense are "embedded" (Yin, 2003). This research uses embedded analysis of case study (Cresswell, 2007) to facilitate the exploration of a phenomenon within its context, using a variety of data sources to reveal and understand multiple facets of the phenomenon (Stake, 1995; Yin, 2003). It adopts the constructivist paradigm, which claims that truth and reality are built upon social construction, are relative and depend on one's perspective (Stake, 1995; & Yin, 2003). This research aims to analyze how science teachers' sensemaking shapes their fidelity of implementation through the methods of teacher surveys, observations of professional development programs, classroom observations, teacher interviews, and teacher self-reports, along with artifacts collection.

The teacher survey (Appendix B) is used for four explicit reasons. They are to (i) find out each teacher's demographic profile and background information, (ii) explore teacher perspectives regarding their professional development, (iii) determine the teachers' readiness of classroom implementation, and (iv) explore each teacher's understanding of the core intervention components of the professional development.

The teacher professional development observation guide (Appendix C) was developed based on the critical analytical dimension and the teachers' activity in their professional development. It reports whether the program's critical features of intervention are evidenced during teachers' professional development sessions.

Based on the critical analytical dimension identified by the original professional development program, classroom observations aim to explore the program's theoretical basis in real-world action (O'Donell & Lynch, 2008). The classroom observation (Appendix E) explores whether teachers' pedagogical practices are reflecting the philosophy, intent and core intervention components of the original professional development. It is complemented with rubrics and a rating scale (Appendix F) to determine how well teacher implementations reflect the intended core component of intervention from their professional development program.

The teacher interviews (Appendix H) are guided by open-ended questions that allow teachers to (i) narrate their thinking about their experiences of professional development, (ii) explore their sensemaking process, and (iii) provide their reasoning and insight behind their implementation. For the purpose of data triangulation, teacher interviews were conducted after classroom observations. Conversations during the interview were audio recorded and transcribed for analysis purposes.

Lastly, teacher self-reports (Appendix I) not only allow the researcher to collect artifacts used by teachers during their implementation, they also allow teachers to justify their thinking and decision making regarding how they planned their lessons and how the actual lessons went against or aligned with his or her plan. The triangulation of methods (survey, professional development observation, classroom observation, teacher interview, and teacher self-report) will provide richness and complexity needed to explain the findings and results (Cohen, Manion, & Morrison, 2013).

LIMITATION

Due to limited resources and time, the coding and analysis process in this research no second coder was used. Although no inter-rater reliability, the researcher has conducted several iterations of coding and analysis to ensure the reliability. The intra-rater reliability (Mackey & Gass, 2005) of this research started with a well-defined construct (teacher sensemaking and implementation fidelity) and supported by literature reviews. Then, the researcher will code the data the same way at different times (two weeks apart). In general, the researcher will use a test-retest method, in which the two sets of ratings are produced by one researcher at two times. If the differences are found, the researcher will consult the teacher participants involved during the interview to ensure clarity as well as consistency between data collected and the real and authentic meaning from the teacher participant.

ASSUMPTIONS AND SCOPE

The site of this research was based on a purposeful sampling strategy. The main reason for selecting schools in the Independent School District in the southwest area of the United States as the site of this research are (i) accessibility of the professional development program; (ii) accessibility of the districts, schools, and participants; and (iii) the reform-oriented approach of professional learning used by the professional development program.

The sampling of participants was done based on the assumption that participants are highly qualified in their field. An invitation to participate in this research was sent out to all teachers who attended the professional development program. The teacher participants in this research agreed to participate in the research. Because of their agreement or volunteering, it is also assumed that they will answer truthfully to the

interview questions based on their personal experiences and will respond honestly to the best of their abilities during classroom observation.

Focusing on four case studies of four different campuses in central Texas although not generalizable to the larger population, allowed for in-depth explorations of teacher sensemaking and teacher behavior and practices, as well as teacher implementation. The in-depth exploration also provided an opportunity to generate or build a new hypothesis of teacher sensemaking orientation in regard to their implementation practices. More importantly, each teacher's thought process is personal. Although some can argue that there exists a general pattern one can identify to make sense of phenomena, thinking is an individual, unique and complex process, which can be very difficult to measure objectively.

SUMMARY

The purpose of this research is to explore how teachers' sensemaking processes of the professional development program influence their fidelity of implementation in science classrooms from a constructivism perspective. The main research question is, how do science teacher sensemaking processes influence implementation fidelity in the classroom?

Although there is limited research that investigates teachers' fidelity of implementation, fields such as mental health and human services have been conducting such investigations for several decades (Borrego et al., 2013). Critically, research of STEM education regarding teacher sensemaking and its relationship to teacher implementation is very scarce. Responding to such needs, the research questions of this research aim to explain how teacher sensemaking processes unfold and influence the fidelity of implementation in the classroom.

Chapter 2 will provide various theoretical frameworks and conceptual frameworks of the research. These theoretical backgrounds include various studies of teacher implementation, an overview of constructivist learning theory, and sensemaking in organization theory, among other subjects. Chapter 2 will also provide a detailed discussion of how teacher implementation in the classroom is influenced by internal characteristics (sensemaking by the teacher), local characteristics (district, community, and principal) as well as external factors (state standards and other agencies).

Chapter Two: Literature Review

INTRODUCTION

Although health science literature has studied and defined fidelity of implementation fairly well, it is as yet hardly reported in large-scale education studies that examine the effectiveness of the K–12 intervention (O'Donell & Lynch, 2008) especially in the field of STEM education (Borrego et al., 2013). At the same time, education curriculum reform initiatives and efforts have moved away from focusing on specific curriculum materials to greater attention on instructional approaches (Vandosdall, Klentschy, Hedges, & Weisbaum, 2007). Therefore, there is a rising emphasis in policy focus on evidence-based practices during the scale-up of reformative instructional approaches and education intervention (O'Donell & Lynch, 2008). Aligning with the emergence of various reforms in K–12 education, the new themes of teaching and learning in the classroom emerged —ambitious science pedagogy.

However, teacher adoption and implementation of any education reform initiative do not happen instantly. Expert-like implementation takes years of practice (Windschitl, Thompson, & Braaten, 2009). Carlgren (1987) stated that for any educational initiatives to change the core of teaching and learning in actual classrooms, the sensemaking processes of teachers should not be taken for granted. The literature relevant to this research is reviewed and synthesized in this chapter. I have organized the literature review into the following primary themes:

- Reform-oriented instructional approach and ambitious science pedagogical approach;

- Sensemaking,
- The conceptual framework of teacher sensemaking;
- Teacher fidelity of implementation and the definition of implementation fidelity;
- Conceptual framework of teacher sensemaking and implementation fidelity of the professional development program that is reform-oriented and ambitious instruction.

REFORM-ORIENTED INSTRUCTIONAL APPROACH

The emergence of various reform initiatives in K–12 education, including the Common Core and Next Generation Science Standards, represent the effort to restructure the expectation and goals of teaching and learning in classrooms since we realized that that the intellectual work students are capable of now "outstrip" what many teachers do and how they are prepared (Stroupe et al., 2017). The educational reform initiative is trying to move away from schools that fixate on conceptual content for the purpose of test scores to schools that emphasize that learning be authentic and meaningful to students (Rudolph, 2014; Stroupe et al., 2017). Learning in schools should provide multiple opportunities for students to connect to their communities and engage in authentic practices of various disciplines (Polman, 2012). To meet this reform's expectations, the work of traditional teaching must change fundamentally.

Drawing on an extensive body of research in learning science, teacher learning, and equity studies, the new direction and expectation of teaching in general consists of three main themes (Stroupe et al., 2017). First, redefining learning (NRC, 2007): Learning is not the memorization of facts that were learned in a linear progression. Learning is best

anchored by a puzzling event that students work to solve over time. In the science classroom, instruction should not be focused on the completion of numerous activities and tasks: it must take into account students' prior knowledge, press for the explanation, and engage in authentic science investigation. Ultimately, the teacher should shape their instruction in order to allow students learn science as practice.

The second theme is redefining teaching (Franke, Carpenter, Levi, & Fennema, 2001; Windschitl, Thompson, Braaten, & Stroupe, 2012): Taking learning into account, the new work of teaching suggests teacher practices that view students as active sensemakers. The new direction of teaching stresses that teaching is not fixed but fluid, based on context and research-practice partnerships. Also, pedagogy practices are supported by tools that reify both theories of teaching and learning as well as the teacher's planning and reflection. This means that teachers, researchers, and instructional coaches can use these tools to support a common vision of teaching and learning. Teachers should also study their own instruction and adapt based on the evidence of student learning. Teacher action and re-action aims to transform their teaching. Ultimately, the teacher takes on a new level of responsibility to ensure all students have robust learning experiences.

Last, building safe and collaborative leaning community (Moll, Amanti, Neff, & Gonzalez, 1992; Warren et al., 2001), teachers' classroom environment and practices should focus on supporting students to actively participate and engage in knowledge construction. The classroom environment must support teacher practices that push for students' voices, ideas, lived experiences, and background that shape an equitable, safe and rigorous learning experience.

Ambitious science pedagogy.

Implied in the three themes of the new direction and expectation of teaching that moved beyond from teacher-centered instruction, researchers are working to unpack and redefine "what counts" as teaching and learning (Stroupe et al., 2017). These efforts set forth a framework for "ambitious teaching." Smylie and Wenzel (as cited in Stroupe et al., 2017, p. 3) constructed a report to improve public schools that talked about "intellectually ambitious instruction." Recent studies of science and mathematics starts to frame the teaching around "ambitious instruction" that provides rigorous and equitable learning opportunities to all students using specialized practices and tools that are learned, developed, and adapted over time (Kang et al., 2016; Stroupe, 2014; Stroupe et al., 2017; Windschitl, Thompson, & Braaten, 2011).

In general, ambitious instruction has seven features (Stroupe et al., 2017). One, teachers anchor students' ongoing learning experiences in the press to understand complex and puzzling phenomena. Two, teachers use students' ideas and experiences as resources. This means that students' everyday ideas, experiences, and questions are treated as resources within the classroom community to advance everyone's thinking. Three, teachers allow students to use science practices for a purpose. Students will be given the opportunities and experiences to test ideas they believe are important to their developing explanations and models. Four, teachers foster productive discourse. Teachers provide daily opportunities for students to reason through talk, negotiate and justify their learning. Five, teachers scaffold students' talk, writing, and participation. Teachers will support students with the skills, tools, and routines to support students' attempts at discipline-specific forms of writing, talk, and participation in activity. Six, teachers make thinking visible and sharable in order to allow students to work on the ideas together toward a more robust and deeper understanding of big science ideas. Seven, teachers help students to build

complex and cumulative understanding over time. Students' learning experiences are sequenced to help them integrate ideas together and revise understandings of "big science ideas."

The perspective of ambitious instruction appears to be aligned with the vision set forth for Making Sense of Science's (MSS) curriculum approach. The four core intervention components are aligned with the seven features of ambitious instruction.

SENSEMAKING

This research explores professional development program implementation by examining the sensemaking of science teachers who attended a five-day workshop to implement a reform-oriented instructional approach initiated by teachers themselves. In accordance with this, the literature review is grounded in the arena of teacher sensemaking and implementation fidelity.

In the education field, studies have begun to use sensemaking perspectives to see how the implementers (teachers) constructed an understanding of their professional development experiences (Quinn, 2009). For example, Spillane (1998) examined how district personnel made sense of the implementation of state reading policies; Coburn (2001) examined how teachers mediated their state's reading policy; Spillane (2004) explored the responses of school districts to new state science and mathematics standards; Schmidt and Datnow (2005) investigated how the teachers' emotions affected their sensemaking of school reform efforts; and Allen and Penuel (2015) used organizational theory's concept of sensemaking to examine teachers' responses to the professional development related to the Next Generation Science Standards (NGSS) within two schools in the United States.

Just as the teacher cannot pour knowledge into students' brains, professional development trainers cannot simply transfer knowledge, skills, and values into teachers' brains. The teachers as the implementation agents will have to construct their understanding and make sense of the program based on the experiences in their professional development. Similar to how we treat knowledge transfer as a process of construction and not a one-time act (Winter & Szulanski, 2001), Fixsen et al. (2005) stated that implementation would neither happen all at once, nor it will proceed smoothly, at least not at the beginning. An implication of the PD program is that teachers will recreate a complex yet ambiguous set of routines in the new setting. Gradually, through experiences and repetition, they will refine their ability and keep the routines functioning (Fixsen et al. 2005; Weick, 1995, 2009; Weick et al., 2005). These also demonstrate that the teachers play a significant role in improving education outcomes; they help the system to stay on track by recognizing and solving common implementation problems in a timely and effective manner (Fixsen et al., 2005). In fact, Wallace, Blasé, Fixsen, and Naoom (2008) stated that the most critical piece of the implementation puzzle is that teachers are the intervention.

Thus, the literature on sensemaking in this research includes sensemaking as discussed in constructivist learning theory as well as sensemaking in organization theory by Weick (1995).

Constructivist learning theory and teacher sensemaking.

In the constructivist learning theory, learning is the process by which individuals construct meaning from their interactions with materials and their experiences (Knoblauch & Brannon, 1984, as cited in Lappan & Briars, 1995). Learners build knowledge based on

experiences and prior knowledge while connecting to social communities (Smith, 2001). Piaget's works from 1936 on learning laid the groundwork for the constructivist learning theory (Smith, 2001).

Constructivism is multifaceted. It can be considered an epistemology, a philosophy, or a learning theory (Ledford, 2006). While constructivism is not considered a teaching theory, it has powerful implications for teaching, as it requires teachers to focus on what students think and what students can do with the material presented to them (Noddings, 1990). Teachers in the classroom are encouraged to provide students with opportunities to engage in problem solving, reasoning, and proof while communicating the content knowledge, making connections between subjects, and using multiple representations (NCTM, 2000).

Smith (2001) called for teacher education or teacher professional development that uses the concepts of constructivism to discuss learning. Smith (2001) described teacher learning as a dichotomy: either learning was transformative or additive. In constructivist terms, accommodation or assimilation. Transformative learning (accommodation) in nature involves "sweeping changes" occurring in deeply held beliefs, knowledge, and habits of practice (p. 3). Additive learning (assimilation) involves new information and skills simply being added to what is already known and understood by the learners. Smith (2001) stressed the critical need for professional development that promotes teachers' transformative learning.

Figure 1 shows the constructivist view of teacher professional learning. Teachers' transformative learning creates disequilibrium in teachers' existing patterns of thinking. Such disequilibrium challenges teachers' existing belief systems and promotes teacher reflection and metacognition. By reflecting on their belief systems in the context of new experiences, teachers may start to see the limitations of their current teaching and learning

practices and begin to construct new ones. However, the state of disequilibrium has to be created in balance and approached with caution. Teachers may reject the new idea or experiences if they find it inconsistent with their existing belief systems (Raths, 2001; Quinn, 2009)

Teachers making sense of their professional learning is about making connections from their professional development experiences with their own learning, their students' learning, their teaching practices, that are all influenced by their belief system. The process through which teachers make sense of their learning actively involves individual thinking about their own learning, even when the teachers do not learn new content (Ledford, 2006).

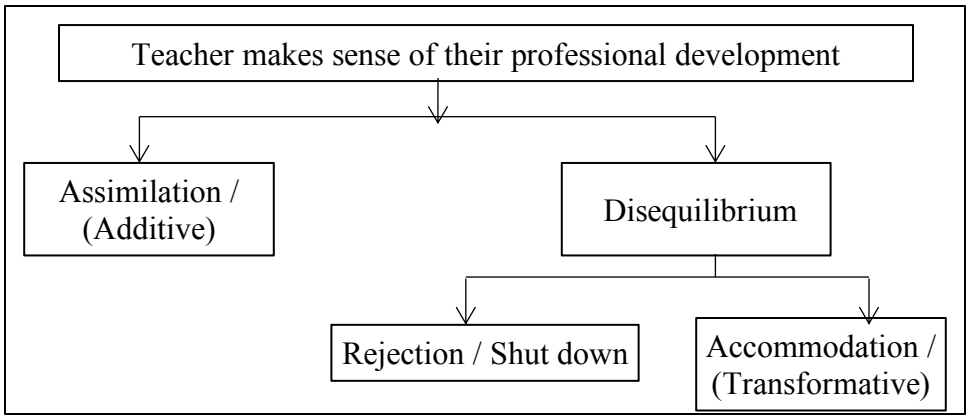


Figure 1. The constructivist view of how teachers make sense of their professional development.

This model (Figure 1) shows the processes that a teacher can undergo during the process of making sense of their professional development. The teacher might assimilate the content or experience disequilibrium. Once the learner has experienced a disequilibrium, the learner may accommodate or shut down.

Assimilation refers to "the process whereby changing elements in the environment become incorporated into the structure of the organism" (Nash, 1970 as cited in Von

Glasersfeld, 1995, p. 62). The assimilation process allows the learner to take new information and fit it into his existing schema. Mental schemas are defined as "mental categories that influence the ways in which a person sees the world and interprets personal experiences" (Penrose, 1979, p. 19). Only new information that is familiar to the learner's schemas can be assimilated by the learner. During teacher professional development, assimilation occurs when the teacher is trying to make sense of the experiences. If the content and the pedagogy match what the teacher perceives to already know or have implemented, he/she will not find it to be problematic and no disequilibrium to the schemas occurs.

Disequilibrium arises when the teacher is not able to assimilate the new ideas/information/experiences into existing mental schemas. Such disequilibrium may be referred to as the source of ambiguity and uncertainty (Allen & Panuel, 2015). It may cause disappointment or surprise to the learner (Von Glasersfeld, 1995). In trying to make sense of the professional development, the teacher will find something that is problematic because it does not match what the teacher already knows or implements in their practices (Ledford, 2006). In order to eliminate the disequilibrium and thus find the equilibrium within the teacher's mental schemas, the teacher can either accommodate or reject the new information.

Accommodation refers to the process through which the learner is unable to assimilate information into his or her existing schemes, experiences disequilibrium, and reorganizes his or her thinking in such a manner that the disequilibrium is reconciled. This reconciliation may occur after a long period of time and changes the way the learner thinks about an idea (Ledford, 2006). In agreement with Smith (2001) and Ledford (2006), this research stresses the importance and potential of disequilibrium that leads to accommodation. Accommodation of new knowledge is often considered as "real learning"

because an accommodation in making sense conveys that the teacher has reconciled a disequilibrium that involved making connections to their own learning or their classroom (Ledford, 2006).

Disequilibrium may also lead to disappointments and rejection. Smith (2001) warned that the state of disequilibrium can "stimulate new learning" but can also serve as a "rationale for rejecting new ideas" (p. 44). Loucks-Horsley et al. (2010) claimed that when disequilibrium arises, teachers might reject the new information. Therefore, when the teacher faces disequilibrium, he/she does not always accommodate the new information; instead, they may simply reject the new idea and shut down. Teacher rejection or shutting down happens when he/she thinks that the new information or ideas are far removed from their existing mental schemas or not worth investing his/her time and effort to think further about. The teacher might reject or shut down consciously or unconsciously (Ledford, 2006). If the teacher does not see the relevance of what is being done in professional development, they are not interested in studying it.

Smith (2001) argues for the potential and critical need for professional development that promotes teachers' transformative learning. Teachers usually attempt to make sense of the education reform in terms of their own practice and what is comfortable for them (Schmidt & Datnow, 2005). They assimilate the new knowledge into their existing mental schemas (Hill, 2001). This leads teachers to miss the unfamiliar and more fundamental transformations that are required (Spillane et al., 2002). Spillane stressed the critical need to structure teachers' learning opportunities so that they can construct an interpretation of what they learn into their own behavior and implement it in their classroom. Teachers must be persuaded to abandon their commitments in terms of their past experiences in order to move forward professionally; they must cease practices related to the old ways in exchange for the repertoires of the new. However, they warned that these would cause many

uncertainties that are often accompanied by great discomfort that is often attached to learning something new.

In most research studies, researchers are interested in the paths that lead learners to disequilibriums and accommodation (Ledford, 2006). Allen and Panuel (2015) discussed that teacher sensemaking provides a useful framework to study teachers' responses to their professional development activities. Focusing on how teachers attempt to resolve the ambiguity and uncertainty will provide a powerful lens to view what influences teachers' decisions about implementing what was introduced in the professional development.

Sensemaking in organizational theory.

Sensemaking is a term that is commonly used without much consideration. It seems straightforward and easy to understand. It is the making of sense. But like most easily understood terms, it means so much more. According to Maitlis and Christianson (2014), the roots of sensemaking in the organizational literature can be traced back to the beginning of the twentieth century, such as in Dewey (1922) and James (1890). However, sensemaking did not begin to emerge as a distinct topic of study until the late 1960s. In the 1990s, the literature on sensemaking research deepened and broadened. One of the most important advances in sensemaking literature is Weick's (1995) seminal book, "Sensemaking in Organizations," which summarized the literature of sensemaking research up and derived a theoretical framework for understanding core aspects of sensemaking.

Weick (1995) argued that "sensemaking is about such things as placement of items into frameworks, comprehending, redressing surprise, constructing meaning, interacting in pursuit of mutual understanding, and patterning" (p. 6). He discussed sensemaking along

with such cognitive processes as understanding, interpretation, and knowledge building (Quinn, 2009) but identifies seven distinguishing properties of the sensemaking process.

One, sensemaking is grounded in identity construction including an individual's personal and organizational identity. Two, sensemaking is retrospective and it is based on experiences. Three, sensemaking is enactive of sensible environments where experiences are gained by doing things with and in the environment. He argues that the environment is created during the sensemaking process instead of discovered by the sensemaker. Fourth, sensemaking is social. Fifth, sensemaking is ongoing; it never starts nor ends. Sixth, sensemaking is focused on and by extracted cues. This means that sensemaking is based on familiar points of reference (cues) that can act as seeds for new meaning. Last but not least, sensemaking is driven by plausibility rather than accuracy (Weick, 1995)

The basic idea of sensemaking is that reality is an ongoing accomplishment that emerges from "efforts to create order and make retrospective sense of what occurs" (Weick, 1993, p. 635). Sensemaking is the process through which an individual works to understand novel, unexpected, or confusing events, and thus has become a critically important topic in the study of organizations. When individuals encounter moments of ambiguity or uncertainty, they will seek to clarify what is going on by extracting and interpreting cues from their environment, using these cues as the basis for a plausible account that provides order and "makes sense" of what has occurred, and through which they continue to enact the environment (Maitlis & Christianson, 2014; Weick, 1995; Weick, Sutcliffe, & Obstfeld, 2005).

Ever since Weick's publication of his classic 1995 text, the research of sensemaking has burgeoned, conducted in varied contexts, and in methodologically rigorous and diverse ways (Maitlis & Christianson, 2014). Weick, together with Sutcliffe and Obstfeld (2005), restated sensemaking. They explained that sensemaking involves turning circumstances

into a situation that is comprehended explicitly in words and that serves as a springboard into action. Their restated sensemaking in some ways preserved the seven properties of sensemaking and is still insistent on the importance of identity. But, their discussions are more future-oriented, more action-oriented, more closely tied to organizing, more visible and behaviorally defined, more infused with emotion and with the issue of sense giving. They discussed how action-taking during sensemaking generates opportunities for dialogue, bargaining, negotiation, and persuasion that enriches the sense of what is going on (Sutcliffe, 2000).

Maitlis and Christianson (2014), in their effort to review the historical overview of the sensemaking field, stated that, "despite, or perhaps because of, this extensive study, the literature on sensemaking has become fragmented. Thus, the depth and breadth of the sensemaking literature pose definitional challenges. Sensemaking is often invoked as a general notion, without an associated definition" (Maitlis & Christianson, 2014, p. 58). When researchers attempt to define sensemaking, it is given a variety of meanings. These definitional disparities uncover the critical underlying ontological assumptions about what sensemaking involves (Maitlis & Christianson, 2014).

Table 1 shows some of the sensemaking literature and their different forms of specialized sensemaking and definitions. There are several recurrent themes across these studies and their definitions of sensemaking.

Form of sensemaking	Definition
Constituent-minded sensemaking	"the process by which an arbiter renders an assignment of blame, guided not only by the arbiter's professional standards and rational analysis but also by his or her own biases and the anticipation of his or her constituents' biases." (Wiesenfeld, Wurthmann, & Hambrick, 2008, p. 235)
Cultural sensemaking	"how entrepreneurs or communities make sense of venture failures." (Cardon, Stevens, & Potter, 2011, p. 79)
Ecological sensemaking	"the process used to make sense of material landscapes and ecological processes." (Whiteman & Cooper, 2011, p. 889) "how actors notice and bracket ecologically material cues from a stream of experience and build connections and causal networks between various cues and with past enacted environments." (Whiteman & Cooper, 2011, pp. 890–891)
Environmental sensemaking	"actors make sense not only of the event itself, but of the broader organizational field." (Nigam & Ocasio, 2010, p. 826)
Future-oriented sensemaking	"sensemaking that seeks to construct intersubjective meanings, images, and schemes in conversation where these meanings and interpretations create or project images of future objects and phenomena." (Gephart et al., 2010, p. 285)
Intercultural sensemaking	"the process involving the selection of scripts that reflect individuals' cultural values and cultural history." (Fisher & Hutchings, 2013, p. 796) "... can lead to various outcomes such as schema development and a higher level of cultural understanding." (Fisher & Hutchings, 2013, p. 796)
Interpersonal sensemaking	"the role of interpersonal cues from others in helping employees make meaning from their jobs, roles, and selves at work." (Wrzesniewski, Dutton, & Debebe, 2003, p. 102)
Market sensemaking	"a macro version of Weick's approach to meaning construction in organizations." (Kennedy, 2008, p. 272).
Political sensemaking	"how powerful social actors construct the relationship between multinational enterprises (MNEs) and their multiple local contexts." (Clark & Geppert, 2011, p. 395)
Prosocial sensemaking	"process in which employees interpret personal and company actions and identities as caring." (Grant, Dutton, & Rosso, 2008, p. 898)
Prospective sensemaking	"the conscious and intentional consideration of the probable future impact of certain actions, and especially nonactions, on the meaning construction processes of themselves and others." (Gioia, Thomas, Clark, & Chittipeddi, 1994, p. 378)
Resourceful sensemaking	"the ability to appreciate the perspectives of others and use this understanding to enact horizon-expanding discourse." (Wright, Manning, Farmer, & Gilbreath, 2000, p. 807)

Table 1. Examples of several forms of sensemaking and their definitions.

The first recurrent theme is sensemaking as a dynamic process that is concerned with transience rather than constancy. Second, cues play a central role in the process of sensemaking. An individual's sensemaking is triggered when we confront events, issues, and actions that are somehow surprising or confusing (Maitlis, 2005, p. 21). Cues also shape sensemaking as it unfolds because it is "focused on and by extracted cues" (Weick, 1995, p. 49), in a process during which individuals "interpret and explain a set of cues from their environments" (Maitlis, 2005, p. 21).

Third, despite ontological differences, the sensemaking process is considered to be social. Individuals making sense on their own are embedded in a socio-material context where their thoughts, feelings, and behaviors are influenced by the "actual, imagined, or implied the presence of others" (Allport, 1985, p. 3, as cited in Weick, 1995, p. 39). Many scholars also see sensemaking as the process by which "people create and maintain their world and produce, negotiate, and sustain a shared sense of meaning" (Gephart et al., 2010, p. 285 as cited in Maitlis & Christianson, 2014).

Last, sensemaking concerns the action that people take to make sense of a situation which, in turn, enacts the environment that they seek to understand. Weick explains it in one of his seven aspects of sensemaking: "enactive of sensible environments" (Weick, 1995, p. 30). These action-meaning cycles occur repeatedly as people construct provisional understandings that they continuously enact and modify.

Instead of agreeing on a single definition of sensemaking, Spillane (2004) used Weick's model of sensemaking and the work of several other cognitive theorists to summarize how teachers make sense of policy:

> Sensemaking is not a simple decoding process of a given stimuli. It is an active process of interpretation that draws on the sensemaker's experiences, knowledge, beliefs, and attitudes. Knowledge and experiences are integrated into a web of interdependent relationships called scripts or schemas. Implementers filter

> incoming information through these scripts. The sense they make thus depends on the sense that they already have … existing knowledge is a primary resource in the development of new, sometimes better, understandings. The new is always noticed, framed and understood in light of what is already known. (p. 76)

Note that sensemaking goes beyond interpretation and in fact involves the active authoring of events and frameworks for understanding, as individuals play an active role in constructing the very situations they attempt to comprehend (Sutcliffe, 2013; Weick, 1995; Weick et al., 2005). Sensemaking is a "motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively" (Klein, Moon, & Hoffman, 2006, p. 71).

Sensemaking is more than a term. It is a richly descriptive body of thinking about perceptions, cognition, action, social interaction, and agency. Sensemaking according to Seligman (2006, p. 109) isn't simply a constant recognition or discernment of cues and making judgments to slot information, actions, or events into expected patterns but is a "Cyclical process of taking action, extracting information from stimuli resulting from that action, and incorporating information and stimuli from that action into the mental frameworks that guide further action."

Halverson, Kelley, and Kimball (2004) argued that sensemaking follows the constructivist approach where one's prior experience shapes learning, and experience produces mental models to anticipate patterns. It is an iterative process where experiences and perceptions can affect and be affected by new experiences and perceptions. This suggests that much of what is noticed or reacted to in the environment is shaped by the patterns one anticipates. Maitlis and Chritianson (2014) proposed an integrated definition which sensemaking is,

> A process, prompted by violated expectations, that involves attending to and bracketing cues in the environment, creating intersubjective meaning through

> cycles of interpretation and action, and thereby enacting a more ordered environment from which further cues can be drawn. (p. 67)

THE CONCEPTUAL FRAMEWORK OF TEACHER SENSEMAKING

Teacher sensemaking is not only associated with constructivism perspectives and stresses the process of interpretation as well as action. Incorporating various literatures of sensemaking, this research defines teacher sensemaking as a process, triggered by cues in the environment (such as issues, events, or situations), that involves continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and take action effectively.

Sensemaking is a form of cognition, a theoretical construct that contains the cognitive and social mechanism for dealing with ambiguity and uncertainty. Spillane, Reiser, and Gomez (2006) reported that the educational implementation studies should start to explore how human sensemaking influences implementation. Spillane et al. (2006) explained, "If implementation involves interpretation, because implementers must figure out what a policy means and how it applies in order to determine how it is used, then a cognitive framework that unpacks the ideas that implementers construct from reform proposals" is useful (p. 49).

Schon (1983) states that even a well-trained teacher does not encounter a problem and decide which research-based strategy can be applied to a situation. Teachers face complex, ambiguous problems in actual classrooms that require them to make sense, interpret, and reflect before devising a solution. Schon (1983) called this "reflection-in-action." Through reflection, teachers select relevant factors to frame the problem and organize the factors based on prior knowledge and an appreciation for the direction of the solution. Teacher sensemaking not only has much in common with Schon's (1983) model

of the reflective practitioner, it also emphasizes social and contextual forces that influence the teacher.

Maitlis and Christianson (2014) more recently discussed that sensemaking is the process through which people work to understand issues or events that are novel, ambiguous, confusing, or in some other way violate expectations. Within the education setting, Spillane, Reiser, and Reimer (2002) illuminated the interpretive or sensemaking dimension of the implementation process. Doing so, they developed a cognitive framework to underscore the need to take account of, and to unpack, implementing agents' sensemaking from and about policy.

Spillane et al. (2002) moved beyond the behavioral focus on what implementing agents do and articulated a model for how they construct understanding of the education policy's message, construct an interpretation of their own practice in light of the message, and draw conclusions about potential changes in their practice as a result. Their framework stressed that the policy messages are not inert, static ideas that are transmitted unaltered into local implementing agents' minds to be accepted, rejected, or modified to fit local needs and conditions. Rather, the implementing agents must first notice, then frame, interpret, and construct meaning for policy messages.

Spillane et al.'s (2002) cognitive framework provided a very coherent model that addressed each element of implementation. First is the implementing agent (the teacher) as the sensemaker and the role their prior knowledge, beliefs, and experiences play in shaping their understanding of policy and their relation to it. They discussed that prior beliefs and practices can pose challenges not only because teachers are unwilling to change in the direction of the policy but also because their extant understandings may interfere with their ability to interpret and implement the reform in ways consistent with the designers' intent. Second, teachers' affective costs to self-images can impact their adoption of educational

reforms. Sensemaking processes are active rather than passive encoding of information, where teachers' values, emotions, and motivated reasoning play a role in teachers' implementation processes. Third, sensemaking occurs in social contexts and thus social interactions can shape sensemaking in implementation. Using and adopting Spillane et al.'s (2002) cognitive framework, Honig (2006) uncovered and outlined these elements and how and why the interactions among these dimensions shape implementation in particular ways.

Adopting from Spillane et al. (2006) and Coburn (2001, 2005), this research develops a conceptual framework as well as research instruments not only to study the distributed cognitive framework of teacher sensemaking, but also examines the teachers' sensemaking that occurs within communities of practice and how campus and district administrators can indirectly influence shifts in practice by shaping the conditions under which learning unfolds.

Cognition: Teacher worldview and knowledge.

Cognition is a concept used to describe the mental processes of knowing things (Mantere, 2000). Quinn (2009) defines cognition as the processing of information, the acquisition of knowledge. The fundamental nature of cognition is that new information is always built upon what is already understood. It is guided by schemas — structures of knowledge that link together concepts for the purpose of sensemaking (Quinn, 2009). When a schema or worldview has been established, it is difficult (but not impossible) to restructure or modify this framework for learning (Quinn, 2009). This means the implementer can misinterpret new ideas as familiar, thus hindering change. Teachers may be distracted by superficial similarities or familiarities and become overconfident about their success in achieving the true intention of the professional development program. This

may result in the drift of fidelity as teachers exhibit understandings and actual implementation practices that diverge from the intent of the original professional developers (Spillane et al., 2002).

Sensemaking is not a simple decoding process of given stimuli. It is an active process of interpretation that draws on the teachers' experiences, knowledge, beliefs, and attitudes. Knowledge and experiences are integrated into a web of interdependent relationships called scripts or schemas (Weick, 1995). Schemas are defined as the knowledge or worldview that is integrated into a web of interdependent relationships (Spillane, 2004). The sense that teachers make thus depends on the sense that they already have; the existing knowledge is a primary resource in the development of new, sometimes better, understandings. "The new is always noticed, framed and understood in light of what is already known" (Spillane, 2004, p.76).

However, the influence of the implementer's cognition is a limiting factor. High fidelity implementation or change in teaching practices needs teacher transformation, hence a teacher's goals, self-image, motivation, affect, and context come into play in making sense of and reasoning about teacher professional learning (Quinn, 2009). Sensemaking involves looking for patterns in one's experience to make plausible judgments about future experiences (Benn, 2004). Teacher sensemaking recognizes the "creative and interpretive" role of the teacher in understanding and implementing a new program. Teacher sensemaking emphasizes the social and external forces beyond the individual teacher's influence.

Affect: Teacher's belief, value, and emotion.

Spillane et al. (2002) also discussed that beliefs, values, emotions, and motivated reasoning all play an important role in sensemaking. People (teachers) are biased toward interpretations that are consistent with their beliefs and values. This means that when a teacher is presented with new ideas regarding their practice in the classroom, they are more likely to focus on information that is consistent with their point of view (Quinn, 2009).

This research defines "affect" as the observable display of emotions, values, and beliefs. A teacher's belief is the predisposition that he/she holds to be true and it guides teachers' thinking and action (Rath, 2001; Quinn, 2009). Borg (2001) defined that a belief is a proposition that may be consciously or unconsciously held, is evaluative in that it is accepted as true by the individual, and is therefore imbued with emotive commitment; further, it serves as a guide to thought and behavior. A teacher's value is the measure of worth or importance of the teacher as they commit to professional development. The teacher is biased toward professional development programs that are consistent with their beliefs and values (Quinn, 2009). A teacher's emotion is the feeling toward and their reaction to their professional learning (Schmidt & Datnow, 2005). Spillane et al. (2002) stated that relations between implementing agents' values and emotions and their sensemaking are not well understood and thus, investigating the emotional dimension of the teachers' values and emotions is likely to be especially fruitful.

In addition, Quinn (2009) and Spillane et al. (2002) warned that the affective costs to self-image could hinder the adoption of an education reform in that teachers want to believe that they have performed well in the past, so they are hesitant to believe that their efforts have failed. Because accepting and adopting new practices introduced in teacher professional development programs could result in a certain degree of loss of teachers'

positive self-image, the professional developer must provide learning opportunities and activities that can motivate teachers to change their practices to meet the program's goals.

Context: Situated, social and distributed teacher education.

Sensemaking is not a solo affair (Coburn, 2001; Spillane, 2004; Quinn, 2009; Weick 1995, 2001, 2009). Because much learning results from the action, teacher sensemaking is situated in classrooms where understanding unfolds from trial and error, leading to situated learning (Quinn, 2009). In addition, Coburn (2001) stressed that teachers make sense of professional development in conversations and interactions with other teachers. They will construct shared and distributed understandings and establish workgroup-specific cultures, beliefs, and routines along the way.

In the past, teachers' learning has been shifted from cognitive to constructivist perspectives and, more recently, to a situative perspective that argues for the importance of both the enculturation process and active individual construction (Brown, Collins, & Duguid, 1989; Driver, 1994; Cobb, 1994). Dissatisfied with overly individualistic accounts of learning and knowing, educators started to recognize the roles of others in the learning process (Resnick, 1991). Driver (1994) and Cobb (1994) explained that teachers' learning is a practice of wider society where it involves active individual construction and an enculturation process. More recently, many researchers have positioned the teachers' growth in a situative perspective (Putnam & Borko, 2000; Greeno, 2003; Borko, 2004; Resnick, 1991).

Wilson (2002) also discussed that the situative perspective emphasizes that cognitive activities take place in the context of a real world, which inherently involves perception and action. Indeed, the situative perspective of teacher learning involves

cognitive or teacher sensemaking processes that are deeply rooted in interactions and engagement with the world. For a teacher, learning occurs in many different aspects of practice. It can occur in the classroom, in school communities, in professional developments, in the hallway, during a discussion with the administration, and much more. In order to study teacher learning, we must examine it within many different contexts. Thus, the situative perspective of teacher sensemaking that takes individual learners and their social contexts into account serves as the framework to do so.

The initial idea of the situative perspective was to help students develop a deep understanding of subject matter (Brown et al., 1989), situate students' learning in a meaningful context (Brown et al., 1989; Greeno, Collins, & Resnick, 1996), and create learning communities that promote rich discourse about big ideas among educators and students (Brown et al., 1989; Greeno et al., 1996; Resnick, 1991). The situative perspective refers to a set of theoretical perspectives with roots in various disciplines including anthropology, sociology, and psychology (Putnam & Borko, 2000; Borko, 2004).

Progressing from the cognitive perspectives of teachers' growth, the situated perspective suggests that teacher growth is constituted through the evolving practices of the teacher in the professional domain. The situative perspective in teachers' learning has gained significant importance in teachers' education programs. For example, Hoban (2002) drew attention to the importance of both the cognitive and situative perspectives in analyzing teacher learning by taking into account individual sensemaking processes as well as social and contextual influences.

Putnam and Borko (2000) adopted the situative perspective in thinking and learning into research on teacher learning, and thus teacher education. They introduced the situative perspective of teachers' learning in terms of how teachers learn new ways of teaching. The situative perspective emphasizes the need to consider both the individual teacher learner

and the social system in which the teachers are participants, a merging of the cognitive and situative perspectives of thinking and learning. The situative perspective of learning is beyond the individualistic account of learning and knowing; instead, it can be explained by three cognitions. These are cognition as situated, cognition as social, and cognition as distributed.

First, cognition as situated emphasizes the authenticity of teachers' sensemaking during their learning experience. Authentic teachers' learning experiences (which are fostered by authentic activities) consider the types of sensemaking and problem-solving skills that would actually occur in the course of teaching. In the study by Wilson (2002), she claimed that cognition as situated is cognition that takes place in the context of task-relevant inputs and outputs. She explained that perceptual information from environments continues to affect the cognitive process.

Second, cognition as social means that how we think and express ideas are products of interaction with people over time (Putnam & Borko, 2000). Lampert's (1990) study showed that participation in socially organized activities of learning, including discourse and the opportunities to learn how to participate in learning practices, are very important. Cognition as social emphasizes the importance of discourse communities, in which teachers as learners can engage in a rich conversation and new insight while they make sense of their professional learning. Through the rich conversation that involves the cognitive tools of concepts, ideas, and theories, teachers will appropriate them as their own through personal effort to make sense of experiences (Putnam & Borko, 2000; Borko, 2004; Resnick, 1991). Hence, the central role of teacher education is to acculturate teachers through various discourse communities; equipping them with competencies of using concepts and forms of reasoning and arguments that characterize the discourse communities (Putnam & Borko, 2000; Borko, 2004).

Lastly, Greeno et al. (1996) explained that the situative perspective views knowledge as distributed among people and their environment, including objects, artifacts, tools, books, and communities. Cognition as distributed considers the teachers' cognition as a property that can be distributed across individuals and a tool that can enable cognitive tasks that are beyond the capabilities of any individual (Putnam & Borko, 2000). Rather than focus excessively on individual teachers' competencies, teacher learning should be engaging in the environments that focus on sharing learning and cognitive performances (Resnick, 1991).

Spillane et al. (2002) summarized that (a) sensemaking occurs in a social context, (b) social interactions can shape sensemaking in implementation, (c) sensemaking is affected by the organizational context, (d) informal communities provide a social context that affects sensemaking in implementation, (e) historical context affects sensemaking in implementation, and (f) values and emotion are key parts of the social context.

Figure 2 following shows the conceptual framework of teacher sensemaking. Note that teacher sensemaking of professional development is situated in the system of implementation that is affected by two external factors: current educational policy and leaders' or administrators' shaping actions. Coburn's (2005) findings showed the role that principals or administrators play in terms of influencing teacher sensemaking and creating conditions for implementation. This influence is called a sense-giving process. Gioia and Chittipeddi (1991) define sense-giving as the process of "Attempting to influence the sensemaking and meaning construction of others toward a preferred redefinition of organizational reality" (p. 57).

Coburn (2005) explained that district and school administrators have greater access to policy messages than classroom teachers, hence they can decide which messages they bring in, emphasize, and/or filter out. Hence, the sense-giving process influences the

sensemaking process of teachers. Administrators can also shape teachers' social construction of meaning indirectly. School administrators can interact with teachers and focus their attention in particular ways or help identify the range of appropriate responses. Last but not least, administrators can create conditions that are conducive for teachers to engage with policy messages in consequential ways.

Later, Coburn and Russell (2008) provided evidence that district or/and state policy impact the nature and quality of teachers' social network by cultivating a structure of ties (referring to the structure of a social network). The tie between teachers, the span and the strength of their ties), access to expertise, trust, and content of interaction refer to the substance of conversations in which actors in a social network engage.

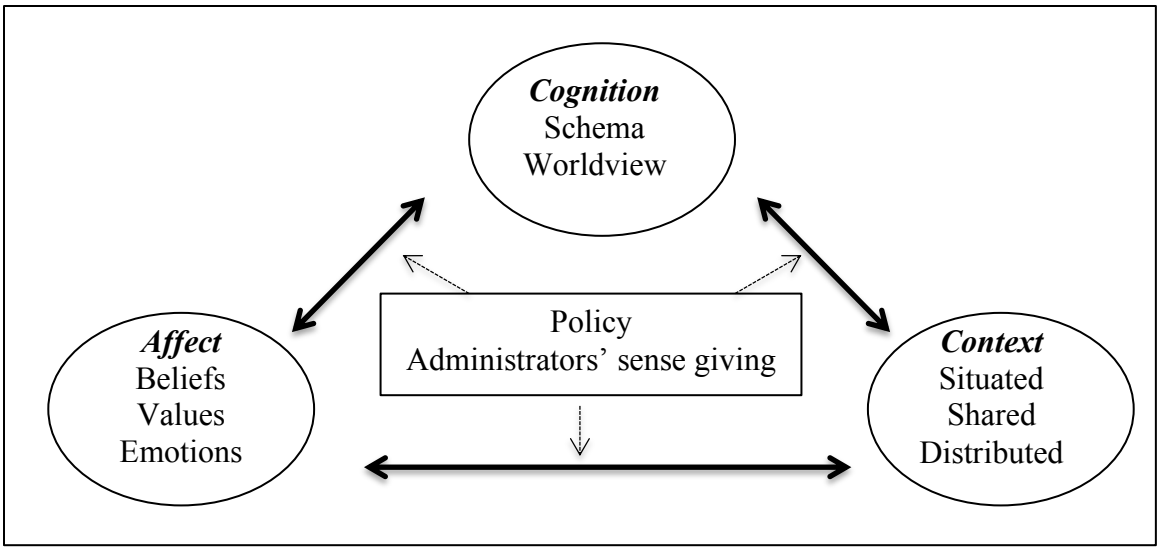


Figure 2. The conceptual framework of teachers' sensemaking

FIDELITY OF IMPLEMENTATION

Professional development is widely understood to be the best way to support teacher implementation in the classroom (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). Large-scale studies have also indicated that teacher knowledge and practice can be improved by professional development (Garet et al., 2001). However, professional development programs are rarely, if ever, implemented as intended and designed (Century, Freeman, & Rudnick, 2008; Kelly & Perkins, 2012; Ringwalt et al., 2003). Successful implementation of any intervention or initiative has not been a simple matter of teachers' implementation efforts; it can be a complex and challenging process. The distinct and various contexts and conditions of implementation sites can very well influence the process of implementation.

Fidelity of implementation is a relatively new construct in K–12 core curriculum effectiveness research, but its use in program evaluation can be traced back about 30 years (O'Donnell et al., 2007). In the past, teachers' learning was viewed as a passive transfer of knowledge and skills. Teachers are considered passive receivers of innovation or intervention. Back then, the fidelity of implementation was defined as "adherence" and teachers would copy or imitate the specific procedures of an innovation introduced in their professional development program (O'Donnell et al., 2007).

Therefore, fidelity of implementation was defined as the determination of how similar an innovation or intervention is implemented in comparison with the original program design during an efficacy and effectiveness study of teachers' professional development (Berman & McLaughlin, 1976; Freeman, 1977; Mowbray, Holter, Teague, & Bybee, 2003; Rogers, 2003; Scheirer & Rezmovic, 1983). Calling this a "profidelity approach" (p. 199), Century and Cassata (2016) stated that this stance has been extensively documented and referenced for decades when it has been the dominant perspective on how

end users should approach the use of novel practices and strategies that are identified as evidence-based. Once an innovation is found and proved to be efficacious, future innovation should not deviate from it. Hence, less attention has been given to studying and identifying the teachers and the contextual factors that promote or inhibit adherence to a program model (Scheirer, 1987; Zvoch, 2009).

In contrast to the profidelity perspective, the "pro-adaptation perspective" (Century & Cassata, 2016, p. 199) discussed that modification and adaptations of innovation elements (rather than strict adherence to them) are key to reproducing positive outcomes from one context to another and bringing about ongoing improvement. Alternatively, implementation research and literature acknowledge that teachers, as individuals, vary in nature. Thus, the extent to which teachers implement or enact any educational interventions or any kind of educational initiative is also different. Inevitably, teachers make necessary adaptations and modifications in response to local needs and backgrounds (Cassata, Kim, & Century, 2015; Fogleman, McNeill, & Krajcik, 2011; O'Donnell, 2008; Sherin & Drake, 2009). In addition, Casatta et al. (2015) stated that, "It is also well-established that interventions in education are complex, involving multiple, iterative, dynamic interactions between students, teachers, schools, and environments" (p. 2). Programs can never be fully implemented by teachers as they were designed.

The tension between fidelity and adaptation was raised and questioned (Dusenbury et al., 2003; Elliott & Mihalic, 2004; Fagan & Mihalic, 2003; Fixsen et al., 2005; Mihalic & Irwin, 2003; Ringwalt et al., 2003). Thus, many studies of fidelity of implementation began to move beyond the traditional view of fidelity. Researchers of fidelity of implementation are now aware that implementation research should seek to do more than answer questions pertaining to efficacy and fidelity. It includes questions about all aspects of the dynamic and complex implementation process (Century & Cassata, 2016).

However, currently in the field of educational research, there is no journal focused solely on implementation research. Vastly different philosophical, theoretical, and practical orientations were found (Century & Cassata, 2016). For example, researchers discuss fidelity of implementation as the five essential elements of implementation (Dane & Schneider, 1998), fidelity as a multi-pronged approach (Hanusein et al., 2014; Knoche, Sheridan, Edwards, & Osborn, 2009), and the importance of the core components of intervention and implementation that derived from the "Active Implementation Framework" (Blasé & Fixsen, 2005; Blasé & Fixsen, 2013; Fixsen et al., 2005). Fidelity of implementation has evolved into a more descriptive discussion, which includes both individual and contextual aspects that influence implementation fidelity to structure (adherences) and fidelity to process (quality of professional development and participants' responses).

Johnson, Mellard, Fuchs, and McKnight (2006) identified four factors that affect teachers' fidelity of implementation. The first factor is the complexity of the intervention or innovation of the program. The more complex the intervention, the lower the fidelity because of the level of difficulty. At the same time, programs that are packaged to simplify the task of implementation are more likely to be implemented with high fidelity than the complex program (California Department of Education, 2007). This means that the more clearly the core components are in place, the better chance that the teachers (as implementers) will be able to adopt and adapt it to local needs of their classroom instruction without drifting away from its original intention. Second, it is vital that all required resources and materials for the implementation are readily accessible by teachers and did not become barriers to teachers' implementation. The third factor is how teachers perceived the credibility of the program's innovations. In order to buy in to the program, teachers will question and analyze the actual effectiveness according to their own experiences and

background. Even with solid evidence-based practices or programs, if teachers perceived the approach will not be effective or if it is inconsistent with their teaching style, they will not implement it well. Next, the number, expertise, and motivation of professional developers who deliver the intervention are one of the factors affecting teachers' fidelity of implementation.

According to Ringwalt et al. (2003), the two strongest predictors of implementation fidelity were teacher professional development and the degree to which teachers perceived that they had autonomy in terms of implementing the program. Ringwalt et al. (2003) showed that the more discretion or autonomy teachers perceived they have, the less likely they are to adhere to the program. In addition, they indicated that most teachers participating in their study believed their school gave them at least some choices in the matter of implementation. That means, if fidelity is perceived as the preeminent goal of the program, then teachers' autonomy needs to be reduced and school administrators must work diligently to stress adherence to the program.

In contrast, many researchers are aware and agreed that adaptations during teachers' implementation are inevitable (Century, Rudnick, & Freeman, 2010; Fixsen et al., 2005; Kelly & Perkins, 2012; Ringwalt et al., 2003). Backer (2001) suggested that a certain degree of adaptation of teachers during implementation not only are unavoidable, but in some cases, can even be desirable. Carroll et al. (2007) argued that teachers' belief systems cannot be omitted from the framework of implementation fidelity of a professional development program.

Moreover, a well-implemented program that uses teachers' valuable class time needs to ensure that all teachers believe the program is worthwhile, have a sense of ownership and autonomy of the program, are motivated to implement, and feel supported by school administration (LaChausse, Clark, & Chapple, 2013). Also, Loucks-Horsley et

al. (2010) stressed that teachers need to have ownership and autonomy in the vision of professional development programs in order to feel competent to create appropriate learning environments for their students.

With disparities of teacher autonomy and implementation fidelity, some educational organizations or campus administrators advise teachers to administer the introduced program, intervention, or curriculum as precisely as prescribed and specified to ensure positive results. They are well aware that teachers as the sole implementer in a classroom may be freely adapting what they learned from professional development to meet the local classroom needs. Such adaptation or modification can be truncating numbers of the lesson taught and adding or modifying the curricular content and strategies (Kelly & Perkins, 2012). Although such modification can be a sign of fidelity drift and decreasing the quality of desirable results, teachers must have autonomy to make necessary adaptations to suit their students' needs. Likewise, modifications and adaptations made by teachers can increase implementers' ownership or autonomy of the intervention introduced in their professional development.

While some degree of adaptation may be both necessary and desirable, teachers as the implementers should work closely with program developers to identify adaptations that may boost or increase the program's impact or uptake versus those that detract from its effectiveness and cause fidelity drift (Fixsen et al., 2005) or program drift (Ringwalt et al., 2003) or erosion of program quality (Kelly & Perkins, 2012). High-quality teacher professional development can help teachers to develop both the skills required to implement the program effectively and clear understanding of the program's objectives, intentions, and potential (Loucks-Horsley et al., 2010; Kelly & Perkins, 2012).

Fullan (1991) stated that stable teacher transformation involves continuous learning and active reflection for teachers. To facilitate teacher transformation that will engage

teachers in changing their practices as well as decision making for engaging in a process of change during their implementation, the intellectual processes of teachers cannot be taken for granted. In fact, it needs to be acknowledged and made possible. The reason is, if teacher transformation is to be successful, the change process should be robust and not an isolated event (Anderson, 2010). That means teacher education should recognize the complexity as well as the importance of teachers' sensemaking process of their professional development. Hoanig (2006) stressed that we must confront this complexity and attempt to build a "base of knowledge that can guide practice in informed, responsible, and productive ways" (p. 22).

Defining Teacher Fidelity of Implementation

Blasé and Fixsen (2005) stated, "only when effective practices are fully implemented should we expect positive outcomes, implementation matters" (p. 10). Unfortunately, there are missing links between a promising program and positive impacts on students (Kutash, Duchnowsi, & Lynn, 2009; Mihalic, Fagan, Irwin, Ballard, & Elliott, 2004). Kutner et al. (1997) stated that while some data reported in the K–12 literature demonstrated that professional development is effective in bringing significant teacher transformation and instructional change for the participating teachers, the key issues in assessing change still revolve around identifying the degree to which the new learning finds its way into an instructor's practice, and whether it persists over time. More recently, Fixsen et al. (2005, p. 2) claimed, "the term of fidelity of implementation is becoming part of the educational vocabulary due to its inclusion in the discussion about the response to intervention" of teachers' professional development program.

The importance of teachers' fidelity of implementation has increased researchers' attention to the study of fidelity in the educational field. For example, analysis conducted by the comprehensive school reform (CSR) program found that schools with uniformly high implementation across the program's components experienced improvements, especially in mathematics and reading (Aladjern & Borman, 2006). In addition, O'Donnell and Lynch (2008) found positive effects on students' achievement only when teachers used inquiry-based materials and with high fidelity of implementation to the instructional strategies embedded in the materials. Fidelity of teachers' implementation is also the explicit requirement of response to intervention (RTI) strategies. It is critical in terms of school-level processes and teachers' use of the approaches (Johnson et al., 2006; Protheroe, 2008).

The National Center on Response to Intervention defines fidelity of implementation as accurate and consistent delivery of content and instructional strategies in the way they were designed and intended to be delivered. While interventions are targeted at learners, fidelity is the measurement that focuses on the individuals who provide the instruction. This puts teachers in an active role. Teachers must be conscious of how the program is conducted and enacted in their classroom as well as schools (Fixsen et al., 2005). Teachers, while obligated to deliver the content with strategies that they originally received from their professional development program, need to make adjustments as needed.

Protheroe (2009) argues, "delivery of instruction must match the instructional design in order to maximize program benefits" (p. 38). Due to differences in school settings, populations, needs, resources, and communities, strict implementation was impossible and local adaptations were inevitable (Century et al., 2010; Fixsen et al., 2005; Kelly & Perkins, 2012, Ringwalt et al., 2003). However, Fixsen, Blase, Naoom, and Haines

(2004) pointed out that it is important to differentiate between the adjustment of a program or approach to better meet local and/or classroom needs and fidelity drift.

Fixsen et al. (2004) suggested that the most effective approach to implementing an evidence-based program is to first put the core components of the program in place and do it right first (accurately and consistently) before making any significant changes. Then, evaluate the outcomes for feedback. If the results are less positive than expected, then thoughtfully consider and plan the next implementation of what to change and why.

The long-standing controversy between fidelity in contrast to the necessity of adaptation has been discussed for many years (Mowbray et al., 2003; Rogers, 2003). Recent research shows that large-scale implementation can occur with a high degree of fidelity (Elliott & Mihalic, 2004; Fagan & Mihalic, 2003; Fixsen, Blasé, Timbers, Wolf, 2001; Mihalic & Irwin, 2003). For instance, Mihalic et al. (2004) found that programs were more likely to have a positive impact when they were being implemented with fidelity. Thus, the main question then raised is, what must be maintained in order to achieve fidelity as well as effectiveness? What and how much adaptation is acceptable when implementing a program (Hall & Loucks, 1977)?

When an effective program is not implemented properly, there exists an "implementation gap" (Fixsen, 2006). The gap occurs between researchers' knowledge of effective intervention and the practice or intervention that the targeted population actually receives (Metz & Bartley, 2012). This means that the original good implementation might disappear with time and turnover (Fixsen, 2006).

Bierman, Coie, Dodge, Greenberg, Lochman, and McMahon (2002), in an analysis of the large-scale implementation of the school and community-based "Fast Track Program" stated,

> To maintain the fidelity of the prevention program, it was important to maintain a central focus on the protective and risk factors identified in developmental research, and to employ intervention strategies that had proven effective in previous clinical trials. Yet, at the same time, flexibility was needed to adapt the intervention in order to engage heterogeneous participants who represented a range of demographic characteristics and cultural backgrounds. In general, we focused on maintaining similarity across sites and groups in the principles of intervention, but allowing the process and implementation strategies to vary within these limits (p. 9-10).

Given the tension and controversy between fidelity and adaptations, the U.S. Department of Education (2009) suggested that program modification or adaptation is acceptable as long as the program's active ingredients or its core elements are delivered as planned and originally designed. Such active ingredients or core elements are known as "core intervention components" (Fixsen et al., 2005; Protheroe, 2009; Wallace et al., 2008). It is the understanding of and adhering to the principles of intervention underlying each core intervention component while allowing for flexibility in form (such as processes and strategies) without sacrificing the function associated with the components (Fixsen et al., 2005).

Thus, this middle ground stresses that when dealing with human services like education, some degree of adaptation is necessary, but educators should always include the "essential and indispensable" elements (Fixsen et al., 2005; Metz & Bartley, 2012; Protheroe, 2009; Wallace et al., 2008). This act of striking the balance between fidelity and adaptation is recognizing that in order to achieve the intended outcomes, educators must look at two important components: (1) what is being implemented, which is the core component of the intervention and (2) how and to whom they are delivered, which refer to the core components of implementation. Guldbrandson (2008) agreed and called it "a difficult balancing act in practice" (p. 16) that aims to maintain the integrity of the program while adapting to local needs.

This research then reworded the definition of the teacher fidelity of implementation as "the degree to which the core components of intervention of a well-defined program are present when teachers in classroom enact the program." How will this definition apply to this research? The implementation fidelity of this research will focus only on the core intervention components of the professional development program. As such, the observation guide (Appendix E) and implementation fidelity rating scale (Appendix F) will focus on the pedagogical components of teachers' fidelity of implementation.

TEACHER SENSEMAKING AND IMPLEMENTATION OF PROFESSIONAL DEVELOPMENT PROGRAM

A program with demonstrated effectiveness in some schools can be ineffective elsewhere, and vice versa. Such variation in outcome has spurred interest in the "science of implementation." For example, comprehensive school reform (CSR) models have contributed greatly to the study of the science of implementation (Protheroe, 2009). Through research-based models, CSR produced different results in different contexts, and the variety of outcomes has often been attributed to differences in the fidelity of implementation (Protheroe, 2009). Evidently, effective programs will not sustain their effectiveness in another implementation site if the way it is being implemented deviates from its original evidence-based design (Blase & Fixsen, 2005; Protheroe, 2009).

The deviation of teacher fidelity of implementation is caused by many factors. One of the most important factors is the implementing agent, teacher, and their sensemaking process. Teacher sensemaking of the professional development effect the behavior, practice, and so, the implementation in the classroom. During the sensemaking process, teachers construct meaning about their experiences and interaction they encounter during

the professional development. If they find that their ideologies are consistent with the introduced educational initiative, they typically support the change and emote positively towards the change (Rath, 2001; Quinn, 2009) and vice versa. It is therefore not surprising that educational innovations are more likely to succeed when teachers inherently believe that the innovations are worthwhile and take ownership of the change process.

Teacher transformation and fidelity of implementation are not a direct causality. Allen and Panuel (2015) discussed that even when teacher professional development has a positive impact on teachers' attitudes, knowledge, and skills, it does not always lead to durable or even immediate direct changes to their instructional change and implementation in the classroom. This research is aware of teacher transformation, as well as teacher fidelity of implementation as influenced by several factors. These factors can arise internally (such as teachers' cognition, belief, values, and emotion) from teachers themselves or externally (such as teachers' context, interactions with others, and education policy) from their school system.

The conceptual framework of how teacher sensemaking influences their implementation fidelity of professional development programs in this research is drawn from various researchers and their cognitive frameworks (Weick, 1995; Weick, 2005; Spillane et al., 2002; Spillane & Anderson, 2012, Coburn, 2005; Coburn & Russell, 2008) as well as the Century et al. (2008) model of school improvement. Figure 3 below showed the conceptual framework of teacher sensemaking and their implementation fidelity of professional development. The framework of sensemaking includes three essential aspects. First, teacher sensemaking of professional development should be explored through the individual teacher's cognition. This aspect considers how teachers' prior knowledge, schemas, and worldview influence the construction of understanding (Spillane et al., 2002). Secondly, teacher sensemaking should be explored through the lens of teachers' affect.

This aspect refers to teachers' beliefs (Spillane et al., 2002; Quinn, 2009), values, and emotion (Schmidt & Datnow, 2005). Last but not least, teachers' sensemaking processes should be explored through the teachers' contexts and environments. Using situative perspectives of learning, this research claims that teachers make sense and come to understand the professional learning by three types of cognition: cognition as situated, shared, and distributed (Putnam & Burko, 2000).

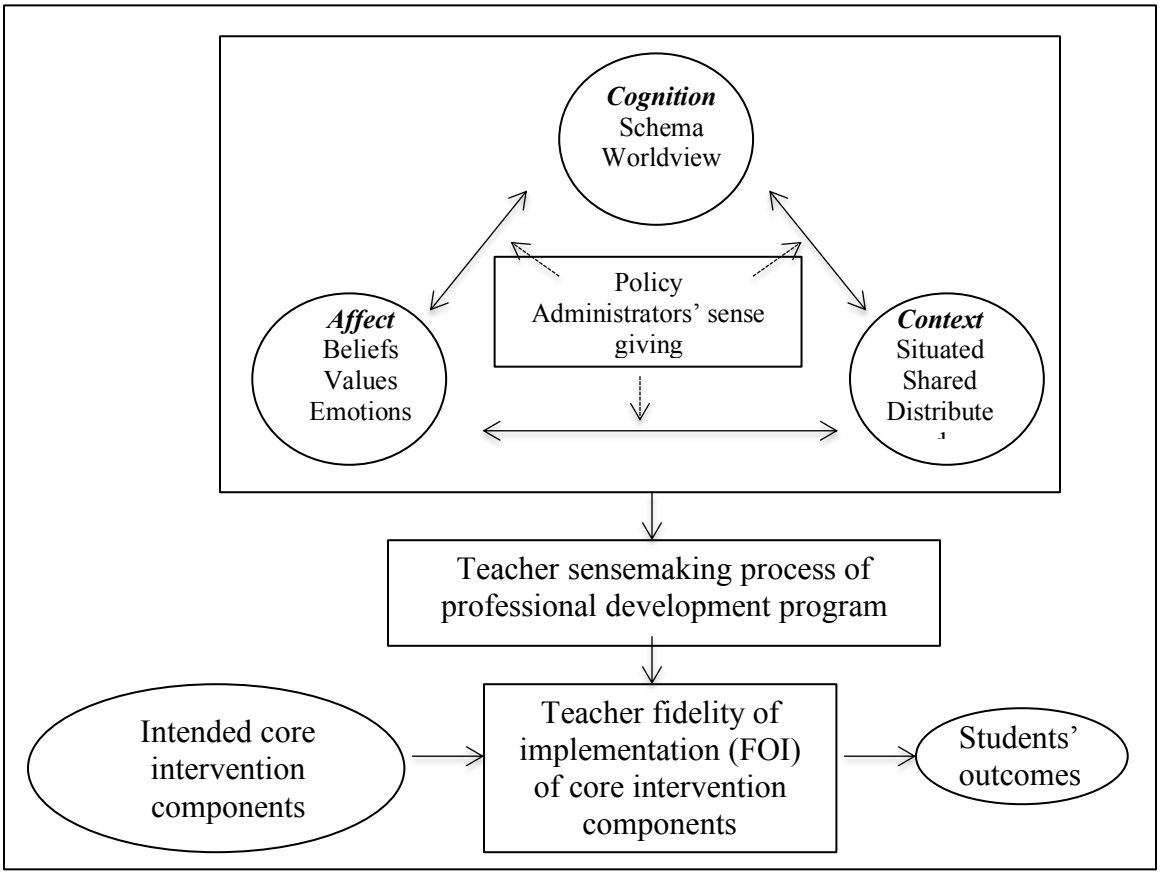


Figure 3. The conceptual framework of teachers' sensemaking and their implementation fidelity of professional development.

Chapter Three: Methodology

The teachers' sensemaking processes of their professional learning experiences appear to be a critical determinant of teachers' behavior in classroom implementation (Schmidt & Datnow, 2005). The processes are mediated by teachers' cognition (worldview, schemas, knowledge), affect (beliefs, values, and emotions), context, policy, and administration (Coburn, 2001, 2005; Greeno, Collins, & Resnick, 1996; Putnam & Borko, 2000; Quinn, 2009; Spillane et al., 2002; Spillane, 2004; Spillane, Reiser, & Gomez, 2006; Weick 1995, 2001, 2009). The purpose of this research is to explore how teachers' sensemaking processes of the professional development program influence fidelity of implementation in the science classroom. The core intervention components of the professional development are based on current education reform initiatives and ambitious instruction.

This research hypothesizes that, as a participant in the professional development program, the teacher has a unique thought process. This thought process occurs because the activities and experiences from the professional development program create new and foreground sources of ambiguity and uncertainty for teachers in their teaching context (Allen & Penuel, 2015). Focusing on how teachers resolve their ambiguity and uncertainties will provide insight regarding when and how teachers' participation in professional development can influence their decisions about implementing the intervention strategies introduced (Allen & Penuel, 2015).

RESEARCH DESIGN

In order to pursue insight, discovery, and holistic interpretation (Merriam, 1998), this research used a qualitative research methodology based on the rationale listed in Creswell (1998). The reasons are that (a) the nature of the research question started with a "what" or "how" so that initial forays into the topic describe what is going on, (b) the variables could not be easily explored and more than likely the theories need to be developed, (c) a detailed and holistic view of the research topic, (d) it studied individuals in their natural setting, (e) the researcher was willing to spend extensive time gathering data in the field, and last but not least, (f) the researcher took on the role of an active learner who can tell the story rather than an "expert" who passes judgment on participants.

Case study methodology aims for an "exploration of a bounded system," or a case over time through detailed, in-depth data collection involving multiple sources of information rich in context (Creswell, 1998, p. 61). The case study in this research adopts the constructivist paradigm, which claims that truth and reality are built upon social construction, and they are relative and depend on one's perspective (Stake, 1995; Yin, 2003). This research aims to facilitate exploration of phenomena within teachers' contexts by using a variety of data sources (Stake, 1995 and Yin, 2003).

This research uses embedded analysis, also known as holistic analysis of case study (Creswell, 2007). The term "embedded" analysis case study refers to the intention of the research to learn about teachers' experience within embedded, hidden networks, situations, and relationships within a larger issue or concern (Yin, 2003). In this research, embedding analysis of case study is locating multiple cases (each teacher participant as a case) within a larger depiction of a program. The important issue is that the case study is located within a broader perspective on the program, and in this sense are "embedded." The embedded analysis of case study in this research is guided by Creswell (2007). Because multiple cases

(teacher participants) are chosen, the research will first provide a detailed description of each case and themes within the case, followed by a thematic analysis across the cases, called the cross-case analysis, as well as an assertion or an interpretation of the meaning from the case study.

The data collection in this case study research is extensive drawing from multiple sources of information (Creswell, 1998; 2007; Yin, 2003). A combination of instruments and methodologies such as teacher surveys, teacher professional development observation, classroom observation, teacher interviews, teacher self-reports, and artifact collection supplement each other to promote deeper and fuller descriptions of answers to research questions. Due to the fundamental intention to explore teachers' sensemaking process and how it influences their implementation in the classroom, mixed methodologies can be very useful, especially when unexpected data or results arise from the research.

The schools and teacher participation were selected based on teacher participation in the professional development program offered by the Texas Regional Collaboratives (TRC) at The University of Texas at Austin. Focusing on fewer teacher participants or case studies not only allows this research to capture the subtle and iterative process of teacher sensemaking while they construct and reconstruct the meaning of their professional learning from their context through social interaction (Coburn, 2001; Coburn 2005; Yin, 2003). It also allows in-depth observation and exploration of teachers' actions and behavior during classroom implementation, such as how the teacher adapts, adopts, combines, ignores, or omits messages and activities during their actual classroom instruction. Although not generalizable to a larger population, the in-depth observation and interviews made possible by fewer case studies provide the opportunity to generate new hypotheses or build theories about sets of relationships that would otherwise remain unobservable (Hartley, 1994).

RESEARCH QUESTION

The main research question is, does science teachers' sensemaking influence their implementation fidelity in the classroom? If so, how? The sub-questions are,

- What are the common triggers of teacher sensemaking instances during and after teacher professional development?
- What are the triggers of teacher sensemaking instances that relate to teachers' rejection of implementation?
- What are the triggers of teacher sensemaking instances that relate to science teachers' additive learning or assimilation?
- What are the triggers of teacher sensemaking instances that relate to teacher transformation in classroom practices to implement the program in high fidelity?

By answering the research question, this research intends to connect the pieces (relationship) between teachers' implementation fidelity and their sensemaking. Doing so, this research identifies the orientation of teacher sensemaking as regards his/her implementation fidelity. For instance, what is the orientation of sensemaking by teachers who are high- and low- fidelity implementers? Figure 4 below summarizes the intention of this research to connect teachers' sensemaking and their implementation practices. In order to do that and answer my research questions, this research consists of several tiers of procedures.

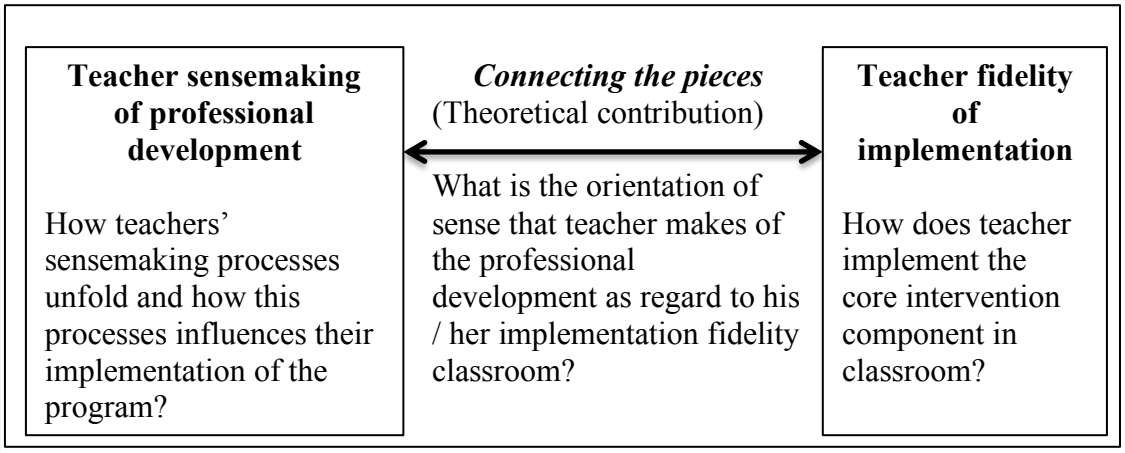


Figure 4. The theoretical contribution of the research to connect teacher's sensemaking processes with the implementation fidelity.

SETTING AND PARTICIPANTS

The professional development program

The professional development program in this research (MSS) falls into the cascade or train-the-trainer model (Hayes, 2000; Griffin, 1999; Loucks-Horsley et al., 2010). It is called Making Sense of Science (MSS) and is designed and developed by WestEd. This program is an evidence-based and research-based program, which empowers teachers and facilitators with the knowledge and skills needed to support a culture of productive learning (Daehler & Folsom, 2016).

Cascade model of professional development refers to the centralized approach that focuses on rapid dissemination of specific skills and content (Gaible & Burns, 2005). It is widely used because of its potential and accessibility to disseminate knowledge and pedagogy skills to large teacher populations throughout the nation or district (Hayes, 2000; Griffin, 1999). However, cascade model of professional development programs face the

common difficulties of linking the effectiveness of the program with teachers' pedagogical practices in the classroom and students' achievement (Hayes, 2000). A certain degree of sensitivity and adherence to the program will be lost as the knowledge and skills are being transferred from the professional development program (first tier) to the facilitators (second tier) and, later to the teachers (third tier).

According to Loucks-Horsley et al. (2010), a cascade or train-the-trainer model of teacher professional development consists of three key elements. First, it has clear and well-communicated goals that are based on teachers' needs. Second, it has a leader or facilitator that guides the participants' learning. Frequently, the facilitator is the primary source of expertise that provides the necessary sources of information needed by teachers. Third, group structures that necessitate collegial learning environment. The learning environment is designed to regulate and encourage teachers' collegial learning. The professional development consists of structured opportunities for teachers to learn from facilitators or leaders with specialized expertise (Loucks-Horsley et al., 2010).

The facilitator who trained the teachers attends and participates in the facilitation academies of the original professional developer of the Making Sense of Science (MSS) course. From the original professional developer of the MSS course (first tier), to the facilitator (second tier), and then to the teacher (third tier), the knowledge and skills regarding how to implement the program are passed down and translated from one tier to another. Figure 5 below shows the cascade or train-the-trainer model of the MSS program.

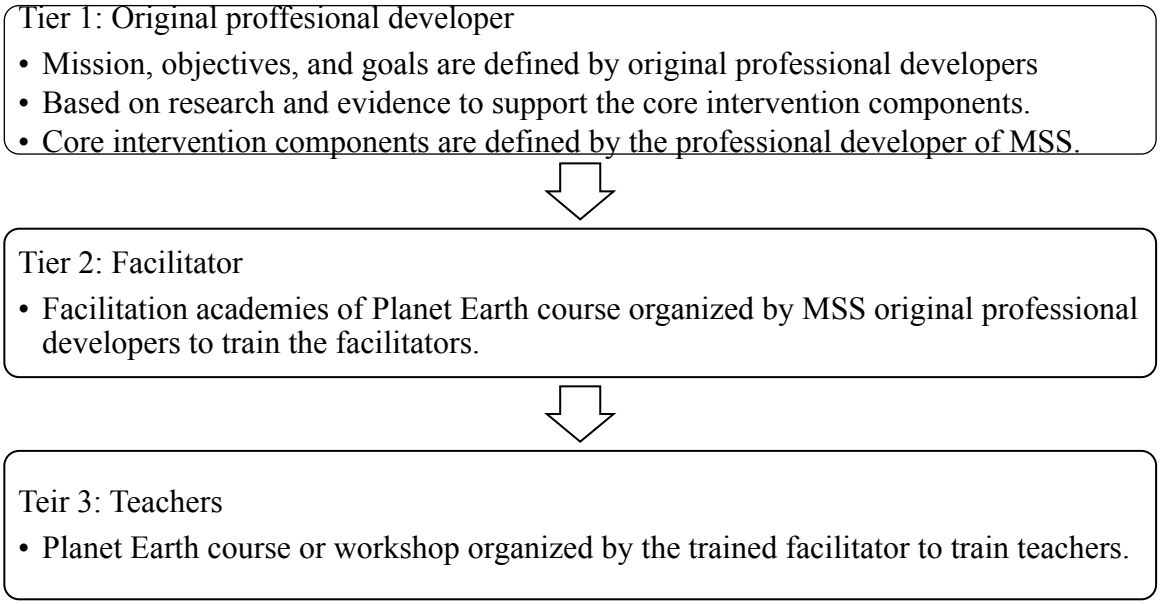


Figure 5. The cascade or train-the-trainer model of the MSS program.

The MSS program uses a transformative approach to professional learning that connects hands-on science with integrated teaching and literacy supports. It is challenging as it involves periods of disequilibrium and encourages participants to confront their preconceived ideas about science, teaching, learning, and literacy. The primary goal of any MSS course is to develop a community of inquiry to support teachers doing the most important job—making sense.

In this case study, the MSS program that the teachers participated in is called "Planet Earth" (Daehler & Folsom, 2016) and it was designed to speak to concerns about teachers' accountability and the Texas Essential Knowledge and Skills (TEKS). The program consists of a five-day workshop that trains and empowers teachers to learn as well as to teach with a reform-oriented approach that includes four guided inquiries. These guided inquiries include Science Investigations (SI), Teaching Investigation (TI), Literacy Investigation (LI), and Classroom Connection (CC). Appendix A summarizes the five-day Planet Earth workshop.

The SI focuses on hands-on activities specifically designed to support adult learners as they explore core science concepts and classic misconceptions. TI is mainly discussions of cases from classrooms, providing a platform or forum for teachers to analyze student work and examine instructional strategies. LI focuses on activities in which teachers strengthen their own abilities to read, write, and converse in science-specific ways (productive science conversation) and learn classroom routines to support students doing the same. CC is a guided reflection on the key science and literacy concepts and how these concepts relate and apply when the teacher is working with students.

The workshop includes key features of professional development that have been associated with increasing student achievement (Birman, Desimone, Porter, & Garet 2000; Desimone 2009): (a) in-depth focus on science content; (b) opportunities for teachers to engage in active and authentic learning; (c) coherence and alignment between the teacher curriculum and standards-based student curricula the teachers were responsible for addressing in their classrooms; (d) substantial duration and length of contact time, and (e) a process of collective participation during which teachers engage in professional discourse and critical reflection.

The workshop is designed for teachers' sensemaking and emphasizes learning through conversation, collaboration, piecing together information or data to figure something out, and re-learning when ideas are incorrect. The theory of action underlying the program's approach stresses that science learning should be situated in an environment of collaborative inquiry. Teacher participants of the MSS curriculum approach are trained and expected to implement the pedagogical practices and reasoning that are evidenced in the core intervention components (also known as four critical dimensions). These core intervention components are, (A) focus on conceptual understanding of learners, (B)

emphasis of collaborative inquiry and sensemaking of learners, (C) focus on learners' thinking, and (D) reflection on teaching and learning.

The four core intervention components are aligned with the seven features of ambitious instruction as well as the three main themes of the reform's direction and expectation of teaching (Stroupe et al., 2017). More interestingly, it addresses the four sets of core practices of Ambitious Science Teaching (Windschitl, Thompson, Braaten Stroupe, Chew, Wright, 2011). The four sets of Ambitious Science Teaching's (AST) core practices start with designing a unit of instruction that focuses on coherent understanding of important science ideas (address in core intervention component A and B); then focuses on making students' current knowledge and thinking visible (address in core intervention component C); teachers then guide students to talk about the investigations or data or readings (address in core intervention component B); and finally scaffold students' ideas or efforts so that their conversations are evidence-based in order to put everything together near the end of the lesson (address in core intervention component C and D).

Informed by these four core intervention components, developing a community of inquiry is the center stage where all of the teacher sensemaking happens. Teachers are trained not only to participate in a community of inquiry, they are also expected to transform the essence of a community of inquiry into their classroom practices. In general, the MSS workshop is designed to support teachers' use of their existing standard-based curricula by building their content knowledge and pedagogical content knowledge. It aims to aid teachers in four aspects. One, MSS helps teachers learn the major concepts of K–8 science (content knowledge). Second, it helps teachers examine and analyze how their students make sense of these science concepts. Third, it helps teachers analyze, refine, and improve their teaching practice. Last, it helps teachers learn ways to support science learning through literacy.

MSS program is based on the belief that teachers learn challenging science by examining evidence, working collaboratively to make sense of their experiences, and deeply exploring their own understanding and misunderstanding. MSS's facilitators are trained to support teachers' sensemaking process and work alongside teachers, but do not do the sensemaking for teachers. Facilitators can help teachers make the experiences transformative by giving them authority and agency in their own learning. Likewise, teachers are expected to carry the same role when they are ready to implement the program in their classroom. Thus, the facilitators' stance (as well as teachers' implementation stance) is based on the following critical guiding principles that support the four core intervention components. They are also referred to as the facilitation principles of MSS (Daehler and Folsom, 2016).

First, keep conversation evidence-based during the discussion of science ideas, teaching practices, and literacy strategies. During the Science Investigation (SI), teachers' conversation should focus on their data collections and data analyses in order to draw conclusions from their results and findings. During Literacy Investigation (LI), evidence may come from someone's personal experience, teaching cases, students' artifacts, and many more.

Second, make thinking visible. When a teacher talks about an idea, it is essential to understand clearly what he/she is thinking. Only when an idea is fully understood, it can be compared with another idea, evaluated in terms of strengths and limitations, and revised if evidence shows it to be incomplete or imprecise. In order to make teachers' thinking visible, facilitators will encourage teachers to say more or invite them to draw, illustrate, or give examples of their ideas. Ideas can be represented in many ways such as charts, tables, drawings, graphs, and Venn diagrams. Representations are an integral part of learning.

Third, don't stop at one. Teachers bring in a wealth of ideas, experiences, and knowledge that contribute to learning. In order to mine these valuable resources, facilitators need to make space and opportunities for teachers to share different viewpoints, mental models, representations, and various ways of thinking. Facilitators not only need to listen to all ideas, but also elicit teacher responses with follow-up questions for further explanations or a variety of viewpoints from the group. The facilitator encourages teachers to wrestle with their own ideas and uncertainty and trust that new and deeper learning will result.

The beauty of collaboration inquiry is that it pushes learners into a period of not knowing the answers, with no clear explanations of the problem, and uncertainty. Sometimes a period of not knowing will cause significant disequilibrium or discomfort. If teachers as learners are given the time and opportunities to share out their tentative mental model, they will work in a group to determine a more accurate and robust concept. The process most likely forces them to engage with prior conceptions about science phenomena that are maybe inaccurate or incomplete. Understandably, it can be challenging, as they have to visit and revise assumptions on many levels. Eventually, the process will result in deeper understanding of the science concept. More importantly, it will open the portal for teachers to comprehend the progression of understanding the science concept; that is, how an accurate mental model evolves from an incomplete one with the existence of misconceptions. Such an evolutionary process not only allows teachers to make sense of science themselves, but also instills the ability to identify, appreciate, help, and guide students toward a deeper understanding of the science concept.

Next, separate ideas from individuals. The workshop is built around the trickiest aspects of science and teachers are very likely to discover their misconceptions and find out that their mental models need refinement in order to be more accurate and complete.

This learning process is expected and important. One way to help teachers feel comfortable and respected is to remind them that it is fine to be wrong; it is an inevitable and crucial process of learning. Through mistakes and misconceptions, teachers will explore and polish their tentative thinking. Sharing out the tentative or incorrect idea is one way to identify students' possible misconceptions or incomplete mental models. Ideally, all ideas, opinions, or viewpoints should be listened to and respected.

Last but not least, explore ideas with words, actions, images, and symbols. Lemke's research has profound influences on the development and design of MSS program (Lemke, 2002). Teachers are encouraged to express thinking through different languages of science, such as words, actions, images, and symbols. Teachers can revisit ideas from various languages of science in order to deepen their understanding.

The theory of action underlying the professional development program in this research stresses that science learning should be situated in an environment of collaborative inquiry. Participants of the MSS curriculum approach are trained and expected to implement the pedagogical practices and reasoning that are evidenced the four core intervention components (also known as the four critical dimensions). These four core intervention components emphasize the reform-oriented instructional approach. It aims to train teachers to transform their current practice to embrace reform-oriented classroom learning.

Site selection.

This case study was based on purposeful sampling strategies. There were many reasons for selecting schools in one of the Independent School District in the southwest area of the United States as the site of this research. They are, primarily, accessibility of

the professional development program; accessibility of the districts, schools, and participants; the transformative approach of professional learning used by MSS; the district's and school's embrace of the initiative of reform-oriented science instructional approach; and my desire to capture the rich experiences of teacher sensemaking.

The Cohort.

In summer of 2016, the principal investigator participated in the MSS Planet Earth course for a week in order to study the turn-around of the program by the facilitator (Tier 2 in cascade model of training). The researcher aimed to discover whether the program's philosophy, intention, objectives, and curriculum approach, together with its four core intervention components, are translated from the original MSS program through facilitators and then to teachers' professional development.

The five-day summer workshop lasted from 8 a.m. to 4:30 p.m. each day. There was a total of 31 participants, comprising four elementary teachers, 24 middle school teachers, two high school teachers, and one secondary curriculum specialist. Using the teacher professional development observation guide, I observed and took field notes over the course of the week. The facilitator of the course delivered and stressed the four core intervention components throughout the training.

During the workshop, the facilitator trained and empowered teachers to learn as well as to teach with a reform-oriented pedagogical approach using four guided inquiries. These guided inquiries include Science Investigations (SI), Teaching Investigation (TI), Literacy Investigation (LI), and Classroom Connection (CC) (see Appendix A). These four guided inquiries stress instruction that engages students as active participants (not audiences) in their own learning process with the ultimate goal of developing complex

cognitive skills. The inquiries push students to "do" science emulating the practices of scientists. Students are expected to generate ideas, plan solutions, collaborate with others, examine patterns, analyze relationships, construct representations to present their data/findings, write reports, and more.

Teachers were actively engaged in activities, productive science conversation, arguments, discussion of possible misconceptions, and shared ideas of how to address students' misconceptions and how to engage students' interests in the science concept. The facilitator not only effectively established a platform, but she also created a safe environment for teachers to learn science and science teaching collaboratively. Although there are several minor adjustments of time frame and modification of activities and tasks during the summer institutes, overall no fidelity drift occurred at this time.

At the end of the workshop, six teachers agreed to participate in the research and took a teacher survey designed to explore (i) the demographic and background information, (ii) teacher perspectives regarding the professional development, and (iii) to their readiness to implement the core intervention components of the professional development in their classrooms. When school began in fall 2016, four teachers remained in the case study and were ready to implement the program (Tier 3 in cascade model of PD).

Teacher participants.

Using convenient and purposeful sampling (Merten, 2010), there are four main teacher participants involved in the research. They are Alan, Julia, Kelly, and Lily. All participants of this research teach science and participated in the MSS Planet Earth professional development course. An invitation to participate and a description of the research were sent out to all participants at the end of the course. Six teacher participants

agreed to participate in the research. Then, a meeting was set up to provide these six teacher participants the details of the research and explain the IRB protocol to them before they agreed to participate in the research.

When the schools begin in 2016/2017, only four teacher participants remained and involved in this research for a year. Although the school district embraces the initiative of reform-oriented science instructional approach, the four teachers expressed that they participated in the PD program voluntarily. Since the participation in the MSS course was initiated by the teachers' own initiative to improve their teaching practices, their implementation is also voluntary. The nature of voluntary implementation will also help this research to explore the intention of their implementation.

Two out of four teacher participants in this research are 8th grade science teachers, Julia and Alan. According to the 8th grade TEKS, students are required to learn the content of Planet Earth in their grade level before graduating to 9th grade. Julia is an 8th grade science teacher and department chair in her campus. She has eight years of teaching experience. She earned her bachelor's and master's degrees in biology. She also held several leadership positions in her school. Alan is also an 8th grade science teacher. He has 13 years of teaching at a Title I middle school and has been with his current school for two years.

Another two teachers, Kelly and Lily, were not expected to be teaching the subject matter of Planet Earth. This is because the content of Planet Earth was not required by the 5th and 7th grade level TEKS. However, they attended MSS: Planet Earth with one common purpose, which is to improve their content knowledge. Lily wants to improve her content knowledge in Earth Science and she plans to move up to eighth grade in the future. Lily is a 7th grade science teacher at a well-known high performing middle school. She earned her degree in psychology and was introduced to the teaching profession while she

was pursuing her master's degree in Psychology. Kelly is a 5th grade science teacher in an elementary school. She participated in the Planet Earth workshop with her intention to explore students' progression of ideas in Earth science. She graduated with a degree in Elementary Education, with an emphasis in US History. She is very passionate about science, too. She has 14 years of teaching experience.

INSTRUMENTATION

The data collection for this paper consists of five instruments, including teacher survey, teacher professional development observation, teacher classroom observation and implementation rating scale, teacher interview, and teacher self-reports with artifacts.

Teacher survey.

The teacher survey (Appendix B) was used to (i) find out teachers' demographic and background information, (ii) explore teacher perspectives regarding the professional development, and (iii) explore teachers' readiness to implement the professional development in their classrooms. The design of this research project is intended to gain insightful descriptions of teachers' sense-making process and how it influences teachers' fidelity of implementation. Thus, the teacher survey does not intend to determine the relationship between independent and dependent variables.

Teacher professional development observations.

The teacher professional development observation guide (Appendix C) was used to guide the observation of teacher professional development. The teachers' professional

development observation guide helped collect data by reporting whether the program's core components of intervention (called critical features of intervention, see Appendix D) are evidenced during teachers' professional development sessions. In addition, the researcher took field notes or described the professional development sessions that were observed.

Unlike the teacher classroom observation, teachers' professional development observation was conducted only once, but for the consecutive five-day workshop. Like the classroom observation guide and its implementation rating scale, the teacher professional development observation guide is developed with the collaboration of the original professional developers. Such collaboration helped ensure that the intention, objectives, and critical intervention components of the professional development program are identified accurately and its observable critical features are classified according to the core components. Most importantly, it upholds high reliability and validity of the instruments.

Teacher classroom observations.

Teacher classroom observations consist of a classroom observation guide (Appendix E) and rating scale with the rubric (Appendix F). In addition, the researcher also took notes or described the lessons observed. Information or data such as, (i) questions asked by teachers and students, (ii) teachers' response to students' questions and inquiries, (iii) classroom activities, (iv) students' work, (v) student responses, (vi) how many groups of students, (vii) learning objectives of observed lesson, (viii) any modifications or adaptations made by teachers, and many more that are related to teachers' pedagogical practice are recorded. Teacher participants in this research project were observed by the principal investigator at least four times in the 2016–2017 school year.

Teacher classroom observations were designed to explore the professional development program theory in real-world action (O'Donell & Lynch, 2008). While teacher professional development observation explores to what extent the critical intervention components of the program are translated from facilitator to teachers, classroom observations were conducted during teachers' actual classroom implementation. The intent is to study to what extent the MSS's core components of intervention are translated by teachers to the classroom (see Appendix G). Ultimately, the classroom observation will provide answers to the following questions:

- To what extent do teachers apply the curriculum approach provided by the professional development program in their implementation?
- How consistent are teachers' pedagogical practice and reasoning with the process, context, and content of original professional development session?
- How do teachers make decisions regarding the modification and adaptations done during their classroom implementation?

Teacher interview.

The principal investigator interviewed each teacher after classroom observation. The teachers' interviews (Appendix H) were developed based on various researchers' frameworks (Chien Chin, Lau, & Lin, 2001; Fendt, 2010; Glickman et al., 2004; Quinn, 2009; Schmidt & Datnow, 2005) and driven by Spillane, Reiser, and Reimer's (2002) and Fullan's (2001) arguments that implementation is complex and affected by internal characteristics (teacher), local characteristics (district, community, and principal) as well as external factors (district, state, government, and other agencies).

Teacher self-report.

The teachers' self-report was used to provide the principal investigator a better picture of teachers' implementation, decisions, and the reasoning behind their pedagogical practices during the implementation. Teachers' self-report (Appendix I) is a tool that allows for teachers' self-reflection and metacognition. Teachers will justify their decisions regarding how they plan their lesson and how the actual lesson does or does not align with his/her plan. It is a very informative way to collect information about teachers' daily instruction and implementation in the classroom.

Teachers were encouraged to include any kind of information or artifacts to provide the researcher insight into their lesson planning, pedagogical practices, and decisions. Teachers' self-reports were not used as a tool of evaluation of any kind; it is in fact a method that helps the researcher to understand the influences of teacher sense-making and teachers' pedagogical practices. The teachers' report included information such as weekly lesson plans, teachers' reflection on their lesson plans and actual lessons, the assessment or task that was used in the lesson, weaknesses and strengths of the lesson plans, critical features that the teacher has implemented in the classroom (if any), the reason for implementation, difficulties or hindrances the teacher faced when implementing the critical features of the program, next steps in order to overcome the difficulties in the lesson plan, and teachers' planned refinements of the lesson in order to overcome the difficulties in their pedagogical practices.

PROCEDURES

In early June 2015, I applied and received permission from IRB (Appendix J) to conduct the research. Below are the procedures conducted in this research.

Tier 1 – Original professional development.

The researcher or the principal investigator (PI) of this research participated in the Facilitation Academies of the professional development program. Through participation in the facilitators' course, the PI aimed to gain an in-depth understanding of the original philosophy, intentions, and objectives of the professional development program. In addition, it helps the PI to explore how the original professional developers deliver the curriculum approach consists of process and content that incorporate with critical features or core components of intervention that were originally designed. It allows the PI to explore whether fidelity drift occurs during the teacher professional development program when the facilitator is training the teachers.

Most importantly, during the Facilitation Academy, the PI collaborated with the original professional developers to identify and interpret the critical features or the core intervention components of the program. By cooperating and collaborating with the original professional developer from MSS, the PI of this research was able to identify the observable critical features for four core intervention components for both teacher professional development and classroom implementation (Appendix E and G). This process enabled the PI to develop the teacher professional development observation guide, classroom observation guide, teacher interview guide, and teacher self-report guide. It also helped the PI to develop the observation rating scale and rubrics. Third, and most critically, it ensures the validity of instruments.

Tier 2 – Teacher professional development.

After the facilitators were trained in the original professional development program, the next tier is for facilitators to train the teachers from their district. Thus, the

researcher studied the turn-around of the program by participating and observing the teachers' professional development organized by the facilitator. My aim was to find out whether the program's philosophy, intention, objectives, and curriculum approach together with its core intervention components are translated from the original program through facilitators and then to teachers' professional development.

Using the teacher professional development observation guide (Appendix C) developed with the collaboration from the original professional developers, the PI reported and took field notes of what was observed. Mainly, the teacher professional development observation is to see whether the core intervention components of the original program are reflected in the training.

Tier 3 – Teacher implementation.

After attending the professional development program, the teachers are to implement what he/she learned in their classroom. The classroom observation guide (Appendix E) as well as its rating scale and rubrics (Appendix F) were developed with the original professional developers and used to determine how closely teacher classroom practices and behaviors reflect the original program's philosophy, intention, and objectives and, most importantly, the core intervention components. The classroom observation (at least 45 minutes) is conducted by checking whether the critical features of each core intervention components are implemented, and, if so, to what extent they are implemented.

As noted in Chapter 2, this research aims to find an in-depth understanding of how teachers make sense of the reform-oriented curriculum approach; that is, how teachers make sense of the four core intervention components of the teacher professional development program. Thus, the rating scales and rubric for implementation fidelity focus

on the curriculum approach and instructional practices that are originally intended from the professional development program.

The rating scale that complements the observation guide was scored on a scale of 1 to 4, with the total adherence scored at 4. If a teacher modified the prescribed lesson of the Planet Earth course but still adhered to the core intervention component, the implementation is scored as 4. This is also a sign of teacher transformation because he/she is able to adapt and transform the prescribed lesson (content) without deviation from the intended curriculum approach and its core intervention components.

Teacher interviews (45–60 minutes) are carried out right after the classroom observation. Teacher interviews are voice recorded and transcribed for analysis purposes. The interview is semi-structured with the intent to explore the sense the teachers made about the professional development experiences. The interviews focuses on the teachers' experiences and sensemaking with the professional development program. It also asks for teachers' descriptions of their implementation in the observed classroom. The semi-structured interview allowed teachers the freedom to share their views, descriptions, concerns, hesitations, or perceptions of the effectiveness of their professional development program.

The guiding framework and protocol of the interview was based on the conceptual framework of teacher sensemaking (Figure 2) and contained guiding prompts to elicit teacher sense-making processes in relation to the design of the program's core intervention components, teachers' affect (beliefs, values, and emotion), teachers' cognition (world view, schemas, and knowledge), teachers' contextual factors (based on situative learning perspective), organizational factors (sense giving), and policy in place.

Pilot Study.

In June 2015, the pilot study was carried out for several reasons. First, it aimed to develop and test the adequacy and practicality of research instruments and thus increase the internal validity of the research. The research instruments include teacher surveys, the classroom observation guide as well as its rating scale and rubrics, and teacher interviews. Second, it was carried out to assess the feasibility of the research. It informed the researcher whether the research is realistic and the scope of the research is workable. Teachers' self-report is one of the most important implications gained from the pilot study. After analyzing the pilot data, the researcher determined that teacher self-reports could provide the case study with more in-depth and personal insight from the teacher.

In addition, the researcher has coded and identified 13 sense-making themes from the pilot study. These 13 coded themes, although un-generalizable, allow me to understand the background of teachers' sense-making constructs and thus refine my instruments. For example, teachers' beliefs or perceptions can be classified into so many categories (education, science education, effective instructions, and more). These 13 themes are:

- Teacher's self-efficacy in science.
- Teacher's beliefs about education.
- Teacher's beliefs about science education.
- Teacher's beliefs and values about good science instruction resonate with the core intervention components.
- Teacher's beliefs about what makes an effective science teacher.
- Teacher's self-efficacy in implementation.
- The form of teacher implementation (student-teacher relationships, students' tasks and assessments, the role of questioning).
- Expectations of outcomes of the teacher professional development program.

- How the teacher interacts with experts.
- How the teacher interacts with coworkers.
- How the teacher interacts with the administration.
- The form of commitment to policy/standard.
- Terms of implementation (voluntary or mandatory).

In addition, the pilot study has identified several components that affect teachers' sensemaking of professional development. These components may cause teachers to assimilate, reject, or accommodate the professional development. The first component that affects teachers' sensemaking process is the inconsistencies between teachers' beliefs and the program's approach. When a teacher's belief is inconsistent with the reform-oriented approach, she is less reluctant to implement it. She needs to know that the reform-oriented approach is achievable in his/her classroom.

The second component that affects teachers' sense-making process is the differences of interpretation regarding the program's core intervention components. In terms of overall implementation, the teacher has different interpretations of a core intervention component as compared to the original professional development. The pilot study showed that such differences could be caused by the teacher's assimilation process. Teachers tend to miss the unfamiliar and more fundamental transformations that are required (Spillane et al., 2002) when they make sense of the core intervention components in terms of their own familiarity and what is comfortable for them (Schmidt & Datnow, 2005).

Third, the learning environments or the classroom can influence teachers' sensemaking of professional development, especially when a teacher is trying to incorporate the reform-oriented core intervention components in the classroom. As a

teacher makes sense of the core intervention component and ponders how to implement it, the classroom and school environment is one factor that influences her interpretation and how she visualizes the effectiveness of the intervention. Classroom environment can be supportive to the implementation, or not.

Fourth, while a teacher makes sense of their professional development and makes decisions about how to implement its core intervention components, the student population in their classroom plays a major part throughout the process. Students' backgrounds, learning motivations, and needs impact on teachers' sensemaking of the core intervention components. In order to meet students where they are, a teacher sometimes has to modify the questions asked, lessons, and activities. Such modifications may cause fidelity drift during implementation.

Next, teachers' sensemaking process can be influenced by their coworkers. Inconsistencies of belief, work attitudes, and values of education among teachers can either encourage effective sensemaking (thus leads to accommodation) or discourage effective sensemaking (thus cause assimilation or rejection). Moreover, it can also affect teachers' implementation practices.

Last but not least, how teachers value the core intervention components affect how the teacher makes sense of the professional development. If a teacher thinks the program's core intervention components are worth trying in the classroom, it is more likely that she/he is willing to invest the time and effort to understand and integrate them into their instructional practices during the implementation process.

While scholars such as Spillane (2002) and Coburn (2001, 2005) have used the sensemaking literatures to frame the studies of implementation, they did not bridge the sense teachers make to their implementation. Not only does the researcher intend to connect them, the researcher also anticipates exploring and identifying the orientation of

sense teachers make as regards their implementation fidelity. The pilot study helped the researcher to develop a framework to capture both sensemaking and implementation (Figure 4), and consequently connects sensemaking and implementation empirically.

Figure 6 was hypothesized from the pilot data. It categorizes teachers into four different types of implementer (rejection, emergent, adherence, and transform) as regards their effectiveness in the sense-making process and fidelity of implementation. By answering the research questions, the researcher explored how teachers' sensemaking of their professional development (how teachers assimilate, accommodate, or reject) affected their implementation fidelity. In addition, the case studies also aim to explore the orientation of sense four teachers make. For example, what patterns of sense does the transformed teacher make? Or what patterns of sense does the emergent teacher make? What patterns of sense do teachers who reject the implementation make? Last, what patterns of sense do teachers with total adherence make?

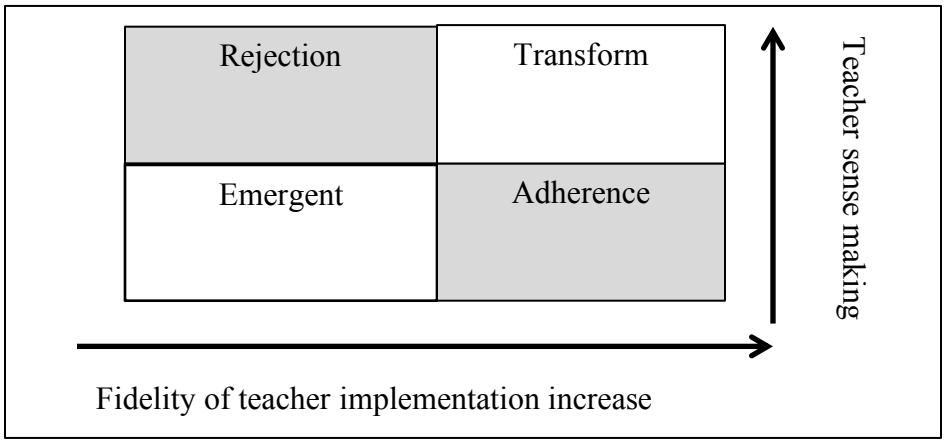


Figure 6. The four quadrants of both teacher sensemaking and implementation.

INTERNAL AND EXTERNAL VALIDITY

All the qualitative instruments were developed solely for this research. In the following sections, the threats of validity are further described and attempts to limit their impacts are identified.

Internal validity of this research is strengthened by the triangulation of data (Cresswell & Miller, 2000). Multiple data sources and collection were used in the research, such as teacher interviews, surveys, observations, and teacher self-reports. Also, the researcher shared the interview transcripts with participants to clarify any uncertainties and filling in any missing data. In addition, a pilot test was carried out to test and refine the instruments used in this research. The PI corrected mistakes, clarified interview questions or refine the items in the instruments, added more questions, and modified questions to elicit misunderstanding. Last but not least, The PI involved the original professional developers from the very beginning of the research. This ensures that the backbone of the development of research's instruments is based on the original sources and thus minimizes fidelity drift.

External validity in this research is strengthened by (i) completely describing the characteristics of the sample, setting, and processes to allow adequate comparisons with other samples, (ii) descriptions of findings to allow potential transferability, (iii) explicitly connect findings to prior theory (Miles & Huberman, 1994). The researcher clearly described the sampling procedure and participants' characteristics. The researcher also described the data collection methods and data analysis in detail. Last but not least, the framework in this research was developed based on theoretical findings of related topics.

A substantial amount of data derived from the interviews with teachers need to be interpreted for analysis. The strategy of member checking was used in an attempt to prevent misinterpretation of teachers' statements. Using member checking allows teacher

participants to comment and clarify not only their statements but also the interpretations that have developed (Maxwell, 2013). Transcripts and interview summaries of each interview were shared with teachers. Teachers were asked to clarify and comment on the interpretation. Maxwell (2013) considers member checking to be the most important method for eliminating misconceptions and uncovering bias in the qualitative analysis.

The research design, instruments, data collection methods, and procedures described above were designed to investigate the research questions presented in this research. The results of the research are presented in Chapter 4.

Chapter Four: Findings and Results

To address the research question, Chapter 4 is mainly organized by both case analysis and cross-case analysis. Prior to the case and cross-case analysis, the chapter also discusses the data collected from teacher survey that consists of the information of participants' demographic data, teachers' perspectives of the program, and their readiness to implement. The chapter will then address the research question using the four research sub-questions.

Combining the case analysis with cross-case analysis, the research found out,

(i) Six common triggers of teacher sensemaking instances which associate with all teacher participants. They are: (a) the value of professional development, (b) emotions, (c) students' needs, (d) state standards, (e) teacher's implementation network, (f) time constraints.

(ii) Four triggers of teacher sensemaking instances that relate to high fidelity implementers' sensemaking instances. They are: (a) accessibility to instructional resources, (b) accessibility to experts, (c) availability of planning time during professional development, and (d) current progression to establish student-centered classroom.

(iii) Four triggers of teacher sensemaking instances that relate to low fidelity implementers' sensemaking instances. They are: (a) abundances of information, (ii) unclear of roles and responsibilities to implement, (iii) setting and environment of implementation, and (d) success measures of implementation.

(iv) Four types of teachers' sensemaking orientation as they implement the PD program. They are: "passive distributive" and "critical evaluative" orientation,

which showed rejection and low implementation fidelity; "creative emergent" and "transformative" orientation showed higher implementation fidelity.

THE CASES

Julia.

Julia is an 8th grade science teacher who is teaching the content of the program – Planet Earth. Julia has seven years' experience teaching middle school science and two years teaching college Biology while she is completing her Master's in Education degree. Julia was the Teacher of the Year in 2014–2015 and she is the department chair as well as the 8th grade horizontal team leader. Middle school teaching is Julia's second career and she shared that it has been really rewarding. Julia is a very kind, loving, cheerful and friendly teacher. Little do the students know, she is actually an introvert and is a very quiet person. However, she has a different personality in front of her students. She admitted that the reason why she loves teaching was that it forces her out of her shell.

Coming from a strong science background, Julia admitted that although her expertise in biology helps her supporting students' science learning process, teaching Earth Science was quite a challenging learning process. Nevertheless, Julia has a positive perception of the reform-based curriculum approach. Julia's teaching philosophy also resonates with the four core intervention components of the approach. She called herself a "firm believer" in it.

Julia admitted that she shifted her teaching practices and started to enact a reform-oriented instructional approach and established student-centered classroom about three years ago. She saw the positive effects on students and she was glad that she made that

"move." Julia thinks that shifting toward student-centered practices is a process that she is progressing and getting better at.

Julia's conversations and interactions with students show that she takes her students' learning, conversation, and experiences in the classroom very seriously. The teacher-student conversations in Julia's classroom are respectful, productive, and center on their shared experiences in classroom activities. Julia describes herself as a good observer. She tends to read students better and quickly and is more sensitive to their needs and interests. Julia is a very innovative teacher, she always looks to better herself as an educator. She also creatively incorporates several of the PD's strategies and reform-based instructional approach in her classroom practices.

Julia believes the purpose of education is to prepare the young generation with skills and knowledge that will help them succeed in the world that they will grow up into and contribute to society. In addition, Julia believes that the critical role of science education is to prepare students with the knowledge of integration of all branches of science, technology, and engineering. Science education should focus on the process of science and engineering design process.

Alan.

Also an 8th grade teacher, Alan is teaching the content of the program – the Planet Earth course. In his survey, Alan indicated that he really likes the program's reform-oriented curriculum approach and planned to implement it in his classroom. Alan received his bachelor's degree in business, but found his passion working with teenagers while doing some social work with a nonprofit organization after graduation. Eventually, he

joined an alternative certification program and is now certified as a highly qualified science teacher. Alan shared that he is passionate in science and science literacy. He said,

> I think I have a good logical apparatus in my head, but I also recognize the limitations of that. I can look at an idea or process of something and understand it at a fairly deep level because I am able to conceptually wrap my head around what the thing might be. What I really enjoy is finding something that does not really make any sense to me and then hearing a description about why this is the way it is, whether it is biology, genetic, earth science, or something.

During the five-day workshop, Alan participated productively in discussion and his reasoning of phenomena showed that he paid attention to detail and was able to gather all the necessary data or evidence to build his understanding of the topics. His critical analysis of data helped all the teachers gain a deeper and more robust understanding of earth science concepts.

Alan thinks education is to better a person and to improve what they do. Thus, education itself is a learning process of an individual discovering their goals, and how they can solve the problems that arise in pursuit of those goals. Alan believes that the purpose of science education is to "create students that are not science illiterate." He thinks scientific literacy is an important key to science education and students should be prepared with the skills of scientists, such as questioning and be thoughtful of the question and solution. Alan believes that observation skills are the most important skills students should develop in order to become scientifically literate citizens.

Alan is a calm, patient, and determined teacher. He admitted that he positions his persistency and determination toward his students' learning as well. Alan feels that he needs to constantly motivate his students. He stated that, "I think that I am the guy that is pushing them to do the stuff that they don't really want to do so I get push back." Alan confessed that he sometimes feels very frustrated and disappointed when students fail to see the importance of education in general, and science learning in his classroom in

specific. According to Alan, students' motivation in his classroom is low and students seem to show little interest in science and science activities. Alan feels like he needs to constantly make things interesting and engaging for students. Even so, Alan holds high expectations for all his students. He is always very supportive of his students' learning and willing to help students in any "reasonable" way he can. Alan shared that he is shifting from "helping students" toward facilitating his instruction to allow the students to help each other. He is empowering students to think critically, independently, and take ownership of their own learning. These efforts indicated that Alan is trying to shift from a teacher-centered to a student-centered classroom.

Kelly.

Kelly is a 5th grade science and social studies teacher. She has 14 years of teaching experience. Kelly majored in American history. However, Kelly has been interested in science since she was young. Her passion and interest to teach science came from her student-teaching experiences. Kelly's educational philosophy and teaching style resonated a lot with her mentor teacher and they have the same common goal to open as many doors as possible for students to learn and be successful.

Kelly is a friendly, fun, passionate, and curious teacher. Kelly was perhaps the most humorous teacher in the workshop. Whenever she talked or presented her learning, the energy in the room shifted and she tended to catch everyone's attention. She is very charismatic and her passion for science really influences the people around her. Kelly admitted that she likes to interact with and learn from others.

Kelly is also a lifelong learner. She is very passionate about teaching because she realizes the legacy of teaching. She shared that, "I love that I could make one life turn to

many lasting legacies." She hopes that students will appreciate such experiences and feelings and share them with peers and pass it on. Kelly always encourages students to be curious and instill self-confidence in students. Like Julia, Kelly has a futuristic view of education and science education. Kelly believes the purpose of education is to make our lives better and easier. She believes that as a human being living in society, we all need to do our share to contribute to society and help each other to live better and easier lives.

In the same way, Kelly believes the purpose of science education is to help guide students, whom she described as the "next generation of learners," into discovering the world around them. She stressed the vitality of science education to prepare students to live in the future of "unknowns." New advances in science are made each day and it is our opportunity to foster the curious minds of this world to see the potential in the unknown. When Kelly was asked how she felt about the reform-oriented curriculum approach introduced by the program, she responded, "I think that they are very beneficial to the 5th graders." She also shared that her beliefs of science education are parallel with the program's objectives and mission.

Lily.

Lily is a 7th grade science teacher in a high performing middle school. She won Teacher of the Year in the 2016–2017 school year. She has nine years of teaching experience. Lily majored in Psychology and wanted to be a counselor. Although she did not complete her master's degree in psychology, she was introduced to something she fell in love with — teaching. She treasured the time and experience she spent teaching teenagers. Lily has always been interested in science, especially biology, since elementary school. However, being a student who received special education services in public school,

she found science dull because her science teachers were not able to break it down to her level of understanding. Her passion and interest to teach science came from her student-teaching experience. Lily believes that the purpose of teaching science is to force kids to think outside the box. She feels that science, unlike other subjects, is more than yes/no. Science is more about reasoning: why is it a yes or no? It causes students think a little bit more than just black and white.

Lily is a happy, positive, honest, and passionate teacher. It is hard to spend time with Lily without laughing along with her. Her experiences in the public school special education system helped her tremendously in understanding students' needs, struggles, disabilities, and capability. She feels that she is able to break things down easily to help students, especially those with special needs and require different support.

Lily believes that the purpose of education is so that individuals can build knowledge for life. She emphasizes that education is not just for graduating from high school or college, or being an expert in a certain subject. But it is beyond that; education is a process that lasts for as long as someone is alive. It is a foundation where an individual finds out what they want in their life and works to achieve their goals and better themselves. Lily describes education as a "growing tool" where people should improve themselves as time progresses. Lily explained that the purpose of science education is to instill in students the value of exploration and problem-solving. Problem-solving is part of the process of science.

THE CODING PROCESS

The coding process focused on data condensation to enable the researcher to retrieve the most meaningful materials, assemble chunks of data that go together, detect

recurring patterns, and condense them into readily analyzable units (Mertens, 2010). Guided by the conceptual framework of teacher sensemaking, the literature review of teacher implementation fidelity, and research questions, the coding process happened in several stages using NVivo.

Initially, the interview transcripts were deductively coded (Mertens, 2010) using the seven properties of sensemaking by Weick (1995). While guided by the research questions, the list of seven codes is derived from Weick's (1995) seven properties of sensemaking. This is done for two purposes, (i) to promote consistency of data to the line of sensemaking literature, and (ii) to promote the research validity by ensuring that teachers in fact make sense of the reform-oriented program. These codes are teacher identity, social context, retrospective, salient cues for sensemaking, sensemaking as an ongoing event, plausibility over accuracy, and teacher's enactment. From the preliminary analysis of the first round of coding, several interesting notions arose and some codes emerged progressively.

For one, sensemaking is both retrospective and prospective. Weick's (1995) works have contributed greatly and have provided vast and meaningful understanding, expertise, knowledge, and acquaintance with human sensemaking process to this research. His writing casts sensemaking as retrospective. According to Weick (1995), when people encounter moments of ambiguity or uncertainty, they seek to clarify what is going on by extracting and interpreting cues from their environment, using these as the basis for a plausible account that provides order and "makes sense" of what has occurred, and through which they continue to enact the environment. His later works with Sutcliffe and Obstfeld (2005) jointly restated sensemaking in ways that make it more future-oriented, more action-oriented, less sedentary and backward-looking, more macro, more closely tied to organizing, meshed more boldly with identity, more visible, more behaviorally defined,

more infused with emotion, and with issues of sense giving and persuasion. In recent years, there has been increasing interest in the possibility of "prospective" or "future-oriented" sensemaking. Gephart, Topal, and Zhang (2010), in their writing on "future-oriented sensemaking," believe it can also be a prospective process. They define sensemaking as "an ongoing process that creates an intersubjective sense of shared meaning through conversation and non-verbal behavior in face to face settings where people seek to produce, negotiate, and sustain a shared sense of meaning" (pp. 284–285).

Later, Stigliani and Ravasi (2012) theorize that prospective sensemaking is based on interrelated cycles of retrospection. During the coding process, all of the teacher participants discussed their future plan during the interviews and/or self-reports after their observed lesson. They reflect retrospectively on their current implementation and practices, but were also aware of and think about their next steps.

Then, the critical roles of teacher's "frames" play as they make sense of the program approach and put it into action or implementation. Sensemaking is about the enlargement of small cues and signals. Spillane and Anderson (2014) added that a teacher's "frames" are critical in the sensemaking process. Much like a picture frame, a teacher's frames demarcate for the viewer what is inside and outside, thus signaling what is and is not worthy of their attention (Spillane & Anderson, 2014; Goffman, 1974). Frames can be conceptually understood as the process by which teachers generate, apply, and/or work to advance particular frames (Spillane & Anderson, 2014). The framing process is vital in helping people decide which phenomena, events, people, and instances to emphasize, and which to neglect as we interpret the situation and attempt to take action or influence others (Spillane & Anderson, 2014; Goffman, 1974).

From the codes and notions arising from the first round of coding, several rounds of coding were conducted. Finally, the researcher re-coded the data in the following frames

of sensemaking: teacher identity, diagnosis, prognosis, classroom, school, teacher's accountability, PD program, and teaching practice. Table 2 shows the frames and the codes used for data analysis in this research.

Frame	Codes
Classroom	Classroom environment; Classroom norms; Students (background, needs, interests, motivation, misconceptions, and struggles)
School	Implementation network; Parents and community; School leadership and administration; Norms and culture
Teaching practices	Assessment practices; Instruction practices; Instructional differentiation; Relationship with students
Teacher Identity	Background/experience; Beliefs; Values; Emotion; Personal meaning of purpose of education; Personal meaning of purpose of science education; "I am" statement; Readiness of implementation; Strength/expertise; Weakness; Roles and commitment
Diagnostic framing	Diagnosis of opportunities; Diagnosis of challenge
Prognostic framing	Teacher vision of growth/growth plan; Motivation/motivated reasoning; Teacher outreach/sense-giving; Teacher articulation of the proposed solution
PD program framing	Content of MSS; Curriculum approach of MSS/Core components of MSS; Effectiveness of MSS; Resources provided by MSS; Limitation of MSS
Teacher accountability	District policy; State standards; High-stakes testing

Table 2. The frames and codes of this research.

Teacher identity. The researcher focused on the teacher's background, attributes, beliefs, values, emotions, and readiness to implement the PD program. It can be a statement that implicitly/explicitly connects between teacher background, teacher beliefs, values concerning, and motivation for being an educator. The researcher also coded all the "I am" statements in which the teacher describes themselves and/or expresses beliefs about their essential qualities, particularly as an educator. Also, any statements about personal

meaning will also be coded as teacher identity. For example, what does the teacher think of the purpose of education and science education? It also captures the teacher's strengths, weaknesses, and their interests or hobbies. Last but not least, this frame captures the roles and responsibilities that they undertake now and has in the past.

Diagnosis/diagnostic framing. The researcher captured what draws/demands a teacher's attention, what they identify as needing attention or change, what they view as opportunities or challenges, and what puzzles them. Diagnostic framing indicates the retrospective properties of sensemaking.

Prognosis / prognostic framing. The notion of prospective sensemaking concerns the role of temporality and sensemaking. Gephart, Topal, and Zhang (2010) proposed that future-oriented sensemaking is embedded in past and present temporal states and uses past and present temporal orientations to provide contexts for proposed future entities. Future-oriented sensemaking or prospective sensemaking is based on interrelated cycles of retrospection, during which "people envision a desired or expected future event and then act as if that event has already transpired, thus enabling a retrospective interpretation of the imagined event" (Gioia, Corley & Fabbri, 2002, p. 623). The codes in this frame include the teacher's articulation of proposed solutions, growth plan, the teacher's sense giving or outreach, and motivation or motivated reasoning. It also captures any explicit rationalizations for the courses of action they do or do not select.

Professional Development (PD) program framing. This frame captures any thinking or effort made by the teacher aimed at implementation fidelity of the PD program in their classroom. The codes include the teacher's comprehension of PD program, including the content of the program, the program's curriculum approach, the effectiveness of PD, the limitation of the PD program, and the PD's resources.

Classroom framing. This is a contextual frame meant to capture the teacher's classroom environment, classroom norms, and students (including students' needs, background, interest, motivation level, their misconceptions and struggle).

School framing. This is also a contextual frame that captures the school and its subgroups. The codes in this frame include the teacher's implementation network (departmental and grade level), each school's community and parents, each school's leadership and administration, and school norms and culture.

Teacher's practices framing. This frame captures teachers' current practice and how it changes as they implement the reform-oriented program in their classroom. The codes include teacher's assessment practices, instructional practice, relationship with students, and differentiation of instruction.

Teacher accountability framing. Teacher sensemaking is influenced by district policy, state standards, and high-stakes testing. This frame intends to capture how state and district policy influence how teachers make sense and implement the PD program.

Using these frames as well as Weick's seven properties of sensemaking, the research managed to find out the key sources of cues for teacher sensemaking instances of the reform-oriented program's approach. Going deeper, the research used cross-case analysis to further explore these sensemaking instances. The research then found that some of the instances of teacher sensemaking are distinctively related to teachers' implementation fidelity.

CASE ANALYSIS

Teacher survey.

The teacher survey was conducted to explore teachers' perspectives of the curriculum approach and their readiness to implement the reform-oriented approach that was introduced by the professional development program. Along with teacher demographic information, the survey also consisted of Likert scale items. Each Likert scale item presented a self-evaluative statement about the program. These include, "I agree with the philosophy of MSS," "MSS matches my belief about how students learn," and many more (see Appendix B). Teachers were asked to rate their agreement or disagreement with each statement. Likert scale items were analyzed quantitatively using Microsoft Excel. For each teacher, their perspective toward the program, or their self-evaluation of how they view the program was calculated based on how much the individual agreed or disagreed with the statements from the survey. Responses to the individual statements were combined to create a composite affinity score for the program (Marshall, Petrosino, & Martin, 2010), from 0, indicating a complete lack of belief of the curriculum approach, to 5, indicating the highest confidence and acceptance of the curriculum approach.

Teacher affinity and implementation fidelity.

Overall, all teacher participants have a highly positive view or affinity of the curriculum approach. Julia has the highest (scored at 4.9/5.0) and most positive affinity, closely followed by Alan (scored at 4.8/5.0) and Kelly (scored at 4.5/5.0). Although she believes in the efficacy of the program, Lily scored the lowest among all participants (scored at 3.9/5.0).

How did teachers' perspective of the curriculum approach relate to how they implement the MSS approach in their classroom? Figure 7 is a graph plot of teacher average implementation fidelity score versus the affinity score. There was no apparent relationship between teacher affinity scores of the PD program and their implementation fidelity score. Plus, due to the small sample size of only four teacher participants, the research was unable to generalize that a positive view of the approach did not translate into the high implementation fidelity in the classroom, or vice versa. However, a gap did emerge.

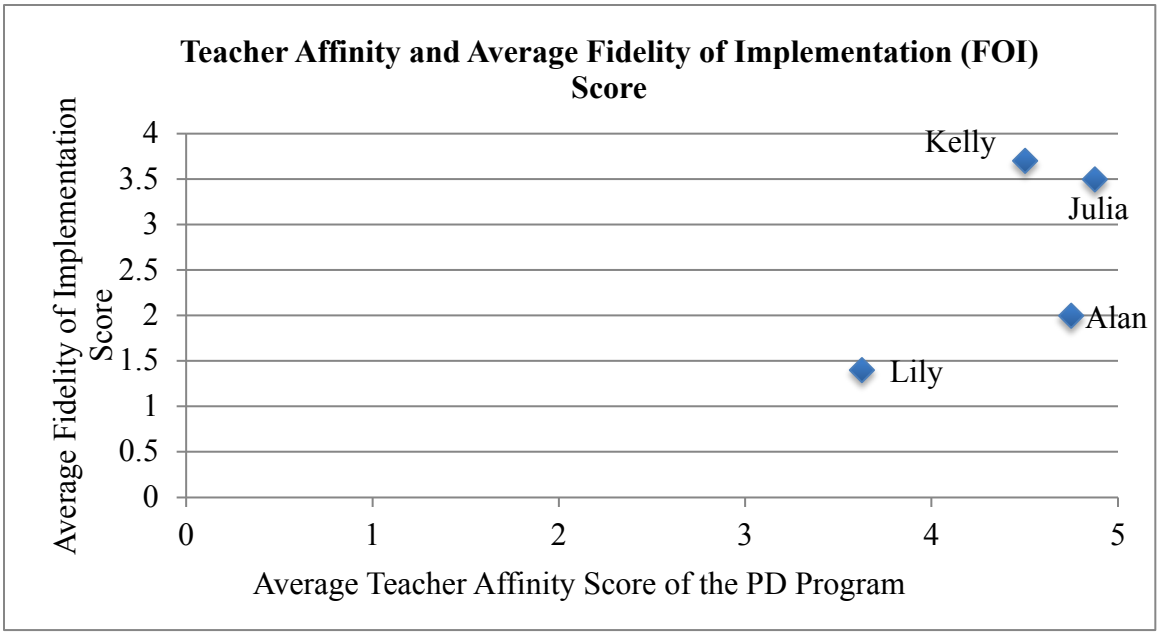


Figure 7. The plot of teacher implementation fidelity score versus the affinity score.

All teacher participants in this have moderate-high to high affinity toward the program's reform-oriented approach. However, a horizontal gap exists between Lily's affinity score and the rest of the teacher participants' affinity score in this research. Similarly, there were two different groups of implementation fidelity scores. Note that there exists a vertical gap. Julia and Kelly were positioned in the far-right corner, indicating

that they have a high affinity for a reform-oriented curriculum approach and were able to implement it with higher fidelity. However, Lily and Alan were positioned in the lower right of the figure, indicating that they have low implementation fidelity. Although they have differences of affinity toward the PD program, from moderate affinity (Lily) to high affinity (Alan) for the approach, both of their implementation fidelity appeared to be fairly low.

Teacher readiness and implementation fidelity.

Along with the survey, teacher participants were also asked about their readiness for implementation. Each Likert scale item presented a self-evaluative statement about the teacher's readiness to implement the four core intervention components of the reform-oriented curriculum approach in their classroom. These core intervention components are, (i) focus on conceptual learning, (ii) collaborative inquiry and sensemaking, (iii) focus on students' thinking, and (iv) reflection on teaching and learning. As noted in Chapter 3, the original professional developers had identified the critical features for each of the core intervention components in the classroom (see Appendix G) that were intended for teachers to translate or implement into the classroom.

Thus, with each core intervention component, the survey asked teachers to rate their readiness to implement the critical intervention features of these four core components of the PD program. Teachers were asked to rate their readiness with each critical feature statement. Likert scale items were analyzed quantitatively using Microsoft Excel. Responses to the individual critical features were combined to create a composite readiness score of each program's core intervention component, from 0, indicating a complete lack of understanding and readiness to implement the program's ambitious curriculum

approach, to 5, indicating the highest readiness to implement the ambitious curriculum approach.

Overall, all teacher participants have moderate readiness to high readiness for implementation, ranging from 3.0 to 4.8. Kelly indicated high readiness in all the core intervention components except core intervention component D. Alan rated himself as most ready to implement core intervention component D. Lily indicated that she has low readiness on all core intervention components and in fact, she is consistently lowest compared to all teacher participants. How did teachers' readiness to implement relate to how they actually implemented the MSS approach in their classroom?

Figure 8 is a plot of teacher implementation fidelity scores versus the teacher readiness score of the four core intervention components of the program. Note that, for core intervention components A and B, the linear relationship between teacher readiness and implementation fidelity score is seen. The more ready the teachers rate themselves in core intervention components A and B, they higher implementation fidelity is evident in classroom practices. However, there was no apparent relationship between teachers' affinity score of the PD program and his/her implementation fidelity score for core interventions C and D. Due to the small sample size of only four teacher participants, this research was unable to generalize that higher teacher's readiness to implement the program's approach did not translate into high implementation fidelity in classroom, or vice versa. However, Lily's readiness and implementation fidelity was consistently low compared to all other teacher participants.

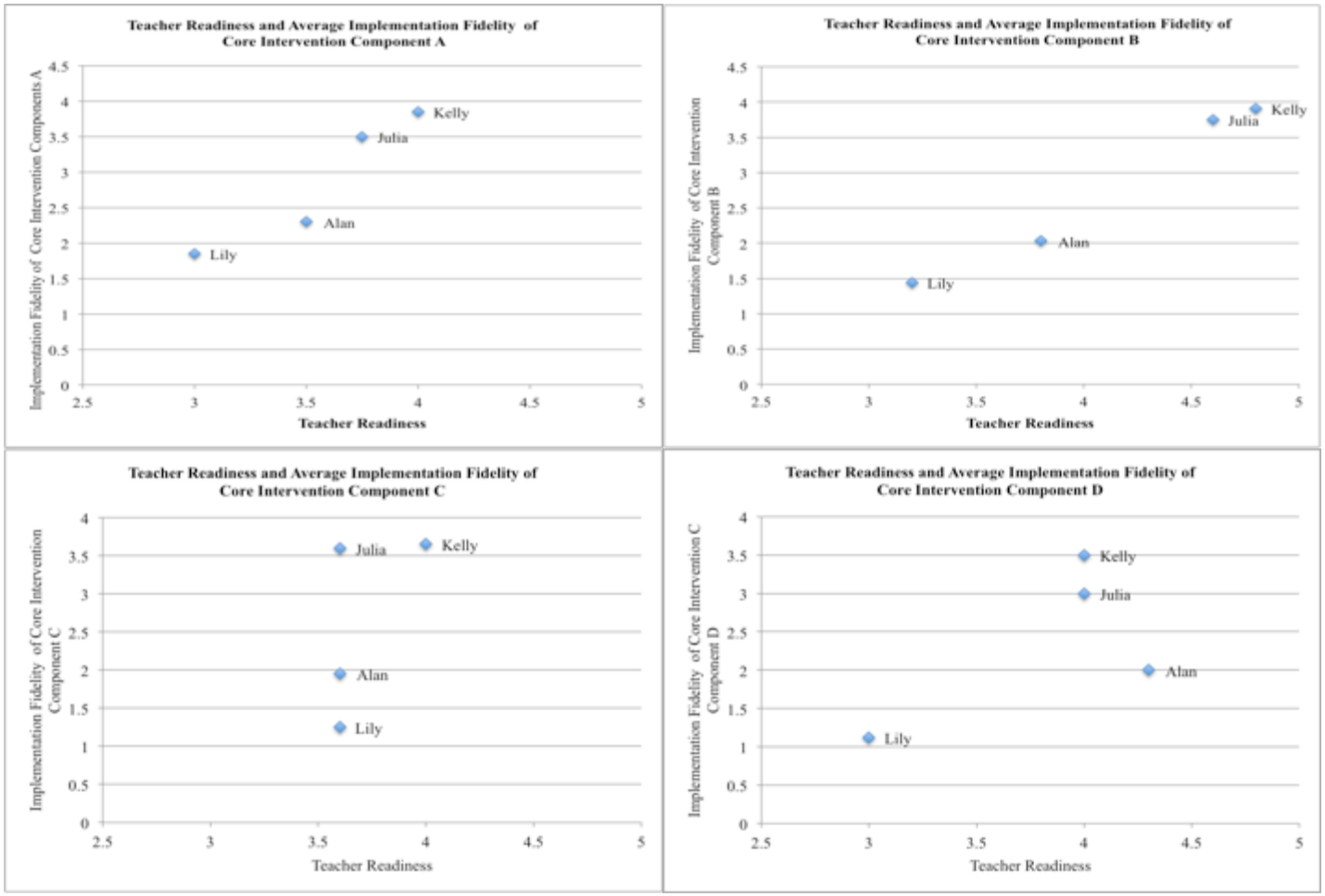


Figure 8. The graph of teacher implementation fidelity versus teacher readiness of four core intervention components.

Teacher progression analysis.

In the following, the research will present the analysis of teacher progression data from the first classroom observation to the last classroom observation for each case (Alan, Julia, Kelly, and Lily). The case analysis of teacher progression data can be summarized in Table 3, which shows the teacher progression data from all classroom visits, including teacher fidelity of implementation (FOI) score of each classroom visit, average FOI score, and teachers' sensemaking orientation as regard to their implementation fidelity.

	Anticipates teaching the subject matter of Planet Earth		Did not anticipate teaching the subject matter of Planet Earth	
Progression data	**Alan (8th grade)**	**Julia (8th grade)**	**Kelly (5th grade)**	**Lily (7th grade)**
Classroom visit 1	Marginally prepared	Glass half full	Challenge accepted	Overwhelmed and drifted
	FOI score: 1.6/4.0	FOI score: 3.2/4.0	FOI score: 3.4/4.0	FOI score: 1.3/4.0
Classroom visit 2	Hopeful	Getting creative	On board	Limited interpretation
	FOI score: 1.7/4.0	FOI score: 3.4/4.0	FOI score: 3.7/4.0	FOI score: 1.3/4.0
Classroom visit 3	Initiation	Innovatively fun	Reflective practitioner	Misinterpretat-ion
	FOI score: 2.4/4.0	FOI score: 3.6/4.0	FOI score: 3.8/4.0	FOI score: 1.4/4.0
Classroom visit 4	On board	Blended and fused	Transforming	Distribution
	FOI score: 2.3/4.0	FOI score: 3.7/4.0	FOI score: 3.97/4.0	FOI score: 1.6/4.0
Average FOI Score	2.1/4.0	3.5/4.0	3.7/4.0	1.4/4.0
Case analysis	Critical evaluative	Creative emergent	Transforming	Passive distributive

Table 3. Summary of teacher progression data of case analysis.

Alan's progression data 1: Marginally prepared.

Summer 2016 is Alan's first experience with the program's reform-oriented curriculum approach. Alan's first observation was scheduled in September 2016. During the first classroom visit, he admitted that he is still trying to understand how he can implement the program's approach in his classroom.

On the first observation in Alan's classroom, his class was learning about how the global weather patterns determine the local weather patterns. However, Alan's observed lesson did not incorporate or implement any of the prescribed science activities from the MSS course. Alan's teaching approaches and instructional practices during the observed lesson drifted from the reform-oriented curriculum approach. Alan's average classroom observation rating for his first lesson was scored at 2.2, with 1.4, 1.8, and 1.0 respectively on the core components A, B, C, and D. The full fidelity of implementation of each core component is 4.0. This means that Alan's average fidelity of implementation (FOI) score for the first classroom observation was only 1.6/4.0. Appendix K shows the scores of classroom observation ratings in each of the critical features of the core intervention components A, B, C, and D for all teacher participants.

Drifting away from the core intervention components of the approach, Alan's lesson was teacher centered. The classroom dynamics centered on Alan. Triangulating with Alan's first interview, Alan stressed that the teacher is responsible for controlling the learning environment because he is responsible for managing the classroom in a way that enables students to focus on the learning objectives. Alan drove the discussion and asked all of the questions during the discussion. Only two students responded to his questions. Students' responses were simple and straightforward and did not build upon one another. When the students made mistakes or gave the wrong response, Alan provided the correct answer and gave an explanation.

During the first interview, Alan shared how he felt during the initiation of the implementation, Alan explained, "I do feel marginally prepared and … I am still creating that process in myself." In addition, Alan reflected in his self-report that the observed lesson was not student-centered and pointed out that his effectiveness as a teacher is depending on "how willing the students are to be engaged with the lesson." He was disappointed by how the class went and wished students were more engaged and actively involved in his instruction.

Alan's progression data 2: Hopeful.

The second observation of Alan's classroom was scheduled at the beginning of November. During the second classroom observation, Alan was not teaching the Earth science content; instead, the lesson was about chemical formulas. Despite the fact that Alan would not be implementing any of the prescribed activities and lessons from the program, the researcher still scheduled an observation and interview with him. The intention was to study Alan's instructional approach and to find out if it parallels with the program's reform-oriented approach.

During the lesson, Alan dominated the classroom discussion and did most of the explanation. Although he asked guiding questions to explore and expose students' current understanding of the topic, the responses gathered from students were very little and passive. Many students struggled. When Alan invited students to discuss their struggles and errors, the students' participation was low and so Alan continued the lesson by offering students his explanation. Alan was patient and motivated to help students.

The researcher conducted another follow-up classroom observation with similar science content. During the follow-up observation, Alan facilitated a whole group

discussion before a stations activity. It was a teacher-led discussion. Then, students spent the majority of the time participating in a small group activity. Students used their journals to take notes as they transitioned from one activity station to another to determine the numbers of atoms and elements and then apply the rules they have been given to decide if the equation is balanced. These stations were set up to allow students to illustrate, read, count, write, assess, analyze, and make predictions regarding balanced chemical equations and chemical reactions. Although the station activities provided some anomalies and patterns toward students' understanding of the concept, they did not involve any manipulation of tools and data. After the station activity, another teacher-dominated whole group discussion was done to discuss the findings of the station activities.

Alan's average classroom observation rating for the second classroom observation was scored at 1.7/4.0. After the classroom observation, an interview was conducted. In the interview as well as self-report, Alan admitted that he kept defaulting himself to a more didactic approach, despite his awareness and intention to shift to the student-centered classroom. He also added that he spent too much time focusing on what he thought students should know and what information he should present to them. Alan viewed himself as the main source of knowledge for students, which made him rely too much on the ideas of how much students need to hear from him. Alan realized that he dominated the classroom conversation and claimed that, "Sadly, they (students) don't say that I make it (science content) relevant. At least, it does not come spontaneously."

Alan shared that his biggest challenge in implementing the reform-oriented program was students' low motivation. In addition, Alan expressed his setbacks in exploring students' misconceptions and oftentimes failed to see students' tentative ideas. He felt that studying students' tentative ideas as prescribed in core intervention component C is very time consuming. Although Alan expressed some frustration, disappointment, and

ineffectiveness in implementing the curriculum approach, these indicated that Alan was still processing the feasibility of a student-centered approach and progressing slowly forward. As Weick (1995, 2005) stated, the sensemaking process is an ongoing and social event. More importantly, sensemaking is "the primary site where meanings materialize that inform and constrain identity and action, particularly in situations marked by ambiguity and uncertainty" (Weick, Sutcliffe, & Obstfeld, 2005, p. 409).

Alan's progression data 3: Initiation.

On the third classroom observation, Alan started the class by revisiting the ideas of plate tectonics and the scientists behind the theory. Alan planned for students to conduct a lab to measure the density of basalt and granite rocks. Although Alan did not give students instructions for the lab, he asked many probing questions to help students explore how they can measure the volume of rocks. He then guided students to come up with the procedure of measuring the density of different sizes of rocks. Alan did not use any activities, resources, or materials prescribed by the PD program.

During the lesson, Alan detected a critical misconception that students showed during the lab activity to measure the density of rocks. He then continued to explain the accurate conception and give examples to prove his points. This showed implementation fidelity drift from the core intervention component C. This core component stresses that the teacher's approach should focus on helping students elicit and interpret their thinking through discussion and investigation that allows them to interact, collaborate, share ideas and thoughts, build on each other's ideas, and demonstrate understanding in varied ways.

Nevertheless, this was Alan's most inquiry-based lesson this far. Collaborating with a teaching assistant, Alan engaged students in the manipulation of tools, materials, and data

instead of station-based labs that only exposed students to concepts and facts. Thus, the observed lesson showed slightly higher fidelity of implementation compared to the first two classroom observations. Alan's average rating for the third classroom observation was 2.4/4.0, and each core component was scored at 2.6, 2.4, 2.0, and 2.5 respectively (see Appendix K). This showed an improvement of implementation fidelity in all core intervention component, especially core intervention components A, B, and D.

Encouragingly, Alan felt the "positive energy" generated from the lab activities. Alan reflected that he could feel students really enjoyed the hands-on labs and they were more invested, engaged, and motivated to learn. Alan reported that, "the lesson works well because it is very 'sciency' and students are engaged." In the self-report, Alan reflected that he was pleased to see students were intrinsically motivated by the hands-on activities. In the future, he will incorporate more hands-on collaborative activities with discussion to allow students' negotiation and presentation of their data.

Alan's progression data 4: On board.

On the last classroom observation, Alan's students were using a computer game (Minecraft) to study topographic maps. In his self-report, Alan explained that his students need the experience of working with contour lines and the contour intervals of a mountain. Therefore, he planned the lesson so that his students got the hands-on experience of how they can use tools such as topographic maps and satellite views to identify land and erosion features. Collaborating with the information technology (IT) teacher, students navigated the Minecraft server to construct mountains. Students marked contour intervals and observed how erosion might change the mountain based on the steepness or gentleness of a particular slope. They then transferred these skills to complete the Molten Lake Activity.

Although students worked individually with a computer, they actually worked collectively and collaboratively to build the features of a topographic map. Alan and his co-teacher walked around to support and redirect students. Students in partners worked to complete the task by interpreting the data provided. The classroom was busy because students communicated and helped each other. Alan was so glad to see students' high level of engagement and collaboration, as well as motivation.

In his self-report, Alan stated that his lesson was focused on the topographic map. He wished it could cover a larger scope of content, such as bridging into satellite maps. Nevertheless, he felt that the time was greatly used and well invested as this lesson got the students to "collaborate to learn."

Alan stated that, "Until they saw the (constructed) mountain, they did not express understanding of contour lines. After completing several levels of lines, they could describe what the differences meant on the site." Although not implementing the prescribed lesson from the program, the lesson fostered collaborative and collective inquiry as students made sense of the topographic maps, contour lines, contour intervals, and earth features of satellite maps. Alan's average rating for the last classroom observation was 2.3/4.0, with the highest fidelity in core intervention component B at 2.8/4.0 (see Appendix K).

Lily's progression data 1: Overwhelmed and drifting.

Lily has participated in the program for two years. Prior to MSS Planet Earth, she participated in the Genes and Traits workshop. She was the only teacher participant in this who experienced the reform-oriented program approach twice. During the first classroom observation, Lily's classroom was learning about weathering, erosion, and deposition. Students were provided with a textbook, packet of worksheets, computers, research

articles, research books, and many pictures or visuals of local landscapes. Lily has an assigned seating chart for the students. Lily explained to students regarding the lesson's goals, her expectations of the task, and what they needed to hand in at the end of the lesson. She also went over the vocabulary words before she allowed students to travel and work in stations. Some students started to flip through the textbook and started ahead. The conversation was mainly led and dominated by Lily.

Then, students in small groups started to travel to their stations. Students completed the task in a variety of ways: looking up information on the internet, cutting and gluing information related to the activity in notebooks, taking notes out of the book, and answering questions related to biomes. Students rotated through stations for each biome. Students constructed charts that related to precipitation and temperature. In general, students were very engaged in the tasks and self-directed. Students' interactions across the groups were very little. Students' interaction in the small groups was mainly task-oriented. The classroom was very organized and students knew their roles and responsibility to complete the task. At the end of the lesson, Lily went over some of the worksheets in the package and dismissed the students.

Lily's teaching approaches and instructional practices during the observation had drifted from the program's curriculum approach. Students' interactions, as well as the classroom dynamic, did not demonstrate implementation of the reform-oriented instructional approach. There were no hands-on inquiry activities, students' conversations and interaction were minimal, and they were not building ideas from one another. Lily's classroom observation rating was low, scoring an average of 1.3/4.0 with 1.8, 1.3, 1.2, and 1.0 respectively on core components A, B, C, and D (see Appendix K).

Lily reflected in her self-report that the stations' activity was the most effective way to provide students with different information and examples. However, she also indicated

that she is making efforts to change her instructional practices from "content before activity" to "activity before content." She wanted to have more hands-on labs in her classroom. She is aware of the reform movement in instruction and classrooms like the PD program's approach, but she was unable to figure out how the core intervention components of the program work in her classroom. She stated that the program approach was too complicated.

From the interview, Lily was content with her current teaching practices, collaboration with her team, support from her team leader and administration, and feedback from students. Although she experienced and knew the movement and the need for a reform instructional approach in the classroom, she has not, at least not yet, found the motivation to initiate the implementation. In her self-report, she reflected that the implementation of the program's approach would create many unknowns. She expressed that she is unsure if the program's approach works in her classroom, including how the approach's core intervention components work in her classroom. She shared that she was overwhelmed with the abundance of information she received from the program. With a huge load of information to digest, she was unable to "extract" the essential or core intervention components, thus lacking the nuances of how to implement the program's approach, such as, what are her roles and responsibilities? How can she assess her effectiveness in implementing the approach? She felt that she was unable to achieve the end results that she experienced from the program.

Lily's progression data 2: Limited interpretation.

Lily's second classroom observation was about ground water and surface water. At the beginning of the class, students completed the warm-up activity, and then Lily

separated students into two groups. Lily set up the environmental landscape model, called the "enviroscape model." Students took turns participating in the enviroscape model activity. As one group participated in the model activity, the others worked to complete the tasks in the package using a textbook and study guide. During the model activity, Lily constantly referred students to their package and they worked together to label and identify upstream and downstream, water table, and the direction that the water flows. Lily used the enviroscape model to demonstrate real-life scenarios like dam breaks and pumping water out of the wells and aquifer. The discussion during the demonstration was pretty straightforward and dominated by the teacher. The conversations did not promote students talking to each other and building on each other's ideas.

Again, Lily's implementation was not aligned to MSS's approaches and scored an average of 1.3/4.0 with 1.6, 1.5, 1.2, and 1.0, of core components A, B, C, and D respectively (see Appendix K). Although Lily referred to the enviroscape model activity as a lab, students did not get their hands wet during the model activity, no data were collected, analyzed, discussed, or presented by students. Instead, they circled around the enviroscape model, paid close attention to Lily's demonstration, and responded to Lily's instruction. Although Lily asked many questions during the activity, the questions were not open-ended and straightforward. Students' responses were short and they did not build upon one another's ideas. Lily tended to correct the errors made by students.

During the interview, Lily hardly discussed her implementation of the program and admitted that she had not spent time and effort to implement the program. She felt much more comfortable teaching the lessons that she collaborated on with her team. Although not observed by the researcher, Lily shared that she implemented the "graphic organizer" at the beginning of the school year. She said, "I love all of the graphic organizers that help my students dissect their knowledge." She claimed that the graphic organizer has helped

her break down the problem and organized her thought process. However, the graphic organizer was only a small part of the strategies used by the program to support students' various modalities of learning and literacy skills. Lily believed that the graphic organizers would open the way to the implementation of gallery walks. Note that the gallery walk is also one of the many strategies to support students' various modalities of learning and literacy skills. Lily's interpretation of the program was limited to the strategies that she was familiar with.

Later, Lily shared that she believed her effectiveness is parallel with students' achievements. With the team of 7th grade teachers, Lily and her peers assess students daily (Daily Assessment—DA) to find out their own effectiveness and how can they support students better. Lily thinks the Daily Assessments not only help her to evaluate her effectiveness regularly and continually, but it also helps her students be aware of their own progress. The implementation of the program's approach will force her to step out of her comfort zone and do things differently than her peers. She was unable to implement the program while she was secure with her current practices and assessment norms in her team and school. Her school's assessment norms and her team collaboration limited her sensemaking of the program. Lily only interpreted the program based on how certain strategies can fit into her current practices.

Lily's progression data 3: Misinterpretation.

During the third classroom observation, the lesson aimed to identify some changes in genetic traits that have occurred over several generations through natural selection and selective breeding. The lesson actually was a good opportunity to implement the Genetics and Traits course that Lily had attended two years prior. However, Lily planned something

completely different from the program's approach. Lily set up five stations with computers, lab sheets, notes, pictures, and illustrations for students to explore the changes in genetic traits due to natural selection. Students rotated through the stations. The stations were: read it, write it, illustrate it, organize it, watch it. Students used stations to answer questions that test their knowledge on natural selection.

Overall, students' collaboration in the small group was minimal. Lily did not facilitate any whole-group discussion for conversation. Lily walked around and supported students and asked a lot of guiding questions. Although Lily gave confirmation to most students' responses, there were times she passed the inquiries back to the group and asked them to figure them out in their group.

There were several confusions and misconceptions detected during the lesson. Instead of allowing students to explore, discuss, share ideas, and make meaning of the concepts, Lily provided the answer for students. Students agreed and the lesson moved on. Lily's implementation drifted from the program approach and its four core intervention components. Lily's classroom observation rating was low at the average of 1.4/4.0; where each core intervention component was scored at 2.0, 1.5, 1.2, and 1.0, respectively (see Appendix K). Although Lily referred to the station activity as a stations lab and provided students with lab sheets, students are not getting any hands-on inquiry and manipulation of data or tools during the activity. The lab sheet contained notes with pictures, questions, and students' answers. There were mostly factual readings before students answered the questions on the lab sheet.

During the interview, Lily shared that she believed students learned to understand the concept by "hands-on with the concepts." She added that, "whatever subject that you teach, make sense for them, because they really need to understand. They also want to know why they need to learn this." Lily thinks that as a teacher, it is her responsibility to

make sense "for" the students. She did not facilitate students' learning experiences so that they can make sense of the science content by doing, investigating, manipulating with data and tools, negotiating, discussing, and collaborating with peers. Instead, she presented the content and facilitated the groups' activities that exposed students to information that she broke down from the science content. Lily thinks she is responsible for making the science concepts sensible "for" the students. Contrastingly, the program's core intervention components aim to present and frame the science concepts with problems, full of interesting inquiries and doubts so that students are intrigued by it and solve the problems by working with others. Consequently, Lily misinterpreted the program's approach and was unable to implement it in her classroom.

Lily's progression data 4: Passive and distributed.

During the last classroom observation, students were learning about the cardiovascular system. Students were actively engaged with a virtual lab, Gizmo (worksheet package), Web-Quest, and note-taking. Students worked individually with computers but collaborated with others in small groups of three or four. Lily gave some simple instructions for the task, reminded students of the due dates, and students went on to gather their Gizmo package, Web-Quest procedures with computers, and start working. Lily walked around to support students and asked some open-ended questions. Several times, students raised their hands and asked questions; Lily referred them back to their notes on the Gizmo package where they can retrieve the facts and evidence regarding the human cardiovascular system. Students' interaction with each other in the small groups to complete the Gizmo packages was low. The interaction and discussion as a whole class

was not seen. Lily mentioned that she would wrap this unit up during the next class and that the researcher was observing the exploration.

Again, Lily's implementation drifted from MSS's approaches and its four core intervention components. Lily's classroom observation rating was low at the average of 1.6 /4.0, and each core intervention component was scored at 2.0, 1.5, 1.4, and 1.5, respectively (see Appendix K). Although students are conducting a virtual lab, students' interaction and collaboration were not aligned to MSS's collaborative inquiry approach. The Gizmo package contains notes, questions, and students' answers. There was mostly instruction to conduct the virtual labs, some factual readings, and interesting facts about animals and blood.

During the interview, Lily shared that although she agreed with the program's intention and reform-oriented approach, she found it difficult to translate it into her classroom, especially since she is not teaching the content. This showed that Lily's sensemaking of the program is limited by the science content as well. Furthermore, she added that the program was "higher-level science content" where she finds it hard to extract what is reasonable, useful, and practical for her classroom.

In addition, she commented on the inconsistencies of the standard and objectives in the PD program; she thinks it covered too much of what she needs to cover in 7th grade. She shared that these were some of the reasons she felt reserved about the program. She was passive and not proactive toward the implementation. Therefore, she passed all the information, books, and handouts to her colleague who teaches 6th and 8th grade and she is sure that they will find it useful. In the future, she wished the program could help her by identifying the activities and objectives based on the state standards.

Julia's progression data 1: Glass half full.

Like Alan, this is the first year Julia participated in the PD program. On the first observation in Julia's classroom, she began the class with a warm-up activity to review the previous lesson and check for students' understanding. Then, Julia asked guiding questions to assess students' thoughts on heating and cooling of land and water. Julia used students' ideas to introduce some key words in the lesson and invite students to find out the meaning when they conduct lab investigation. Julia then explained the expectation of the lab and modeled how students needed to record this lab in their notebook. Students were given 10 minutes to talk about the lab, plan the procedures, and their data collection methodology based on the resources and materials given to them. Although no procedures were given to students, Julia guided them by asking them to clarify how they set up a data table. Students conducted the investigation at their own pace with Julia's supervision during the process of data collection. Before the class ended, Julia facilitated small group and whole class discussion about results and limitations of the lab.

Julia's lesson and lab investigation were prescribed from the program. She felt good about the lesson and lab, despite having a limited number of infrared thermometers. She modified the group setting in her classroom, but overall, she felt the investigation and discussion went as planned. Her classroom was loud and busy because students were actively engaged in conversation, activities, building, or experimenting. The technology was well incorporated into her classroom. Julia's students uploaded their lab reports on Google Classroom and posted their reflections on their e-journal. Julia also shared resources on her website and Google Classroom.

Julia's teaching approach and instructional practices during the observed lesson were fairly aligned to MSS's approaches and four core intervention components. Julia's average classroom observation rating was scored at 3.2/4.0, with each core component

scored at 3.2, 3.6, 3.4, and 2.5 of the core components A, B, C and D, respectively (see Appendix K). After the observation, the researcher interviewed Julia. Julia is very welcoming and friendly. During the interview, Julia shared that she started to shift to a student-centered teaching approach about two years ago.

Julia's instructional practices emphasized student-centered classroom practices. Her classroom setting and environment was established as a safe place for all to interact with tangible and intangible things as they progressed in their learning. As students participated in the activities, Julia played several roles. She was always ready to support and guide students with their current needs and understanding. At the same time, she ensured that students have sufficient time and resources to make sense of their learning and be aware of the progression of students' ideas.

Julia checked in with students frequently to ensure their conversations were "on track" and productive. She added that students' conversations are frequently sidetracked from the learning goals and became social conversations. Julia added that being proactive in finding out where students were actually promotes the positive and trusting relationship between her and her students. Not only does it help to find out what student is still struggling with what, it also allows students to get to know her better. The stronger the relationship, the better Julia can support students and vice versa.

Julia is also an optimist. She likes to look at the situation as a glass half full. Half empty, because the implementation of program's approach incorporating all core intervention components does not come easy and spontaneous. In addition, she gathered that students' conversation and discussion revealed some gaps in her current practices. But, half full because she has the flexibility to personalize how she wants to steer the ship. She believed in the positive effects of incorporating a student-centered approach because students gain more knowledge and sustain their knowledge for a longer period of time if

she allows them to explore, experiment, and execute their own learning. Julia was also a reflective practitioner. In her self-report, Julia reported that she was glad that students spent a good amount of time talking about their lab and data. She added that her next step is to get better at questioning students and keeping a great discussion flowing.

Julia's progression data 2: Getting creative.

Julia's second classroom observation were student-centered, hands-on, and focused on collaborative inquiry lab investigation. The researcher scheduled two classroom observations, but the actual lesson lasted for 10 instructional days. Julia framed the investigation and activities to cover the current and previous units using an Argumentative Inquiry Driven (ADI) instructional model as well as incorporating all core intervention components of the program that emphasizes on collaborative inquiry and productive science conversation approach. Unlike the first observation, Julia was not using the prescribed lesson from the program due to different science content.

Julia started the lesson by facilitating small group discussion. Then, she facilitated whole class discussion to gather students' responses and information about their current understanding. Julia paced, facilitated, and supported students' conversation. She asked questions and referred students to available resources. Then, after she went over the expectations, students were provided with various chemical substances and tools; they designed their own investigation to explore "how does the total mass of substances formed as a result of a chemical change compare to the total mass of the original substances?"

During the investigations, students were actively engaged in the task, making predictions, collecting data, analyzing data, constructing data representation, and justifying their lab results. Julia as a facilitator walked around asking questions and clarifying

students' inquiries. It is obvious that Julia had a strong and trustworthy relationship with her students. She trusted her students to try their best, and students trusted that Julia would support their investigation as best she can. Students were very open to questions and critiques. They were respectful and productive. The classroom was loud because students were on task with a lot of conversations happening.

Next, students presented their data. Before students' presentations, Julia explained her role and her expectations of participation both as presenters and audience. She asked students to be considerate and responsible. She asked students to honor the presenter as well as being able to contribute to the diversity of the pool of discussions where critiques or questions were welcome. Adopted from the professional development program's facilitation principles, Julia asked students to keep their conversation or claims evidence-based, think out loud, separate ideas from individuals, and use as many representations as they can to illustrate their thoughts, even though it might be wrong. In addition, Julia also adopted and implemented the Claim, Evidence, and Reasoning (CER) strategy that she learned from the program.

Alongside with the program's productive science conversation and facilitation principles, Julia framed the whole lesson using the ADI approach. Student lab investigation was guided by guiding questions. Then after data collection, students developed their initial argument in response to the guiding questions of the lab investigation. The initial argument was based on claims, evidence, and justification of evidence. Students explained whether they accepted and rejected their hypothesis and why. Then, they justified their conclusion with supporting data and disclosed any possible errors made during the investigations and how it may have affected the data. Last, students explained why the evidence matters. After rounds of discussion and revision, the last part of the lesson was to produce a lab report regarding their investigation, findings, presentation, errors and modification, and

conclusion. Julia implemented the reform-oriented approach from the program without the prescribed lesson. Her second classroom observation rating was scored at the average of 3.4/4.0 with 3.8, 3.8, 3.6, and 2.5 of core components A, B, C, and D, respectively (see Appendix K).

During the interview, Julia shared that she believed students benefit from the reform-oriented approach that focused on a sensemaking process using collaborative inquiry and productive science conversations. She likes how her lesson gave students opportunities to not only develop explanations for natural phenomena, and also gave students the authorship of designing solutions to the problem using the guiding questions (Sampson et al., 2016). She added that the ADI instructional model and MSS program's approach both allow her to do so. She thinks ADI strategies provided her a clearer procedure and pacing of how to facilitate students' discussion and conversation. Creatively, she incorporates ADI in Chemistry (Sampson et al., 2016) in her lesson alongside with the program's approach. She blended both the MSS and ADI approaches and modified them to work in her classroom. When the researcher asked how she felt about the lesson, Julia said, "I would say, overall I was pleased when I saw it happening."

Julia also shared that she is still making sense of the MSS and ADI herself. She thought that although they are different in the procedure and strategies, the frameworks and fundamental principles of the two programs complemented each other during the 10 days of instruction time. Julia thinks blending two approaches promotes her plan to teach ambitiously by incorporating the reform-based principles and practices.

She liked that ADI provided her with the tangible steps of implementation. At the same time, she appreciated the facilitation principle from the MSS that promotes sensemaking of science content as a community of learners. Julia wanted her students to take ownership of their own sensemaking. Although Julia loves to share her expertise, she

explained that she couldn't possibly know everything and have answers to all inquiries. She assures students that she is not the only resource on their journey of science learning,

Julia's progression data 3: Innovatively fun.

The third observed lesson was scheduled in early February. The lesson took a little over a week of Julia's instructional time. During this lesson, Julia began by facilitating small group discussion and investigations regarding what they know about Newton's Law. Students conducted various mini labs to investigate the three Newton's Laws. Later, using engineering design process, students applied their understanding of Newton's Laws into the design and construct a prototype of a "balloon car." Later, students presented and justified their car design before they competed with each other to see whose car either traveled the furthest or the fastest.

The lessons were fun and engaging. During the lessons, Julia asked many questions. Her questions focused on (i) the content—using Newton's Laws in ways that make the car move faster/further, (ii) the process—using engineering design processes, how can you improve the speed or distance the balloon car traveled, and (iii) the evidence—what have you changed and what are the results. Although students designed their own balloon car, they were collaborating with each other. Students were very competitive and they tried to improve their balloon car prototype. The classroom was full of students talking, hammering, and full of movement and actions. While Julia's classroom looked very chaotic, everyone knew and engaged in his or her roles and goals.

Julia valued students' ideas and liked to put the tentative ideas on the spot for students' discussion. She stressed the importance of being transparent about the tentative ideas and always encouraged students to think out loud. She stated that,

> The thing I found the best now is to put students' tentative ideas right on the spot. […] it's really having them figure it out. Having them teaching each other and just having that conversation. That's how they best dispel their misconceptions.

Although Julia's third lesson did not implement the prescribed lessons by the program, her instruction approach and strategies reflected the program's reform-oriented approach. Julia's third classroom observation rating showed relatively high fidelity, scoring an average of 3.6/4.0 with 3.4, 3.9, 3.6, and 3.5 of core components A, B, C, and D, respectively (see Appendix K). After the lesson, Julia shared during the interview that she received a lot of positive feedback from students as well as coworkers regarding this lesson.

Unlike Alan, Julia's self-reports did not include discussion regarding students' willingness to engage in her lesson. Instead, she mentioned several limitations on her part that she would love to improve in the future. First the lack of certain materials and tools she used in her lab investigations. Second, she wanted to work on providing students more time to reflect and write their conclusions and lab report. Julia believed that by giving students some time at the end where they can think and rethink for themselves what they have gained and learned will help them become a reflective practitioner. Third, Julia considered making some changes in the group setting so students are able to work more effectively in small groups. Next, she wanted to continue to improve her questioning and communication skills and strategies. Last but not least, Julia wanted to work on providing students with more freedom to investigate their own questions so that students' interest is higher and increases their independency of learning.

Julia's progression data 4: Blended and fused.

Julia's fourth lesson observation was conducted from March 1–8. Before the classroom visit, Julia informed the researcher that this lesson would be about plate boundaries and it will be another implementation that contains both features of MSS and ADI, and she was very excited about it. She incorporated both the content, resources, and approach prescribed by MSS and ADI, as well as modified the original prescribed procedures for a 10-day lesson from ADI.

Students spent most of the time discovering how crustal features are affected by moving plates. The guiding question of the science investigation was, "how do plates interact along plate boundaries?" Students in different small groups (arranged by various specialties including topography, seismology, volcanology, and geochronology) explored plate boundaries by analyzing a world plate boundaries map depicting data in different specialties. Then, students shared their expertise with specialists in different areas and used all this information to answer how plates interact along plate boundaries. Students then presented their analysis via gallery walk. Then, students were asked to complete their research project by completing their own ADI lab report on how plates interact along plate boundaries.

Julia facilitated students' discussion and scientific investigation, which showed strong indications of a reform-oriented approach of collaborative sensemaking and productive science conversation. She kept referring to the principle of facilitation from MSS so students' conversations were flowing and productive. Julia's final average classroom observation rating was scored at 3.7/4.0 with 3.6, 3.8, 3.8, and 3.5 of core components A, B, C, and D, respectively (see Appendix K).

When the researcher asked Julia to describe ADI approach, she answered confidently, "ADI is Argument Driven Inquiry and it has eight strategies. Exactly eight

steps," and continued to explain all eight steps. It seems that Julia is comfortable with the ADI approach. When the researcher asked Julia what she thought about the "blend" of MSS and ADI in her classroom, she confidently shared that the lessons have a balanced fusion of both approaches. Julia was having a hard time deciding whether ADI or MSS had more stand-out features in the lesson. She pointed out the eight steps laid out by ADI helped her plan and implement it in the classroom. She explained that, "I think it's a good blend. I think the way they overlap, the whole having it to be student-centered and having it to be more inquiry-based."

Julia thinks students learn best when they manipulate tools and data and figure things out with their peers. She stressed that blending both approaches allows students to figure out the how and why of the science ideas, plus fosters students' scientific literacy and proficiency. She also shared that as she implemented the reform-oriented approach in her classroom, she could see more and more why science classrooms should be student-centered. She added that,

> I think the thing that I am doing now is that I am really more focused on the process, catching things as we go along versus the products. … So, I think I missed out before. I think now … because I am listening to them more, I can ask them a question instead of telling them they are wrong.

As Julia implemented the reform-oriented approach and shifted her teaching practice to a more collaborative, process-oriented learning and student-centered classroom, the more she appreciated the process as well as the result. She shared that her skills in responding to students' questions have improved. She learned to turn the tables and let the students own the process of finding their own solutions. Julia reflected that giving students ownership of their learning and allowing them to have that process of building, tinkering, and coming up with solutions themselves gave them pride and a sense of worth.

Additionally, they understand and retain the concepts much better, as they can see how they progressed from one side of the understanding to a complete understanding.

Kelly's progression data 1: Challenge accepted.

Kelly is a 5th grade science and social studies teacher. She is the only teacher participant who teaches elementary school. Like Lily, Kelly was not teaching the content of the professional development program. The first classroom observation was a little delayed as requested by Kelly for two reasons. First, Kelly mentioned that her lessons were mainly social studies at the beginning of the year. Second, Kelly shared that she was taking the time to establish the norms and expectations in her classroom to support students' collaborative inquiry and sensemaking.

During the first classroom visit, students in Kelly's classroom were exploring the characteristics of light by participating in concave and convex light station activities. The learning objectives that were posted on the board were, "I can determine how concave and convex objects affect how light travels" and "I can defend and argue my opinion or claim with evidence and facts." Note that the learning objectives were written in terms of a student's ability: "I can." Also posted on the board were sentence stems to guide students in making their claims. Kelly's classroom has a student who is a native French speaker, and one who is a native Korean speaker.

Kelly started the lesson by drawing students' attention to how many lab stations students needed to explore and investigate in order to figure out the light behavior. Before the exploration started, she went over the social contract and her expectations during the explorations. During the station activities, students were very engaged with the guiding questions and actively participated in the discussion and negotiated their ideas. Kelly

walked around to facilitate students' discussion and explorations. She asked guiding questions as well as probing questions to elicit students' ideas and keep their conversation flowing and productive. Students participated in many hands-on investigations about the behavior of the light. They were using concave and convex lenses, concave and convex mirrors, prisms, and infrared beams to investigate the focal point of concave and convex lenses. In each lab station, Kelly asked students to write a statement of claims from the evidence they gathered from the stations' exploration.

In addition, Kelly gave students creative affirmation. Such as, "That is interesting! That makes me wonder about … how is that possible?" Instead of confirming or dismissing students' answers, she encouraged students to draw, illustrate, model, color, or use other representations to explain their claims. She empowered students to justify their own thoughts.

After the exploration, Kelly facilitated whole-class discussion. Kelly revealed students' ideas of light by asking them to share their claims (correct or incorrect) and they constructed deeper meanings to the claims. She asked students to support their claims using evidence and justify how the evidence supported the claims. Students built on each other's ideas or responses. Kelly skillfully guided students' conversations, argumentations, and negotiations to reach a complete understanding of the lights. Kelly's implementation was aligned to MSS's approaches and its four core intervention components. Kelly's classroom observation rating was fairly high at the average at 3.4/4.0, scored at 3.6, 3.6, 3.4, and 3.0 on core components A, B, C, and D, respectively (see Appendix K).

During the interview, Kelly shared that she faced some challenges while trying to implement the core intervention B that focuses on collaborative inquiry and sensemaking, as well as core intervention component C that aims to elicit students' ideas and tentative ideas. She added that she found it especially difficult to facilitate a productive science

conversation in her classroom where students are expected to work together collaboratively to make sense of their ideas and thus learning. Establishing the social contract and instituting jobs for students allowed students to listen and talk to one another. She felt that the conversation became more productive because she ensured equal participation and collaboration occurred in small groups and whole-group discussion. The initiation of implementation took a while, but it was worth every minute that she invested.

Furthermore, Kelly assigned a strict seating chart in her classroom. Students were seated in groups of six. Nevertheless, students' roles and responsibilities within their group changed from time to time as they engaged in different activities and group discussion. Students understood their roles and were aware of their responsibility to their group as well as to their classroom as a whole. Kelly established a social contract in her classroom. Not only did it help students take ownership of their own learning process, most importantly, it helped students to be aware of their social accountability to their peers in their group as well as their class. Kelly shared that ownership of self-learning is important, but taking pride in your social responsibility is also critical in a student-centered classroom.

Kelly implemented Claim, Evidence, and Reasoning (CER), which was introduced to her in the professional development. She shared that she took some time to explain and model to students how the CER strategy works. As she modeled the strategy with students, the implementation of the strategy, and how it resonates with the collaborative inquiry approach become clearer. She reflected that,

> It gets better and better each time we use it. In a way, we use claims, evidence, and reasoning at an elementary level every day. ... I use this because it gives tangible proof to concrete science concepts, helping them understand and connect better.

Kelly's progression data 2: On board.

The second classroom observation was an indoor and outdoor exploration activity. The learning objective posted on Kelly's wall was "I can identify how energy is transferred from one object to another." At first, students in small groups received two tennis balls. They were asked to drop the ball vertically at the same time. Before students' exploration, they were asked to make a prediction, negotiate their prediction with others, and write down their final prediction in their journal before they investigated how the energy is transferred between two tennis balls of equal weight and size. Then, Kelly gathered students for a whole-class discussion regarding their observation, data collected, and what they figured out regarding how energy transfers.

The second exploration was conducted by students using an "astroblaster" to show how energy transfers between different objects with different sizes and weights. The "astroblaster" was made of bouncing balls of different sizes that were linked together; it was color-coded to indicate the different sizes and weights of the bouncing balls. Again, Kelly asked students to discuss their predictions of what would happen to the red ball, which is also the smallest ball, when she dropped the "astroblaster" in the basketball court. Later, students returned to their classroom to do more exploration of energy transfer using the Newton's cradle, radio, and laptop. Likewise, during the previous exploration, students conducted their explorations after they negotiated and wrote down their predictions.

After each exploration, Kelly asked students to write down their claims. Then, Kelly facilitated small-group discussions in which students discussed their claims, evidence to support their claims, and justified their evidence to support their claims. Using the CER strategy, students were seen to engage in negotiation and justification of their understanding; overall, the lesson was very fun, engaging, and hands-on. Students were actively engaged in small group exploration activities as well as conversation.

The process of students' learning in Kelly's classroom focused on how they can use language, science ideas, and the practices of science to make sense of the natural phenomena collaboratively. In Kelly's classroom, she emphasizes that learning is both individual and personal, as well as social, as students process together to figure out and explain the natural phenomena. Kelly's implementation was aligned to MSS's approaches and its four core intervention components. Kelly's classroom observation rating was high at 3.7/4.0, scored at 3.8, 3.9, 3.6, and 3.5 on core components A, B, C, and D, respectively (see Appendix K).

During the interviews, Kelly stressed that the lesson she planned was focused on how she can support students' understanding by giving them multiple opportunities to get the data and information. Students were exposed via the verbal/linguistic modes of learning through the notes and discussion, manipulation of different materials, and interpersonal via peer discussions. Kelly stressed that although it might be faster if she went over the concepts by direct teaching, she wanted students to experience the concepts by applying them to multiple scenarios. Doing so gave students practice time to apply their thoughts and strengthen their understanding as they make sense.

As Kelly implemented the collaborative inquiry approach of the program, she recognized that the program's approach was applicable to her science as well as social studies lessons. She shared that since she was not teaching the content of the Planet Earth course, she apprehended the program's approach and its core intervention components as more valuable to her than the prescribed lesson and content.

Although Kelly has always been a good questioner, she was a little unsure how the core intervention component C would work in her classroom. To start, Kelly was concerned about how to look for or find out students' misconceptions. She felt that misconceptions were blocking students from moving forward and she had to confront their misconceptions

before she and her students could move on. She felt that only when the wall (misconceptions) is torn down could her students see the path in front of them that would eventually lead to the goal of complete understanding of the concept. Kelly looked at students' misconceptions as something that needed to be challenged and erased in order for them to move forward in their learning. Plus, she felt that she need to reveal those misconceptions or students' hesitance so that they could work together toward a complete conceptual understanding. She added that, "To find misconceptions, you have to give students the opportunity to tell you about them."

Kelly shared that by allowing students to express their thinking and challenge it with claims, evidence, and reasoning (CER) is the best way to address misconceptions. In addition to questioning strategies, Kelly explained that well-paced questions are essential to challenge students and help them make sense of their learning. With addition to open-ended and thought-provoking questions, Kelly believes that well-paced and well-placed questions can take students' learning to a new level.

Kelly's progression data 3: Becoming a reflective practitioner.

Kelly's third classroom observation was scheduled in February and took two days. The learning objective posted on the board for the observed lesson was, "I can determine how the rotation of the Earth affects cycles on Earth." Kelly facilitated an activity to allow students investigating how the Earth's rotation affects the cycles (day and nights) on earth. During the investigation, students in small groups constructed a "sky viewer" to investigate, ponder, and figure out which of the two models demonstrates why and how the sun appears to rise and set: the earth-moving model or the sun-moving model. Students used their sky viewer to figure out as well as to resolve which theory may be correct. Using

the CER strategy, students in small groups were asked to talk and argue about their findings and evidence. Kelly reflected in her self-report that, "We continue to work on Claims, Evidence, and Reasoning … It is so important that students continue connecting their observations to explaining science phenomena."

Overall, the lesson was very fun, engaging, and hands-on. Students were actively engaged in small group exploration activities as well as conversation. Again, Kelly's implementation was aligned to MSS's approaches and its four core intervention components. Kelly's classroom observation rating was high at 3.8/4.0, scored at 4.0, 4.0, 3.6, and 3.5 on core components A, B, C, and D, respectively (see Appendix K).

During the interview, Kelly shared that she wanted her classroom instruction to be equally engaging and challenging. She planned her lesson so that students are aware of the learning objectives using guiding questions and works to figure out the objectives. Her goal was to find the balance between making sure that her students are challenged by her but also know that the tasks that are put in front of them are manageable and the results are attainable if students are engaged and work together. In order to achieve the balance between "engaging and challenging" lesson, she decided that, "The next step is to continue modeling good scientific observations and evidence alongside CER. I also plan on using their reflections more explicitly to guide my next steps in the implementation."

Although her teaching practices and classroom observation indicated that her instructions were aligned to core component D, note that it was scored the lowest so far on all observations. Also worth noting is that the researcher did not share the classroom observation rating scores with Kelly. Kelly noticed her own weakness as time progressed. She realized her limitation in using students' reflections to guide her lesson planning and knew that her next step was to become a more reflective practitioner who is sensitive to her progression as well as the students' progression. Kelly's sensemaking of the program

evolved while she implemented the approach. It implied that Kelly's sensemaking and implementation of the approach occurred simultaneously, but in different gradual stages. At first, she made sense of the collaborative approach and resonated with the CER strategy. Then, she resonated with the core intervention component D—reflection in teaching and learning.

Kelly's progression data 4: Transforming practitioner.

During the last observation, students conducted an investigation to explore the carbon dioxide cycle. Students were seated in small groups for scientific investigation and discussion. Kelly helped students to recap the water cycle by facilitating a whole group discussion. Then, she went over the investigation with students and reminded them of their responsibility and the purpose of the social contract.

During the investigation, students were trying to prove the carbon cycle using Bromothymol blue and deductive reasoning. Each group had one container of Bromothymol blue mixed with water. Proper safety gear was used, including overspill trays and safety goggles. Students blew into the container and watched the solution turn green due to the carbon dioxide in their breath. Then, students added dry ice (solid carbon dioxide), which changed the solution to yellow. Last but not least, students added a plant to the solution and waited 24 hours to watch the solution turn back to blue, completing the cycle.

Prior to each procedure of the investigation, Kelly facilitated small group discussion that allowed students to predict what would happen, shared their predictions, and negotiated or justified their predictions. The teacher paced students' discussion and investigation time. She walked around to support students' investigations and inquiries.

After the investigation, Kelly facilitated a small group discussion in which she asked students to make and write a claim from the findings, gather evidence, and justify the evidence to support the claim. Then, students were asked to discuss their claims and evidence. It was an engaging and productive conversation where students shared ideas and built upon one another's ideas. Kelly walked around to pass out colored markers and pencils. She encouraged writing as well as drawing pictures of the claim, evidence, and reasoning. Later, Kelly facilitated a whole class discussion to allow more opportunities for students to build ideas from one another before she concluded her lesson.

Overall, the lesson was very fun, engaging, and hands-on. Students were actively engaged in small-group, hands-on investigation as well as collaboratively and actively involved in the conversation. Again, Kelly's implementation was aligned to MSS's approaches and its four core intervention components. Kelly's classroom observation rating was the highest at 3.97/4.0, scored at 4.0, 3.9, 4.0, and 4.0 on core components A, B, C, and D, respectively (see Appendix K).

Note that Kelly concluded the class by asking students' feedback and remaining questions to ponder upon regarding the lesson. She wrote it down on her computer. She was happy that her students really enjoyed the two-day lesson on proving the carbon dioxide cycle. Although she had done this investigation many times and it had proven effective, she had grown tired of doing the same activities. This time, it was more engaging and challenging for the students as she incorporated the program's productive science conversation and collaborative inquiry approach. Based on students' reflection on her lesson, she will continue to do this investigation and continue to pair them with the implementation of the program's approach.

During the interview, Kelly shared that the reason she implemented the reform-oriented approach was that it makes the curriculum meaningful and interesting to students.

She strived to provide students with opportunities and experiences in which they can apply their knowledge to real-world situations. She explained that making students' learning relevant to real life is very important and it is one of her strategies to keep students motivated and interested, and thus sustain their sensemaking process.

Problem-solving in Kelly's classroom usually takes place over a period of time. It is obvious that Kelly incorporated a lot of hands-on inquiry into her lessons. She believed that students learn best by doing and experiencing instead of sitting and listening. Hands-on learning allows students to connect the information they gain to outer stimulus, apply to various situations, and thus increase the likelihood of becoming their long-term memory. Students are encouraged to illustrate and share their predictions and justifications before an experiment. By doing hands-on lessons, students are able to create, build, observe, design, and interact with others. Most importantly, as a public school teacher, it is critical for students to be able to connect their experiences to 2D test questions.

Kelly believes that questioning strategies are essential to challenging students' learning and promotes sensemaking. She likes to ask open-ended questions that provoke students' thought and increase students' curiosity. Thus, it captures their interest and sustains students' sensemaking; over time it becomes a mundane practice in her classroom. However, Kelly stressed that it took time and effort to establish and maintain this norm in her classroom. Kelly is also a proactive teacher; she does not like to limit her teaching to the content stated in the standards. When she thinks students are ready to move forward to more complicated science concepts, or whenever students are making sense of science and making connections to relate their understanding to higher-level scientific concepts (such as middle school science standards), she felt bad and discouraged if she couldn't go any further. So, she would like to be involved in TEKS revision at the state level so that the state can see the importance of multiple-subject integration.

Teacher's improvement of implementation fidelity.

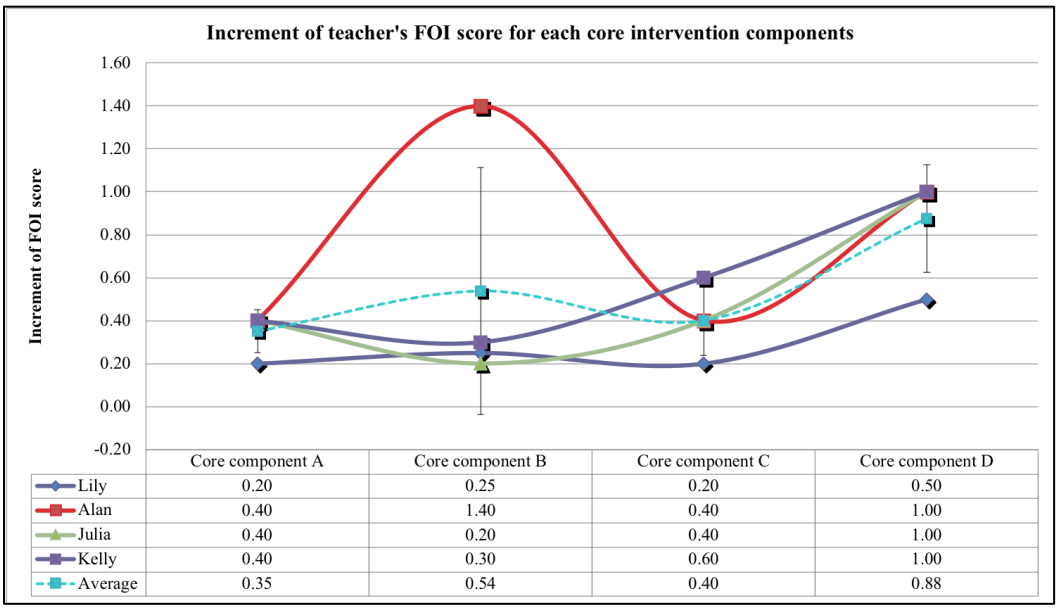
Table 4 below shows that all teacher participants showed an increase of fidelity of implementation (FOI) score for all four program's core intervention components. They range from small increments (+0.20) to big improvements (+1.40) in practices. For example, Lily's implementation of core intervention component A scored at 1.8 / 4.0 in the first classroom observation. During the last classroom observation, her implementation fidelity of core intervention components A increases to 2.0 / 4.0. This showed that Lily's FOI score of core intervention component A has increased +0.20 over time. Another example, Kelly showed improvement of +0.60 in her FOI score of core intervention component C. However, are these improvements expected to happen due to time? Or it is a substantial improvement of implementation fidelity of core intervention component A?

Increment of FOI score for	Lily	Andy	Julia	Kelly	Average	SD
Core intervention component A	+0.20*	+0.40	+0.40	+0.40	+0.35	0.10
Core intervention component B	+0.25	+1.40*	+0.20	+0.40	+0.56	0.56
Core intervention component C	+0.20*	+0.40	+0.40	+0.60*	+0.40	0.16
Core intervention component D	+0.50*	+1.00	+1.00	+1.00	+0.88	0.25

Table 4. The increment of teachers' FOI score, the average increment, and the standard deviation of each core intervention component.

Average FOI score and standard deviation (SD) of each core intervention component for overall teacher improvement of implementation fidelity were used to find out if the improvement or increment of teacher's FOI score is a substantial change. Quantitative T-test was not conducted due to small sample size. Instead, this research compared the improvement of teachers' FOI score with the average increment of each core

intervention component respectively. If the increment of FOI's score was above average, it means that the teacher has shown changes in practices or improvement of implementation fidelity that is not merely expected to happen due to time. It is not an average improvement, but it is an important change in their instructional practices that are worth studying. More distinctively if the improvement of FOI score is more than a standard deviation. The graph below (see figure 9) shows the increment of FOI score of all core intervention components that each teacher participant gained from all the classroom observations over a school year. It also shows how the increment of teachers' FOI scores compared to the average increment (dashed line) and standard deviation of all core intervention components. Let's look at the analysis by the improvement of fidelity score of each core intervention component.



	Core component A	Core component B	Core component C	Core component D
Lily	0.20	0.25	0.20	0.50
Alan	0.40	1.40	0.40	1.00
Julia	0.40	0.20	0.40	1.00
Kelly	0.40	0.30	0.60	1.00
Average	0.35	0.54	0.40	0.88

Figure 9. The graph of teachers' increment of FOI of all core intervention components compared to the average improvement of FOI and its standard deviation.

First Lily's changes of practice or improvement of implementation fidelity of all core intervention components were below average. Her graph was almost parallel with the

average increment of FOI; almost all core intervention components are more than a standard deviation lower (except core intervention component B). This means that not only her implementation of program core components is low overall, her classroom practices did not change and improve as what should be expected when time passed. In addition, Lily's FOI score also made a great contrast compared to all other teacher participants. Although within a standard deviation of increments, Kelly, Alan and Julia showed above-average improvement of implementation fidelity of core component A.

Second, and the most interesting finding, is how much Alan improves in his implementation of core intervention component B. Contrastingly, the high fidelity implementers' (Julia and Kelly) improvement of FOI in this core component were below average.

Third, core intervention component C. Besides Lily, all teacher participants gained improvement of implementation fidelity that is at or above the average increment of FOI score of core intervention component C. However, only Kelly showed substantial improvement of implementation fidelity in core intervention component C. Note that Kelly's improvement of FOI in core intervention component C is more than one SD.

Last, core intervention component D. All teacher participants gained improvement of implementation fidelity above the average increment of FOI score of core intervention component D (except Lily). However, no teacher showed improvement of implementation above one SD.

Also, some interesting notions emerged from the graph. Note that Julia and Kelly's improvement patterns (curved) of FOI of all core intervention components are somewhat similar. Also, their improvement of FOI in core intervention component B is less than average. In contrast, Alan improves substantially in core intervention component B.

CROSS-CASE ANALYSIS

With four teacher participants, the teacher surveys and case analysis suggested two different group of teachers' implementation fidelity. Thus, along with case analysis, the cross-case analysis was conducted with the aim of exploring the differences in teachers' sensemaking of the professional development program as relates to their implementation practices in the classroom. The two teacher participants who implement MSS with higher fidelity showed a substantial difference in the number of codes within their sensemaking frames of "diagnosis" compared to teachers with low implementation fidelity. Two codes subside within the frames of "diagnosis." These two codes in the "diagnosis" frame are distinctly different from one another; they are "diagnosis of challenge" and "diagnosis of opportunities." These codes captured how teachers diagnosed the program as prospective opportunities for classrooms and students; or, conversely, how teachers viewed the program as a critical difficulty to overcome. Based on the frequency analysis of these two codes, there were disparities in how these four teacher participants made sense of MSS as they implemented the professional development program. Table 5 shows the frequency of diagnosis of challenges and diagnosis of opportunity codes within teachers' diagnostic frames of the professional development program.

Implementation	Higher implementation fidelity		Lower implementation fidelity	
Teacher	Kelly	Julia	Alan	Lily
Diagnosis of opportunity	10	16	5	4
Diagnosis of challenge	2	3	13	5
Total frames of sensemaking	12	19	18 ^	9 *

Table 5. The frequency of diagnosis of opportunity and diagnosis of challenge within teachers' diagnostic frames.

Kelly and Julia, who implemented the program with higher fidelity, made sense of the professional development program as though it would provide them significantly more opportunity to improve their practices than as a program that hindered their current practices. Although with challenges, Kelly and Julia viewed the program as worth investing their time, and prospectively advancing their classroom practices. Note also that Kelly and Julia were making progress toward establishing a student-centered classroom.

Alan's and Lily's effort to establish the student-centered classroom was minimal. Their pedagogical practices mirrored very teacher-centered classroom practices. At the end of the year, Alan stepped out of his comfort zone and started to implement student-centered activities. Compared to Julia and Kelly, Lily and Alan, who implemented the professional development program with low fidelity, show two different sensemaking patterns. Alan makes sense of the program as significantly more challenging, or a difficulty to overcome, rather than providing more opportunities to improve his teaching practices. Also, note that Alan scored the highest frequencies in the diagnostic frames of sensemaking. Although with low fidelity and facing many intrinsic and extrinsic challenges, he continued to power through the sensemaking process of the program (high frequencies of codes in the diagnostic frame of sensemaking).

On the other hand, Lily, who scored the lowest implementation fidelity among all teachers, did not show much difference within the diagnostic frame of the program's sensemaking. This indicates that Lily makes sense of the program's implementation in her classroom neither as challenge to overcome, nor as an opportunity to improve her teaching practices. More, Lily's sensemaking of the program scored the lowest total frequency of diagnosis of challenges and diagnosis of opportunities, and it was significantly lower than all other teachers' participation. She showed a rather passive orientation toward the program.

Maitlis and Christianson (2014) explain that sensemaking is triggered by cues, such as situation, event, or issues. Sensemaking begins with the sensemaker and the efforts of sensemaking tend to occur when the current state of the situation, event, or issue is perceived to be different from the expected state of the world. Gioia et al. (1994) state that sensemaking starts when the flow of events or situation and organizational circumstances turn into words and salient categories. Thus, sensemaking is, importantly, an issue of language, talk, and communication (Weick, 1995). Situations, events, and environments are "talked into existence" (Weick, Sutcliffe, & Obstfeld, 2005, p. 409).

Another crucial property of sensemaking is that the processes of sensemaking are "progressively clarified, and the clarification often works in reverse" (Weick, 1995, p. 11). When teachers talked and had conversations about the program, the outcome of the conversation develops the prior definition of events and situations. Teachers' sensemaking of the professional development program occurs when they talk the program into existence. Therefore, teachers' conversations about the professional development progressively from a year of classroom visits can be seen as the gateway to explore the teacher sensemaking. Case analysis and cross-case analysis revealed that teachers in this research established some patterns and common characteristics as they made sense of the professional development program. Using the teacher sensemaking frames (Spillane & Anderson, 2014), this research managed to find out the triggers of teacher sensemaking instances of the reform-oriented program's approach. The cross-case analysis also revealed that some triggers of sensemaking instances arise uniquely concerning the teachers who implemented the program with higher fidelity as compared to teachers who implemented the program with low fidelity. Table 6 showed the frequencies of triggers of teacher sensemaking instances that arose during a year of implementation. Noted that some triggers of teacher

sensemaking instances arise uniquely with high fidelity implementers like Julia and Kelly, and some arise only with low fidelity implementers like Alan and Lily.

	The triggers of teacher sensemaking instances	Lily	Alan	Julia	Kelly
1	Abundance of information gained from the professional development experiences	-	2	-	-
2	Availability and accessibility of instructional resources	-	-	1	1
3	Value of program to classroom	4	1	3	12
4	Emotion / feeling	2	5	11	5
5	Accessibility to the experts	-	-	1	3
6	Availability of planning time during the professional development	-	-	5	-
7	Current progression toward establishing student-centered classroom	-	1	5	4
8	State standard	4	1	-	2
9	Students' needs	1	4	3	4
10	Roles and responsibilities to implement the program's core intervention components	2	3	-	-
11	Setting and environment	-	3		1
12	Implementation network – district and coworkers	3	3	8	1
13	Success measure of the implementation	1	7	-	4
14	Time is lacking	1	2	4	4
	Total instances	18	32	41	42

Table 6. The frequency of teacher sensemaking instances.

Julia and Kelly, who had higher program implementation fidelity, express their thoughts and thus make sense of the program differently than the teachers who have lower implementation fidelity. Julia and Kelly's conversations about their professional development experiences and implementation are closely tied to their (i) availability and accessibility to instructional resources, (ii) accessibility of the experts, (iii) current progression toward establishing student-centered classroom, (iv) availability of planning time during the professional development. Contrasting from Julia and Kelly, Alan and

Lily's conversations about the program were focused on the challenges, problems, and struggles, such as (i) abundance of information gained from professional development experiences, (ii) lack of clarity about their roles and responsibilities, (iii) lack of clarity about setting and environment, and (iv) success measures of implementation are lacking.

The Venn diagram in Figure 10 illustrates the triggers of teacher sensemaking instances for teachers with high implementation fidelity and teachers with low implementation fidelity. The overlapping area shows the common triggers of teacher sensemaking instances for all teacher participants.

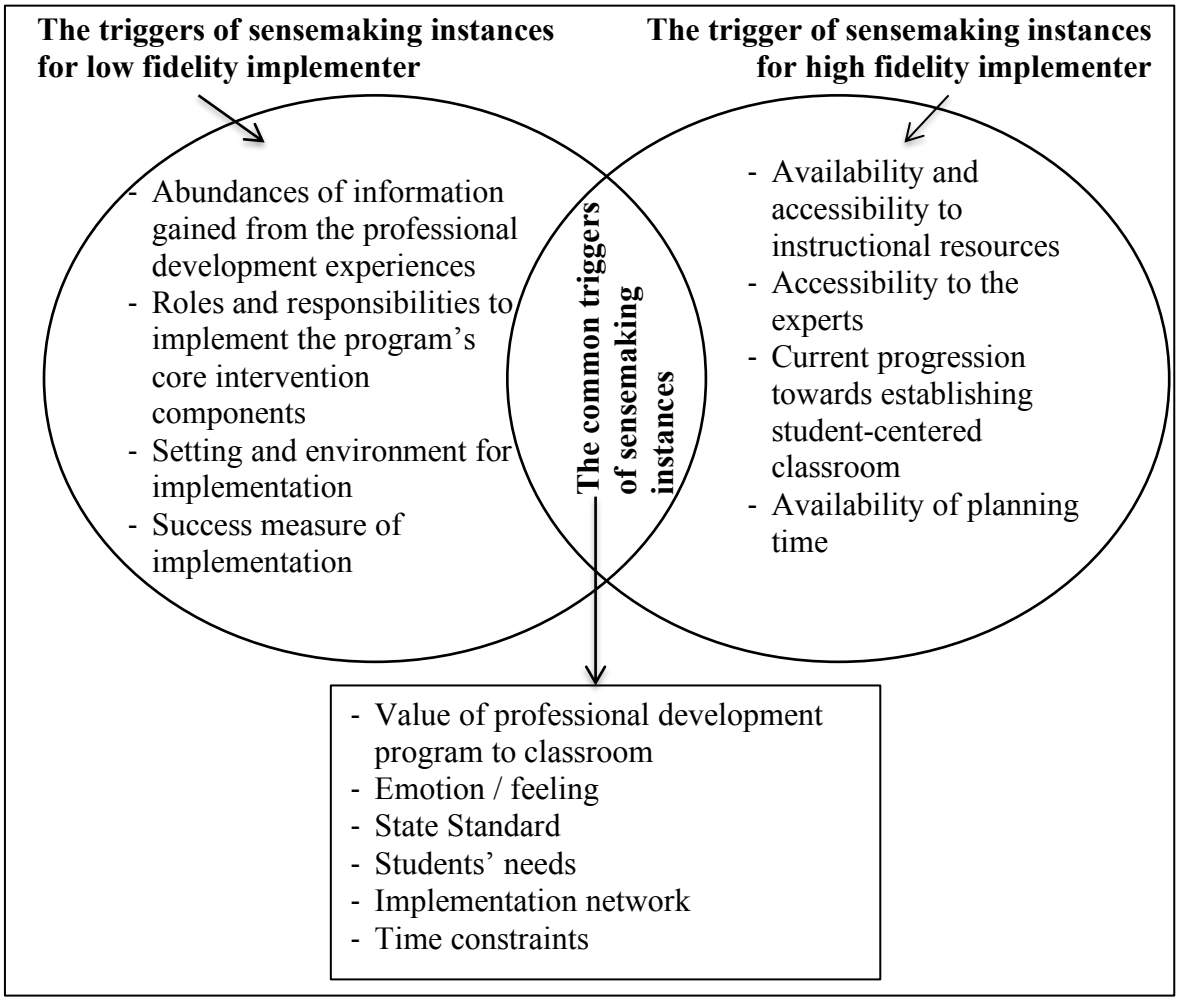


Figure 10. The Venn diagram of teacher sensemaking instances.

SUB RESEARCH QUESTION 1: WHAT ARE THE COMMON TRIGGERS OF TEACHERS SENSEMAKING INSTANCES DURING AND AFTER THEIR PROFESSIONAL DEVELOPMENT?

Weick (1995) explains that people punctuate the flow in predictable ways and neglect a large portion of it. As flows of events increase and the load of information is abundant, people begin with the omission, then move to greater tolerance of error, filtering, bracketing, chunking, and abstracting (Miller, 1978; Powell, 1985; Weick, 1995).

Case analysis revealed that teachers in this research establish some common characteristics as they make sense of the professional development program. There were six common triggers of teacher sensemaking instances that are shared by all teacher participants: (i) the value of professional development in their classroom, (ii) their emotion or feelings regarding implementation of the program, (iii) the relevance of the professional development program to students' needs, (iv) the relevance of the professional development to state standards, (v) the implementation network that operates within school/campus and, (vi) time constraint.

The value of professional development in their classroom.

All teacher participants described the professional development program as valuable and worthwhile. They explained that it has helped them improve their content knowledge and understanding. They described the activities, lessons, and hands-on explorations as engaging and challenging at the same time.

Alan thinks the workshop was a great opportunity to improve his content knowledge of earth science and expand his current practice. Specifically, he explained that his experiences in the workshop helped him to value students' ideas more and how he can provide the platform in the classroom so that students can investigate their ideas. As much as the program showed him how his ideas and thoughts were valuable resources for his learning as well as his peers' sensemaking process, he understood that students' ideas and thoughts are just as important and worth sharing with others in their venture of content sensemaking.

Likewise, Julia shared that the program expanded her perspectives and strengthened her skills in looking at students' ideas and thoughts. Kelly shared that her

experiences in the program exposed her to up-to-date earth science content. It provided her the platform to learn her next steps to prepare students for middle school. Kelly also shared that the program's reform-oriented approach provided her a better idea of helping students to progress from their tentative ideas toward a complete understanding of earth science concepts. Kelly really appreciated the CER strategies in the science productive conversation approach. She learned that the more kids are able to interact and express ideas with each other, either in the small group or whole group discussion, the more they learned and were able to build their understanding. Although Lily shared that the science content of the professional development program exceeded the school, district, and state requirements, she definitely appreciated the level of rigor and content understanding she gained from the program.

Emotions and feelings regarding the implementation of the program.

Weick (1995) explained that when people perform an organized action sequence and are interrupted, they try to make sense of it. Likewise, when teachers are implementing the program in the classroom, they stumbled into many things and were interrupted. The longer they search, the stronger the emotion (Weick, 1995). Whenever teachers are making sense of, discussing, and implementing the program, their actions were closely infused with emotions and feelings. The reality of flow becomes more apparent when that flow is interrupted and it typically induces an emotional response, which then paves the way for emotion to influence sensemaking (Weick, 1995). Each teacher expressed different emotions regarding the program and its implementation process. Table 7 shows the teachers' various emotions or feelings when they were in the professional development program and during a year of classroom implementation.

Teacher	Julia	Kelly	Alan	Lily
During PD program	"Hurts before it feels good"	"Fun"	"Complicated" "Great opportunity"	"It forced us to think outside the box"
Classroom observation 1	"Hands are tied"	"Motivated and encouraged"	"Disappointed" "marginally prepared"	-
Classroom observation 2	"Excited. Sort of parallel to students"	"I feel as though that's just the most satisfying thing"	"Unsure and frustrated" "Feeling pushed back by students"	-
Classroom observation 3	"Successful and it went really well"	"Positive" "Pleased"	"Encouraged"	"I feel that the program is a supplement"
Classroom observation 4	"I really feel good, like students just step up and are more invested"	"Joy" "The more I have done it, the more confident"	"Daunting" "Feel better understanding of how to apply"	"It is really hard for me personally"

Table 7. Teachers' emotions during the PD and one year of classroom implementation.

Julia thought the program increased her confidence to implement the reform-oriented pedagogical approach as she felt that the program has improved her explanatory and predictive powers and the use of student input. Julia also shared that the program showed her how to figure out, understand, and utilize their tentative ideas and why they might have such tentative ideas. As she implemented the program approach, she gathered students' reactions and feedback, and observed the classroom environment. These helped her to plan and progressively implement the approach. She was always happy with the results and that motivated her to keep implement the program's approach. In addition, Julia felt that as she empowered students to participate and making sense of the content

themselves, they became more invested in their learning and more confident in their discussion and group activities.

Julia admitted that student-centered approach was a revolutionary change for her. She shared that it was a hard transition and she wished she had started off her teaching career implementing a student-centered classroom. Nevertheless, she was glad that she had transitioned from a teacher-centered to student-centered classroom three years prior. She realized and experienced the positive impacts of the reform-oriented approach. She shared that,

> To me, the world has been teaching in a certain way, there is such a revolution going on... It's just hard to transition. I wish that I had started out being student-centered so I would not have this other way of teaching.

Julia admitted that due to the limits of instructional time and standardized tests, she sometimes feels that her hands are tied and she has to skillfully plan her implementation. Although some of the lessons will take much more time, the coverage of the content was deeper and wider. Thus, if she plans the implementation skillfully, she will be able to catch up with the district timeline and state requirements.

Kelly really likes the collaborative inquiry approach of the program. Although at the beginning Kelly had to spend time and effort to establish a productive social collaborative environment by instituting citizenship and collaborative roles in her classroom, she was pleased to see the results.

Lily showed the least emotion toward the program. Along with the lowest implementation fidelity of the program, she hardly discussed or expressed her feelings about the program and its implementation. She viewed the program as a supplement to her current practices. She had a hard time making sense of the program's reform-oriented approach. She was also uncertain if she would be able to translate her learning experiences

into classroom implementation. She anticipated many uncertainties and ambiguity if she would implement the program. Lily shared that her students were goal oriented and self-motivated. She felt that her current teaching practices were aligned with her students' needs, team practices, school needs, and district's requirements. She was content with her teaching practices. Therefore, she viewed the program as an "add-on" to her classroom that is great to have, but the effort to alter her practices was "unjustifiable," especially when she was confronted with many uncertainties and much ambiguity about the program's approach.

The relevance of professional development program to students' needs.

During implementation, all teachers discussed and made sense of the program in terms of the program's approach met or did not meet their students' needs. Students' needs actively influenced teachers' thought processes and actions. When Alan was asked about the challenges he faced during the implementation, his responses tied closely with students' motivation levels. He shared that his biggest challenge during his implementation was students' low motivation level. He was uncertain about his effectiveness of implementation as well as the program's effectiveness in his classroom. He experienced the program's approach with groups of adult learners, so he was uncertain how the program's approach would work in his classroom with middle school learners, especially with low motivation levels toward learning. He questioned whether his students were able to elucidate their understanding and non-understanding.

The lack of information about how to implement the program approach with his students discouraged Alan. He shared that he also lacked a reference point for where to start, how to continue to build on students' ideas, and what the end result looks like. He

said, “I felt like… I am lacking in that nuance of how do you shift this to where it is supposed to be, and where it is supposed to be?”

Lily thought that the program approach was “higher level.” She thought the program’s content was so broad and rigorous that it exceeded the state requirements. Julia had different views of the program’s approach and its relevance to her students’ needs. Julia believed the program’s approach met her students’ needs, as well as her own, in parallel. Similar to how she appreciated the experiences of learning the content with exploration, manipulation of tools, and collaboration with peers, she thought that such experiences of building, tinkering, and collaborating will empower students in their learning process as well. On the same hand, Kelly stressed the importance of having these experiences, especially for young learners, because they are important skills that they will carry throughout their life. She strived her best to ensure every kid is able to think and communicate with others.

The relevance of professional development to state standards.

Teachers compared the content and approach of the professional development program to the state standards, the Texas Essential Knowledge and Skills (TEKS). Alan was very concerned that the prescribed activities and hands-on investigations were not meeting the grade level TEKS. Alan’s students will be taking the high-stakes assessment called the State of Texas Assessments of Academic Readiness (STAAR). He wanted to ensure the prescribed lessons and activities were covering the 8th grade TEKS standards. He explained that the earth science content that was covered in the program was aimed for multiple grade levels; many won’t be tested in the 8th grade science STAAR. He thought

the implementation was troublesome when the content did not align with the supporting and readiness standards of TEKS.

Lily's attitude toward implementing the MSS program's lessons and activities was very passive and reserved. Because the 7th grade science TEKS focus on life science, she did not see the need of implementation. She passed the materials and resources to her peers who are teaching 8th grade science. With the combination of (i) not seeing the relevance of the program to the 7th grade state standards, (ii) feeling that students' needs were not met, (iii) being content with her current teaching practices, and (iv) being unable to translate the program's core intervention components to her classroom, Lily reduced her uncertainty and ambiguity by passing the program's materials and resources to her peers with hopes that they would find it useful.

Although Kelly expressed her concerns about the relevance of the program's content to her 5th grade TEKS, she thought it provided her the knowledge and background information for how the students will progress in their learning of earth science content. Evidently, Kelly firmly believed in the program's approach. Not only does she think that they provided her students with important skills for learning and doing science, she shared that it met her needs as well as her classroom needs in terms of improving students' productivity and collaboration skills.

The implementation network that operates within the school.

Although sensemaking is an individual activity, the account created is developed in a social setting. The implementation network that was commonly discussed by teacher participants includes their principal, grade-level co-workers, and departmental-level co-workers. Only Julia and Kelly included the district's curriculum specialist and the content

specialist—the professor of geological science from a local university who participated in their program and collaborated with the professional development programs.

Alan shared that he and his grade-level team members plan lessons and discuss students' data. They did not collaborate to implement the hands-on and collaborative inquiry approach. During the collaboration, they laid out their unit plan, lesson plan and activities, and timeline together.

Contrasting with Alan, Julia's implementation of the program approach was supported by her grade-level team members. Julia shared that everyone in her Professional Learning Community (PLC) was on the same page about implementing a student-centered teaching approach and hands-on inquiry lessons. Julia collaborated with her grade-level peers to push out the reform approach to teaching (such as MSS and ADI) into the classroom.

Kelly appreciated her peers for being open-minded and allowing her to share her ideas and goals. Kelly and her peers collaborated productively to implement the program's approach. Kelly also invited her peers to participate in MSS in the future. She was hoping they could collaborate more productively to implement the program approach.

Despite the discussion of how she collaborates with her grade level and department level to do the Daily Assessment (DA) and activities in her classroom, Lily did not express how they work together in the implementation of the reform-oriented pedagogical approach. She admitted that she passed the program materials to her coworker in 8th grade since they are more likely to teach the content.

Time Constraints.

All teacher participants talked about the lack of time when they implemented the reform teaching approach and its core intervention components. Alan shared that setting up and creating a safe and collaborative environment to foster a collaborative inquiry approach was very time consuming. He was also uncertain that he was adequately prepared and trained to implement such a student-centered approach.

Julia shared that she sometimes felt that her hands were tied because she needed to follow the district timeline and state standards, which were her primary implementation constraints. Even so, she and her peers also tried their best to fit the student-centered lessons into the curriculum map. She described it as difficult and a "growing pain." Julia shared that,

> I think they are all valuable, it is sometimes not feasible. Even though the one that we really try … we still have to cut some corners… trying to fit it into the curriculum is sometimes hard. It's a growing pain.

With high implementation fidelity, Kelly also faced time constraints. Kelly felt stress about the limitation of instructional time and shared that, "It is always challenging to make sure you have enough time for students to delve into it in a deep way." She explained the importance of allowing more time for students to share ideas and work through their struggles and tentative ideas, but it was a fact that she was limited by time and the district curriculum map.

SUB RESEARCH QUESTION 2: WHAT ARE THE TRIGGERS OF TEACHER SENSEMAKING INSTANCES THAT RELATE TO TEACHERS' REJECTION OF IMPLEMENTATION?

Based on the case and cross-case analysis of teacher sensemaking and implementation fidelity, Lily "rejected" implementation of the program. Although Lily had

participated in the MSS program more than the rest of the teacher participants, she "failed" to implement and thus make sense of the program approach. In addition, her interpretation of the program was limited. Her interpretation of the approach was focused on the strategies that she was familiar with.

She thought the transformative approach of professional learning that connects hands-on science with integrated teaching and literacy supports was very "powerful." She also admitted that it improved her own content knowledge. However, she found the implementation was too complicated and the content of the program was too "high level." In addition, Lily was very content with her current practices. She believed her current practices met her students' needs. In addition, Lily's current classroom practices closely followed the school's and team needs. Her collaboration with her co-workers operated within similar needs, goals, and purposes to maximize students' achievement and maintain her school as a high-achievement campus. Their daily operation, decision-making, assessment, and instructional practices were closely related to one another.

Therefore, she viewed the program as a "supplement" to her current teaching practices. This implies that Lily's sensemaking of the program involved new information and skills simply being passively "added on." Since it is additional information and skills, she opted to implement or not implement them in the classroom. In Lily's case, she opted not to implement, as she was uncertain of how it would work in her classroom, especially since she was confused and uncertain of her roles, her responsibility, and the end results.

Although all teacher participants discussed how the implementation was challenged by the misalignment of program's content with state standards, Lily, however used it as a legitimate reason to not implement the core intervention components. Julia and Kelly, on the other hand, understood that the misalignment as a risk to take; they still implemented the core intervention components. Alan, although was overwhelmed and very concerned

about his accountability to state standards and the district's timeline, he managed to implement a few critical features of core intervention component B.

SUB RESEARCH QUESTION 3: WHAT ARE THE TRIGGERS OF TEACHER SENSEMAKING INSTANCES THAT RELATE TO SCIENCE TEACHERS' ADDITIVE LEARNING OR ASSIMILATION?

At the beginning of the school year, Alan shared that he felt marginally prepared to implement the approach. He was unable to grasp the core intervention components of the program and translate into his classroom. Alan stated,

> It is daunting when I think about it, because it seems like such a huge hill to climb. But, I know that is the right direction to go. So, I feel like something that changes for me is really committing to the idea of pushing it out to the kids more.

He initiated his implementation by incorporating the gallery walk introduced in the program's approach, one of the many strategies to support students' various modalities of learning and literacy skills. After the implementation, Alan was discouraged. He felt "pushed back" by his students as he pushed the student-centered approach in his classroom. His students' low motivation level has always been a concern in his teaching.

Although discouraged, Alan was not rejecting the program. He trusted that the implementation of the program's core intervention components is the right path to move forward in his practices as well as in his classroom. He continued to make sense of the approach. On one of his next lessons, he demonstrated the "convection bottle lab" with students. The "convection bottle lab" was one of the many lab activities that were prescribed in the program. Distinctively different from the core of program's approach, students were not involved in any data or tools manipulation and group discussion. This demo lab indicated that Alan's implementation had drifted from the core of the program's approach; he was unable to make sense of the program's core intervention components. In

addition, it also indicated that Alan defaulted himself to the traditional didactic approach that he was familiar with.

Alan only incorporated the gallery walk and demo part of the prescribed lab activity for most of his implementation practices. His efforts at implementation indicated that he only incorporated the strategy or activity using the practices he was familiar with. His sensemaking of the strategy and teaching approach was based on his existing understandings and familiarities.

Toward the very end of the school year, although Alan had not implemented any of the prescribed lessons and activities from the professional development program, he began to get on board to establish a student-centered classroom. He changed his practices a little at a time, a few critical features of core intervention components B at a time. These features are focused on helping students to make meaning through participation, inquiry and observation, and hands-on data and tools. The last classroom visit showed that he allowed students to participate in the hands-on investigation using Minecraft. He admitted that the lesson was not at all prescribed from the program's approach, but he was pleased to see the positive feedback from students' participation. Although he still questioned his own effectiveness in a student-centered classroom and doubted the end results, he knew that his budding efforts in establishing a student-centered classroom were a step in the right direction.

Alan's efforts to implement the program approach were limited and conflicted with the core intervention components of the program. He was distracted by superficial similarities or familiarities and became overconfident about his understanding of the true intention of the professional development program. So, what components relate to Alan's superficial sensemaking and additive learning?

Alan shared his own weakness when he tried to implement the collaborative inquiry and students' sensemaking approach (mainly core intervention component B and C). He was unsure how to shift his current classroom toward a student-centered classroom. The lack of the necessary information, knowledge, and skills jeopardized his effectiveness as a teacher. With the time limitation and his fear of accountability as a teacher, Alan felt uncertain about the implementation. He was neither able to assess the outcomes of the program's implementation, nor anticipate the setting and environment of the program's reform-oriented approach. He was uncertain of what roles and responsibilities that he needed to play during the implementation.

In general, Alan's sensemaking instances were focused on the following: (i) abundance of information gained from the professional development program, (ii) unclear of his roles and responsibilities to implement the core intervention components, (iii) unclear of setting and environment to implement the core intervention components, and (iv) success measures of implementation are lacking.

The abundance of information gained from the program.

Alan specifically had a hard time taking in and making sense of all the information, knowledge, and content that he gained during the professional development. This had made the implementation harder because he had a tough time processing and choosing the useful materials out of a "myriad of things." He thought focusing only on his grade-level science content as required by state standards and the district would help him to better support his students. He shared that, "It is about selecting the materials out of the variety that we got and deciding what is going to be useful and what's not."

Alan thought that although the professional development program deepened his understanding of Earth science content, it was too broad in relation to the state standards. He explained that the content knowledge from the program was aimed for all grade levels' content in middle school. As Alan tried to make sense of the professional development, he paid particular notice to his grade-level appropriate content. He wanted to filter and select only the "mandatory" content to cover. During the last interview, Alan shared that as he was filtering, selecting, and making sense of the program, he managed to only get the "bits and pieces" and putting them all together and puzzling through the program's approach became complicated. Like putting together a puzzle, Alan seemed to have trouble getting the whole picture of the program approach. Thus, he leaned toward his team planning that followed the district requirements and curriculum closely, which he also found to be more straightforward.

Roles and responsibilities to implement the program.

During the implementation of the professional development program, both Lily and Alan were unclear about their responsibility. They were unsure of how to apply or incorporate the program's approach in the classroom. Alan was uncertain of the process of how to provide or set up the safe environment for students to participate and discuss productively and respectfully. In general, his uncertainties centered on questions such as: How much support does he need to give students? How much scaffolding does he need to give so students can hold themselves up at all? How can you encourage students to branch out and risk?

He described that it was tough for him to figure out how to implement the program's approach into his classroom with 13-year-olds. He wished his professional development

experiences could show or prepare him how the implementation can be done in an 8th grade classroom. He shared that, "That sort of interchange like we experience in the summer training is high-level stuff, I would not use that as a thing of saying I saw how it's being done."

Alan admitted that he is not a risk taker. With the time constraints and state requirements, he found it difficult to manage the implementation of reform-based instructional practices especially if he was not sure if it was applicable and the success measures or effectiveness were unclear. Likewise, Lily admitted that she would need someone from the professional development program to show her how it can be done in a middle school classroom. Although the level of motivation and achievement level of Lily's and Alan's students are very opposed, they both felt that the approach would not work with their students.

Setting and environment for implementation.

Alan also felt that his classroom was not an ideal environment to implement a reform-based instructional approach. For one situation, he thought his students' motivation level was too low and they would not cope well with changes. Alan thought his classroom was too crowded. He admitted that this was not his first attempt to implement a reform-based instructional approach. He gathered from previous experiences that he was unprepared and did not receive much positive reaction from students. When he was pushing forward to establish a reform-based instructional approach and a student-centered classroom, students' negative reactions pushed him back. Students were unwilling to share ideas, refused to participate in group activities, were unwilling to cooperate, and many more negative behaviors. He shared that he is not sure if his students are capable of

participating in reform-oriented classroom activities and discussions. His deficit thinking limited his sensemaking and implementation of the reform-oriented instructional approach.

Next, Alan did not feel supported by his co-workers. He shared that all the science teachers on his campus were required to follow the district timeline and curriculum map. His team leader and his peers had put together a Strategic Instructional Model (SIM) to represent the content visually (like a concept map), activities and materials that they need to cover in his grade level. He leaned forward to follow the SIM, and thus away from the program approach for several reasons. One, the model was pretty easy to interpret for implementation; especially since the resources and activities were well organized and in place for him. Second, the SIM model was used campus-wide. This meant that all of Alan's grade-level and department-level peers were using it in their classrooms. Alan faced many struggles and hiccups while trying to implement the program. He had a hard time making sense and processing the abundance of information from the program that was too complicated and was uncertain of its success. Alan analyzed the pros and cons of the program implementation critically. Evidently, he leaned toward the SIM model as he felt that he was not alone and he could access help and resources more easily.

Success measures of implementation.

Alan was uncertain how to assess his effectiveness as well as his students' learning. He asked, "How do you assess that conversation, and how do I make sure that it is directed toward the final goal?" Alan admitted that not only was he having difficulty in assessing his own effectiveness, he was very confused about the approach as he did not know how to utilize and assess students' conversation. He added that,

> I am not sure that I can assess how well I had the students making sense out of what they were learning. I don't know that is any different from being able to assess their learning? I am not sure that I was not doing that, but I don't think I was thinking in those terms (collaborative inquiry approach). I was thinking more in terms of just straight learning, not so much of the important piece of them working together and collaboratively building something around that knowledge.

Alan understood that the program's collaborative inquiry approach and productive science conversations were designed to support students' conversation around what they don't know and what they do know. But, since he was unsure of how to assess students' conversation and he had no frame of reference for what was successful or productive, he felt that it was "fraught with peril to be seen as incomplete." Alan also revealed that his success measure was ultimately based on content understanding and hands-on inquiry, but certainly lacked the importance of collaborative and communication skills.

The high-fidelity implementer (Kelly) discussed the success measure of the program's core intervention components as well. In contrast to Alan, Kelly, who implemented the program with higher fidelity, had a different perspective on the success measure of implementation. She had a clearer idea of how she could assess students' conversations and participation. Although she did not talk about the specific example of each critical feature, she discussed clearly how she assessed her effectiveness based on her students' success as a whole, including the attainment of knowledge and skills.

> I think it is not just do they have that content knowledge or can they spew it back out again. So, it is looking at the person as a whole. Whether they are more confident, whether they can problem solve with other people, whether they can communicate in a different kind of group, whether they can take their peers' ideas and evaluate what they have, whether they can represent their ideas so their peers can understand, whether they can put themselves out there and be ok if they are wrong, that's what I am looking for, as well.

SUB RESEARCH QUESTION 4: WHAT ARE THE TRIGGERS OF TEACHER SENSEMAKING INSTANCES THAT RELATE TO TEACHER TRANSFORMATION IN CLASSROOM PRACTICES TO IMPLEMENT THE PROGRAM WITH HIGH FIDELITY?

Comparing all teacher participants in this research, both Julia's and Kelly's instructional practices resonated with the core intervention components of the program. Their instructional practices centered on students' participation in small-group activities. Although Kelly is not teaching the program's content of Planet Earth, she found the approach and its core intervention components very practical and she was able to implement the program's approach. She explained, "The essential approaches are definitely something that I can apply. Not direct lessons, because it's not geared for 5th grade specifically; it is the 'essential' practices and strategies that I can implement."

Like Kelly, Julia resonated with the program's core intervention components because it is reform-oriented and geared toward establishing a student-centered classroom. It supported her teaching practices, especially as she strived to establish a student-centered classroom. She felt that with every implementation she tried in her classroom she figured out more ways to establish a student-centered classroom.

From the analysis, Julia and Kelly, who have higher program implementation fidelity, expressed their thoughts and thus made sense of the program differently than the teachers with lower implementation fidelity. Julia's and Kelly's discussion of their professional development experiences and implementation were closely tied to their (i) availability and accessibility to the instructional resources, (ii) accessibility to the experts, (iii) implementation progression, and (iv) availability of planning time.

Availability and accessibility of instructional resources.

Instead of talking about the abundance of information they received from the professional development program, Julia claimed the program "supplied such a wealth of resources for me." She appreciated the instructional resources, activity resources, and ideas that come with the professional development. Likewise, Kelly also added that she especially liked the fact that she is able to access to the real seismology data from the program and experts. Kelly explained that she felt more motivated and invested knowing that her teaching and students' activities are well supported by scientists and scientific data.

Accessibility to the experts.

Only Julia and Kelly talked how the program gave them access to experts' advice and knowledge. Julia and Kelly liked to work with experts. Kelly shared that she likes to talk to an expert because "she will extend my thinking on geology a lot more than I would have expected."

Kelly shared that she was motivated and inspired by her professional development experiences because it provided her the opportunity to understand the content knowledge rigorously and able to collaborate with the expert who teaches the earth science content in universities and she has great resources in the most current knowledge and skills.

Current progression toward the student-centered classroom.

Julia shared that her implementation of the reform-based core intervention components in her classroom was part of her effort to establishing a student-centered classroom. Julia referred to her implementation of the program's approach as part of the

process in her continuous effort to establish a student-centered classroom. She admitted that this is her third year since she realized and started her effort to construct a student-centered classroom. Julia reports that each year has gotten better, especially since she has improved her questioning skills. She shared that, "every time that I do it, I am always happy with the results. I don't know why it's so hard to transition over because it should be just, hey, it works, why don't I do it all the time."

Like Julia, Kelly started implementing a more student-centered instructional approach a few years ago. However, this is the first year she experienced and implemented a collaborative inquiry approach in her classroom. Without much consideration, she thought the approach would fit right in her progressive effort of establishing a student-centered classroom. Unfortunately, she faced a big hiccup at the beginning of the implementation. In order to implement the program's approach, she had to institute jobs and a social contract in her classroom. She modeled and practiced along with her students throughout the year. She especially liked a CER strategy that was incorporated into the program's productive science conversation. She explained that it suited her students' needs and helped students to participate productively in classroom discussion and activities.

Availability of planning time during professional development.

Julia and Kelly discussed how important and helpful is for them to have some planning time during the professional development program. It helped them figure out how they could implement or incorporate what they learned in their classroom. They liked to bounce ideas off of other teacher participants and think about their own plan to make the program's approach work in their own classrooms. Julia shared that,

> I liked the time when we are bouncing ideas about each other's learning and really thinking about what would I have to gather, how much time will I need, what steps do I need to make sure I have covered in order to have these work well in the class … if you don't have the time to think about it and make a plan of how you are going to implement it, it will never get fit in.

Julia and Kelly were both progressing toward establishing student-centered classrooms. Thus, the program's four core intervention components were not alien to them. However, there are certain core intervention components and its critical features that that stood out for them. For one, both Kelly and Julia had become better reflective practitioners. Julia was reflecting on her questioning skills so that she can better elicit students' understanding. Kelly learned a lot from students' misconceptions. Two, Kelly as a high-fidelity implementer, managed to show substantial improvement in her implementation of core intervention component C. She became very aware of her roles, responsibilities, her classroom environment and setting in order to elicit students' thinking. She instituted citizenship and social contracts to help her fifth graders utilizing the CER strategy to stimulate, elicit, and extend their own thought process. She managed to transform her strong questioning skills as a practitioner of the CER strategy to implement core intervention component C.

Chapter Five: Discussion

As an aid to the reader, the final chapter of the dissertation restates the research problem and reviews the major methodology used in this research. The major sections of this chapter summarize the results of the research question and its sub-questions. The chapter will then discuss the implications of the results and make suggestions for future research.

Many researchers have extensively studied empirical research of sensemaking, but it was the work of Weick's "Sensemaking in Organization" (1995) that has burgeoned the sensemaking research into various contexts and methodologies (Maitlis & Christianson, 2014). Sensemaking is a form of human cognition in which people make sense of their environment (Weick, 1995).

The primary research question in this research is, does teacher sensemaking influence their implementation fidelity? If so, how? The exploration of this main research question is guided by four sub-questions. They are:

- What are the common triggers of teacher sensemaking instances during and after teacher professional development?
- What are the triggers of teacher sensemaking instances that relate to teachers' rejection of implementation?
- What are the triggers of teacher sensemaking instances that relate to science teachers' additive learning or assimilation?
- What are the triggers of teacher sensemaking instances that relate to teacher transformation in classroom practices to implement the program with high fidelity?

Why study the sensemaking of teacher professional development program? To better understand the impact and influences on the implementation of the program, it is crucial that we explore the mechanism by which the implementing agents understand the program and connect their understanding of the program to the classroom practices (Coburn, 2001; 2005; Coburn & Stein, 2006; Coburn & Russell, 2008; Cohen, 1990; Quinn, 2009; Spillane et al., 2002). Teachers as the implementing agents of the professional development program are the sensemakers who interpret, adapt, and even transform the program into their classroom. Many researchers begin to suggest that studying teacher sensemaking of their professional development experiences is much needed and long overdue since there is very little research on this topic (Quinn, 2009; Spillane et al., 2002).

As explained in Chapter 3, this research uses a case study method of qualitative research that adopts a constructivist paradigm (Creswell, 1998; Stake, 1995; Yin, 2003). This research aims to facilitate exploration of phenomena within teachers' contexts by using a variety of data sources such as teacher surveys, teacher professional development observation, classroom observation, teacher interviews, teacher self-reports, and artifact collection supplement each other to promote deeper and fuller descriptions of answers to research questions. The case study covered teachers' 15 months of sensemaking and practices in the classroom, from when they participated in the professional development program in the summer of 2016 and their implementation in the classroom a year (2016/2017).

The primary goal of the research's professional development program is to train teachers to develop a community of inquiry to support students doing the most important job—making sense of the classroom content. The theory of action underlying the professional learning experiences stress that science learning should be situated in an environment of collaborative inquiry. Teacher participants are trained and expected to

implement the pedagogical practices and reasoning that are evidenced in the core intervention components. These core intervention components are, (A) focus on conceptual understanding of learners, (B) emphasis of collaborative inquiry and sensemaking of learners, (C) focus on learners' thinking, and (D) reflection on teaching (teacher) and learning (students). Appendix G showed the critical features of each core intervention components when teachers are implementing them in the classroom.

These four reform-oriented core intervention components of the professional development program (MSS) evidence the common critical features of inquiry-based instruction. More importantly, the components address the four sets of core practices of Ambitious Science Teaching (AST) that center on intellectual engagement and attention to equity (Stroupe, 2014; 2016; Windschitl et al., 2011). The four sets of Ambitious Science Teaching core practices start with designing a unit of instruction that focuses on coherent understanding of important science ideas (core intervention component A and B); then focuses on making students' current knowledge and thinking visible (core intervention component C); teachers then guide students to talk about the investigations or data or readings (core intervention component B); and finally scaffold students' ideas or efforts so that their conversations are evidence-based in order to put everything together near the end of the lesson (core intervention component C and D).

AST aims to get all students to understand important, big ideas in science, participate in the discourses of the discipline and solve authentic problems (Lampert & Graziani, 2009). Ambitious science instruction scaffolds students' learning of science-as-practice as they act as epistemic agents in their learning (Stroupe, 2014; 2016). In addition, the classroom is not just a learning place for students, but for teachers as well. Students' conversation, discussion, artifacts, and questions arising in the classroom are valuable resources for teachers' actions as well as learning. Learning from teaching is best achieved

through systematic cycles of inquiry into practice and using evidence generated by these examinations to re-shape instruction (Jacobs, Franke, Carpenter, Levi, & Battey, 2007).

The MSS program is evidence of the reform movement in science education that highlights the two key qualities of ambitious teaching (Windschitl et al., 2012). First, it stresses the importance of teachers' instructional practice that is guided by students' emerging needs and ideas. Second, teachers work with students' ideas and needs over time. Teachers use students' science ideas (incomplete or complete) as resources for the purpose of adapting their instruction. The teacher is not "fixing" the tentative ideas, rather he/she is constantly involved in the process of revising, decision making, and scaffolding to revisit and deepen students' understanding as they engage in the authentic work of investigation and negotiation (Windschitl et al., 2012).

Teachers who experienced the four core intervention components themselves are prepared to provide students science learning experiences by giving them authority and agency in their own learning. For example, teachers will allow and provide an environment for students where they can make their thinking visible using conversation, collaboration, manipulations of data, negotiation of meaning with others, and metacognition. Students will be presented with situations, data, activities, discussion, and investigations, which they will be pushed into a period of not knowing the answer but will be supported by the teacher to explore and build upon their prior knowledge toward a more complete and robust understanding of the science concept.

This research examined a more fundamental and practical but yet less explored aspect of educational professional development program implementation—the sensemaking of the implementer of the professional development program (Coburn, 2001; Coburn, 2005; Roehrig et al., 2007; Spillane & Anderson, 2014; Spillane et al., 2002; Quinn, 2009).

FINDINGS AND DISCUSSION

The main research question is, "does a teacher's sensemaking influence their implementation fidelity? If so, how?" Before begin the discussion of this question, following are some of the important findings of this research.

- Six common triggers of teacher sensemaking instances.
- Four triggers of teacher sensemaking instances that related to teachers' additive learning or assimilation, and thus low implementation fidelity.
- Four triggers of teacher sensemaking instances that related to teacher transformation of practices, and thus high implementation fidelity.
- The connectivity between teacher sensemaking and implementation – the higher the frequency of teacher sensemaking instances, the higher the implementation fidelity.
- The four orientations of teacher sensemaking instances with regards to implementation practices.
- The importance of scaffolding tolls in reform-oriented instructional approach.

What are the common triggers of teacher sensemaking instances during and after their professional development?

Case analysis revealed that that there were six common triggers of teacher sensemaking instances shared by all teacher participants, (i) the value of professional development in their classroom, (ii) their emotions and feelings regarding the implementation of the program, (iii) the relevance of the professional development program to students' needs, (iv) the relevance of the professional development to state standards, (v) the implementation network that operates within school/campus and, (vi) lack of time.

Weick (1995) explains that people punctuate the flow in predictable ways and neglect a large portion of it. As flows of events increase and the load of information is abundant, people begin with the omission, then move to greater tolerance of error, filtering, bracketing, chunking, and abstracting (Miller, 1978; Powell, 1985; Weick, 1995). Those punctuations they do make highlight portions of the residual and heighten its impacts on subsequent sensemaking. Common among sensemaking, interruptions and arousal influence sensemaking. As Weick (1995) observed, sensemaking is triggered by a failure or any kind of cues to confirm one's self. In other words, these six common triggers of teacher sensemaking because it poses potential threat to teacher self-identity.

As teachers implement the program's ambitious approach in the classroom, the principles of the reform-oriented and student-centered approach will challenge their current ways of doing things in the classroom, such as how do they interact with students, interact with co-workers, school administration, and many more. They started to question their roles, responsibilities, and obligations. They are challenged with the construction of a new identity because the reform-oriented pedagogical approach requires them to think and act differently than they have in the past (City, Elmore, Fiarman, & Teitel, 2009). In general, teachers in the traditional classroom play a different role compared to the student-centered classroom. For example, the teacher is not the only source of content knowledge in reform-oriented pedagogical practices. Instead, students and teachers interact with the content equally. The task is central to this interaction (City, Elmore, Fiarman, & Teitel, 2009).

Teacher identity construction meets the needs for self-enhancement, self-efficacy, and self-consistency (Erez & Earley, 1993). When one or more of these come under threat, people are triggered to engage in sensemaking around the sources of threat, acting so as to restore their identity (Maitlis & Christianson, 2014). Teachers make sense of these six cues

uniquely depending on how they view and react to such cues in order to restore their identity.

Alan thinks the program is a great opportunity but the program's approach to implementation is too challenging, problematic, and ambitious. To restore his identity, he continues to make sense of the program by implementing what he is able to and familiar with at the moment. Such addition of a new strategy (gallery walk) to an old practice (additive learning) meets his need of self-consistency. He maintains his identity as the sources of knowledge in his classroom by implementing the program superficially.

However, Alan believes the program's reform-oriented approach and ambitious teaching practice is the right direction to move forward in his teaching career. He is determined to become an effective teacher in the student-centered classroom. His self-efficacy and self-enhancement convince him to implement a few features of the program's core intervention components B at a time. Gradually, his implementation fidelity of core intervention component B improves substantially. He also gathered positive reaction from students and pleased with the results.

Lily (who rejects the program implementation) is satisfied with her current classroom practices, as it meets her students' needs, campus expectations, and also aligns with her current collaboration practices with her teams and department head. She does not see any need to change her current practice toward a more reform-oriented approach or ambitious teaching practices. Like Alan, she sees the program's approach implementation as challenging and demanding, but unproblematic. The implementation is unproblematic because Lily does not think the implementation is needed and there is no "problem" with her current practices that need solving. In addition, therefore, to restore her identity, she passed the program and thus the source cues to another teacher in her campus. Petriglieri

(2011) discussed that when a well-established identity is threatened, sensemaking is more likely to focus on the importance of that identity, and will reduce the impact of the threat.

In the other hand, the high-fidelity implementers, Julia and Kelly, see the implementation of the reform-oriented approach as not only essential but also continuing to help them solve problems in their classroom and improve their classroom practices. Thus, the key source of cues from professional development, in a way has helped Julia's and Kelly's identity construction to meet their needs for self-enhancement, self-efficacy, and self-consistency (Erez & Earley, 1993). They are overwhelmed with the problems that arise during sensemaking and implementation and they can't help but feel being challenged. Nevertheless, they did not stop there. In addition to interpreting the feasibility of the program approach in their classroom by reflecting and extracting cues from their classroom environment, they take action to create the desired environment and continue to implement and thus make sense from the program's approach. Instead of worrying about how the program's effectiveness can be measured (if possible) in the classroom, they are clear and certain how they can evaluate their current effectiveness based on students' reaction and feedback.

When people encounter moments of ambiguity or uncertainty, they seek to clarify what is going on by extracting and interpreting cues from their environment, using these as the basis for plausible cues that provide order and "make sense" of what has occurred, and through which they continue to enact the environment (Brown, 2000; Maitlis, 2005; Weick, 1995; Weick et al., 2005). Thus, sensemaking goes beyond interpretation. It involves active authoring of events and frameworks for understanding as people play a role in creating and constructing the very situations they attempt to comprehend (Sutcliffe, 2013; Weick, 1995; Weick et al., 2005).

What are the triggers of teacher sensemaking instances that relate to teachers' rejection of implementation?

Lily did not implement the program's reform-oriented approach in her classroom. In addition, she scored the lowest frequency of sensemaking instances. Although Lily has participated in a reform-oriented program twice, she hardly makes sense and implements the program approach. She explained that the implementation of the program was too complicated and labeled the program as "higher level." She shared that her students were very goal-driven, self-motivated, and high achieving. Even so, she doubted the program implementation would be worthwhile to change in her current practices. She felt that her current practices meet her students' needs, as well as her team's and campus's norms and expectations.

Nevertheless, Lily voiced her concern about the program. She was unable to make sense of the core intervention components because she was uncertain of her role and responsibilities if she were to implement it. The professional learning experiences and her sensemaking of the programs failed to provide her with a concrete understanding of her roles and instructional task to implement core components. Due to such uncertainties, Lily refused to implement as she sees no need to change her current practices, especially when she lacked clarity regarding how to measure her own effectiveness during her implementation, and more critically, how to evaluate students' understanding.

Research on how sensemaking is accomplished emphasizes three main sensemaking moves. These are noticing or perceiving cues, creating interpretations, and taking action (Rudolph, Morrison, & Caroll, 2009; Weick, 1995; Weick et al., 2005). Failure to take action and implement the program in the classroom only allows Lily to interpret the reform-oriented program. However, her interpretation of the program was limited to a few strategies that she was already familiar with, such as graphic organizers.

Teachers usually attempt to make sense of the education reform in terms of their own practice and what is comfortable for them (Schmidt & Datnow, 2005). In Lily's case, she used the graphic organizer separately from the program's core intervention components, she added the familiar strategy into her existing practices (Hill, 2001). This led her to miss the unfamiliar and more fundamental transformations that are required by the reform-oriented and ambitious pedagogical approach (Spillane et al., 2002).

To sum up, Lily's rejection of program implementation was caused by two components. One, the program and its reform-oriented approach was unable to change Lily's current identity as a teacher in the conservative classroom that operates as information delivery system. She is glad that the program has improved her content knowledge so she can better make sense of the content and present it to students. Plus, she sees no problem in her current state of teaching and thus no need to change. Two, although the cascade model of professional development program (Hayes, 2000; Griffin, 1999) created a certain level of ambiguity and uncertainty in Lily's learning, unfortunately, the amount of ambiguity and uncertainty was only sufficient to improve Lily's content knowledge but failed to change her pedagogical practices and implementation.

What are the triggers of teacher sensemaking instances that relate to science teachers' additive learning or assimilation?

Alan admits he is not a risk-taking person and his sensemaking and implementation was impeded by many factors. He initiated his implementation by incorporating the gallery walk introduced in the program's approach. However, gallery walk does not signify the program's reform-oriented approach. It is one of the many strategies to support students' various modalities of learning and literacy skills. The case and cross-case analysis revealed

that some teacher sensemaking instances highlight certain cues that prevent the teacher from transforming their current practices, instead leading teachers to assimilate their experiences into their current practices. In Alan's case, these cues are (i) abundance of information gained from professional learning experiences, (ii) lack of clarity regarding his roles and responsibilities to implement the core intervention components, (iii) lack of clarity about setting and environment during implementation, and (iv) success measures for the implementation are lacking.

First, how the teacher views and takes on the information load plays an important role in continued sensemaking and implementation (Weick, 1995). The information load is the cue that triggers people to make sense. For example, Alan was overwhelmed by the abundance of information he gained from the professional development program and how complicated it is to bring it back to the classroom. Lily does not think the information she gained from the program is a "load" to implement.

Once something is labeled a problem, that is when the problem starts (Weick, 1984; 1995). To label something undesirable as a "problem" is to imply that it is also something to be solved. Lily does not see abundance of information as problematic because she sees no need to make sense of the information. Alan views the abundance of information as problematic during his implementation and sensemaking of the program's approach. The vital difference between Alan and Lily is that he is unsatisfied with his current classroom practices. Alan sees the need and wants to explore how the program can help improve his classroom practices, support his students' needs, and motivation level.

Second, the creation of setting and environment is important for sensemaking. In life, we often produce the environment that we face (Pondy & Mitroff, 1979 as cited in Weick, 1995). Sensemaking and interpretation are sometimes used interchangeably, but sensemaking goes beyond interpretation. It involves the active authoring and creation of

events and frameworks for understanding. Sensemaking is when we play a role in constructing the very situations that we attempt to comprehend (Sutcliffe, 2013; Weick, 1995; Weick et al., 2005).

Alan gathered that his classroom and students' motivation level was neither productive nor supportive to implement the program approach. He is unclear as to what kind of setting and environment will support the program's approach to implementation. When conflicts happen between his classroom environment and the program's approach, Alan reduces the conflict by defaulting back to his current practices that align with his campus culture and norms. In addition, because Alan also lacks the frame of reference and information to evaluate the effectiveness of his implementation, he does not have the confidence to let his students be in the driver's seat during lessons. His classroom practices and implementation fidelity showed that he struggles to provide students with the environment where students are encouraged to drive the conversations and build upon one another's ideas. Thus, Alan's implementation of core intervention component C was very low.

Instead of taking action by starting to establish the environment, Alan focused his efforts on analyzing what needs to be changed. How much did he need to change in his classroom and practices? How much difficulty would he encounter? How hard is it to support students' ongoing changes in thinking? How much time does he have? Which students will struggle? And, how much risk would he be taking before he can achieve that? Alan listed the pros and cons. He then critically evaluated the cons and felt overwhelmed by his responsibilities.

Next, the lack of success measures of program's implementation can be problematic to teacher sensemaking and implementation. Alan is unsure how the effective implementation of the collaborative inquiry approach and productive science conversation

look like in his classroom. He does not know how to assess his implementation, his effectiveness, his students' productivity during his implementation, and his students' understanding if he implements the program's approach. He admits that he can only refer to paper and pencil tests to be sure.

Last but not least, due to the lack of success measures for the program's implementation, Alan is uncertain and confused about his roles and responsibilities to implement the program. Alan thinks that the professional development experience does not give him a clear, defined set of activities, instructional tasks, responsibilities, and guidelines that he is expected to perform. He felt uncertain about making good decisions in selecting the materials and activities. He wished that he were able to see how the program approach is implemented in classrooms with 13-year-old children, that doing so would better guide him to know what to tweak or adapt in order to take what he learned into the classroom.

Nevertheless, the most interesting finding is Alan's substantial improvement of implementation fidelity in core intervention component B. More interestingly, the high-fidelity implementers (Julia and Kelly) did not show substantial improvement in their instructional practices as regards core intervention component B. Alan's improvement, on the other hand, is well above a standard deviation. Note that Alan neither evidenced high fidelity in the implementation of core component B in all of his classroom observations, nor is his implementation of all critical features in core intervention component B high (see Appendix K). The critical features that showed significant improvement in Alan's implementation fidelity are (i) students' inquiry and observation of scientific phenomena using hands-on investigation and data, (ii) students finding patterns and connections of data and science ideas, and (iii) students representation of phenomena and ideas. In common, these critical features focus on the hands-on scientific investigation. By focusing on only a

few critical features, Alan's practice and implementation increased from a minimum of 1.4/4.0 in the first classroom observation to 2.8/4.0 at the end of the year.

Although both the high-fidelity implementers (Julia and Kelly) are new to the program and its core intervention components, the program approach that focuses on student collaboration and hands-on investigation is not unfamiliar to them. They both admitted that they participated in the professional development program in the summer to polish their skills in their efforts to progressively establish student-centered classroom practices. Thus, their implementation fidelity started higher and continued to improve.

It is interesting that Alan's improvement in implementation fidelity of core intervention component B surpasses the high-fidelity implementers. Why? One, Alan truly believed the reform-oriented pedagogical approach is the right direction to move forward in his career. More importantly, he sees the need to change his current teaching practices. As a teacher who just started to establish a student-centered classroom, he had a lot of room to improve. He gradually pushed the program's collaborative inquiry out with hopes he could improve students' low motivation level and support their ongoing changes in thinking. As he changed his practices, a little at a time, he gathered information and students' feedback from the new environment that he created in his classroom. The gathered information will then become the input factors and cues of his next steps.

Two, Alan implemented the core intervention component B without using the prescribed activity from the program. His concern about how the content and activity of the program did not align with the TEKS led him to improvise by incorporating a new activity. He began to implement just the core features without the prescribed content and activities from the program. His modification indicated that his sensemaking of the program was challenged by the misalignment of the program's big ideas to the state standards and district timeline.

Three, the teacher has to implement the core components of the program in order to start, and more importantly, to continue making sense of the core components of the program. This finding is evidenced in the case of Alan. Alan is an experienced science teacher with 22 years of teaching experience. Yet the change to a reform-oriented teaching approach does not happen easily. Just participating in the professional learning is not sufficient. The action of doing, creating, and constructing his/her own way of implementation and sensemaking is fundamental and cannot be taken for granted (Quinn, 2009; Spillane et al., 2002).

This is an interesting finding because it shows that changes from the teacher who is comfortable with teacher-centered classroom practices by default requires effort and time (Windchitl et al., 2011). The teacher has to understand and believe in the student-centered instructional approach. He/she has to really understand that the shift and the changes are attainable and valuable. Teachers need to be prepared and well supported. Especially when the teaching expectations envisioned in an ambitious pedagogical approach require deeper knowledge of subject matter, as well as pedagogical decision-making that is more complex and contingent on changing unpredictable classroom situations than either traditional teaching or direct instruction methods (Spillane & Thompson, 1997).

Also, it is the accumulation of each small step that counts. Alan takes small steps at a time to implement. These steps might seem trivial at times in the beginning, but with time, the teacher accumulates more information from the environment he/she created. With aggregated experience and information, they will be more skillful and selective. More importantly, they will be able to keep making sense of the core components as they implement. Slowly, the teacher will get there. In the meantime, professional developers can support teachers by creating a focus group or discussion group where teachers can check in periodically to dissect their efforts, to navigate with others, and to have a collective

reasoning environment where the teacher continues to make sense of the program's core components.

What are the triggers of teacher sensemaking instances that relate to teacher transformation in classroom practices to implement the program with high fidelity?

On top of the common cues of sensemaking instances faced by all teachers, Julia's and Kelly's discussion of their professional development experiences and implementation are closely tied to their (i) availability and accessibility to the instructional resources, (ii) accessibility to the experts, (iii) implementation progression, and (iv) availability of planning time.

Besides the common cues of sensemaking instances that arise from all teacher participants, note that Kelly and Julia both speak about their efforts to solve problems. They go beyond asking, "What is the story here?" to "What can I do?" In addition, they valued collaboration. Besides of "What can I do?", they continue their effort of sensemaking by asking "What can we do?"

Kelly and Julia's diagnostic frame of sensemaking about the program was focused more on how the program provides opportunities to improve their practices, and less focus on how the program implementation is a challenge to overcome. The discussion of their professional development experiences and implementation are closely tied to how they can access the program's resources, seek advice and connect with experts and other teachers, and their own experiences and progression in the implementation of a reform-based instructional approach as a way to establish student-centered classroom. The implementation of the collaborative inquiry approach of the program is part of their effort

to continue developing, polishing, and refining their practices in a student-centered classroom.

In addition, Kelly and Julia's sensemaking and implementation of the program showed an important disparity compared to Alan and Lily. Rather than focusing on analyzing how the program fits into their current environment, they take on author and creator roles to create and establish the environment that fits the program implementation. For example, Kelly institutes citizenship and collaborative roles for students in the classroom to increase the effective implementation of program's reform-oriented approach. Julia creatively combines two reform-oriented teaching approaches, MSS and ADI (Sampson et al., 2016). She extracted the essences of two approaches that work in her classroom and timeline and fused them together to teach the big ideas of science.

Similarly, they both take action and solve the problem by creating what they think would be a "productive" environment for the program implementation. Distinctively, there is no definite way to create this environment; they both take a different approach. But they are able to extract cues from their current environment and the environment that they created and continue to implement and make sense of the program.

The most interesting example of transformation is when Kelly showed a substantial improvement of implementation fidelity in core intervention component C that focuses on students' thinking, which publicly frames and examines students' conceptual change and how students make sense of science concepts using different learning modalities. Kelly admitted that her teaching practices changed after the professional development program. At her first interview, Kelly stated that, "the first time learning about that I realized, oh yes, I should be addressing those misconceptions to them (students), I should be trying to figure that out before I do the lesson."

At the beginning of implementation, Kelly emphasized identifying most (if not all) students' misconceptions. She felt the need to fix and eliminate it as soon as she could. She was inclined to confronted students' misconceptions if she identified any students encountering them. But later, Kelly began to look at students' misconceptions differently. She looked at them as impending complete conceptions instead of errors or faults that "she" needs to address and eliminate. During the last classroom observation, she responded that,

> So, looking at misconceptions as a precursor helped guide my instruction a little bit. Now… it is more, just understanding like, kids are going to have misconceptions and you need to be aware of them. But, let them work on it. Let them talk and figure it out. This is like a huge thing for me now.

At the end of the school year, Kelly responded to specific student difficulties and ideas by probing nuances of student understanding, posing follow-up questions based on student responses, and improvising and adapting activities as needed. She provided various opportunities, and interaction for students to figure out the "insufficiencies" of their current notions and build toward a complete understanding of science content.

Ambitious teaching implies generative learning (Stroupe, 2016) when teachers constantly use resources to support students' disciplinary thinking, to create opportunities to unearth and support students' emerging and changing ideas, and to elevate science ideas to the public plane of classroom interaction for the purpose of revising the ideas over time (Franke, Carpenter, Levi, & Fennema, 2001; Windschitl, Thompson, Braaten, & Stroupe, 2012). Stroupe (2014) added that working on students' ideas does not imply "fixing misconceptions"; rather, teachers use students' science ideas as resources for the purpose of adapting instruction to provide opportunities for students to revisit and deepen their understanding.

Kelly's case also proved that change needs time. Despite being a high-fidelity implementer, Kelly, who thinks she has good questioning skills, still struggles at first

regarding how to use students' thinking as a resource. In order to see and sustain changes in teachers' practices, the professional developer needs to provide teachers with ample time to make sense of the program, a platform or support network so teachers can discuss their implementation, and coaching whenever is needed (Loucks-Horsley et al., 2010).

DOES TEACHER SENSEMAKING INFLUENCE TEACHER IMPLEMENTATION FIDELITY?

In order to answer this research main question, this research wants to address some questions that arise along the research. First, why do teachers make sense of their reform-oriented professional development program?

Sensemaking starts with chaos or when the current state of the world is perceived to be different from the expected state of the world or when there is no obvious way to engage the world (Weick et al., 2005). In such circumstances, there is a shift from the experiences of immersion in endeavors to a sense that the flow of action has become unintelligible in some way. A central theme of sensemaking is that people organize to make sense of equivocal inputs and enact this sense back into the world to make that world more orderly (Weick et al., 1995). To make sense of the disruption, the teacher looks first for "reasons." What kind of reasons? Any reasons that will enable the teacher to resume the interrupted activity and stay in actions.

Using the teacher sensemaking frames, case analysis showed that these reasons for sensemaking are pulled from (i) the progression of current plans, (ii) expectations and success measurement, (iii) institutional constraints, and (iv) acceptable justifications and traditions that are inherited from the campus. Cross-case analysis of two groups of teacher participants showed that teachers with higher implementation fidelity (Julia and Kelly) drew their reason for sensemaking with different perspectives and attitudes as compared

with teachers with lower implementation fidelity (Alan and Lily). The professional learning experiences created some sort of disequilibrium and disruption for teachers. In order to resume and reduce the interruption, teacher participants showed two different attitudes and reasoning perspectives. They were, "I like it, but…" and "I like it, so how do I make it work."

Teachers with the "I like it, but" attitude and reasoning perspective showed somewhat critical yet passive attitudes toward the professional development program. They interpreted the program superficially. Their interpretations were limited to certain strategies (such as gallery walks and graphic organizers) that teachers were familiar with or they viewed the strategy as a "stress-less" add-on to their current classroom practices. Nonetheless, teachers evaluated the program critically. Their criticisms were mainly about the effectiveness of the program based on (i) the needs and motivation level of their students, (ii) state standards, (iii) district curriculum and timeline, and (iv) their current grade and departmental collaboration norms.

Both Alan and Lily's implementation fidelity is low and their classrooms did not demonstrate the features of the program's core components. Although they agreed with the program's approach and indicated positive affinity toward the program's core components, Lily and Alan hardly showed any implementation of the program's core intervention components and their sensemaking of the program was very limited. To resume their activities in the classroom, Lily and Alan's continuous sensemaking of the reform-oriented program's approach was "impeded" and "limited" by two reasons.

This first reason was institutional constraints such as state standards, district curriculum map, and their school's policies and agendas. They found it hard to make sense and implement the program's approach because of the various institutional constraints that caused by campuses' agendas as well as state and district agendas and curriculum. On top

of that, they both shared that time was limited because they were concerned about their accountability to prepare students for the STAAR assessment. They felt like implementing the reform-oriented instructional approach is another obstacle. Alan explained, "I think that the program's reformative approach is awesome to get done. But, I have to say that the time it takes to create that (safe) environment is time consuming."

The second reason is the justifications and traditions that teachers inherited from their campus culture. In other words, the school's norms and culture played an important role in how teachers took action and made sense of their professional development experiences. Even though Alan and Lily agreed with the potential and benefits that the reform-oriented instructional approach will bring to their classrooms, they defaulted back to their teacher-centered classroom practices because their current teaching practices were supported and resonated with the campus norms and culture. Says Alan,

> So the times that I have branched out to be more student-centered, it has not worked really well, mostly because I still come back to this default position (of teaching). So, it really does need to develop over time.

Alan struggled to implement the program's approach in his classroom despite his "buy-in" and "hopeful" attitude to implement the program. His network of implementation overshadowed his "hopeful" attitude. Alan's network of implementation consisted of his grade-level team, departmental team, school administration, and district administration. For example, Alan shared that he felt more comfortable with his campus's Strategic Instructional Model (SIM). His department and grade-level coworkers were using that as a way to follow the district and state timelines. It was basically a concept map or model of how the bigger science themes are broken down into smaller objectives with suggested timeline and activities.

Along those same lines, Lily also defaulted herself back to what she and her peers were accustomed to on her campus. Unlike Alan's campus, Lily's campus is a high-ranking middle school in the district. Her campus was well known for their high achievement. Students on Lily's campus were motivated and goals-driven. Lily has a very good relationship with her team and coworkers. She collaborated and planned with her team. So, she felt more comfortable to plan and enact the same things with her coworkers. She spoke highly of her team leader. She admitted that her decisions and practices stayed very close to their team planning. She explained her team planning:

> We take the TEKS and we dissect them and know what students need to know exactly, then we try to find a lab that coincides with that. Our particular district actually does it like Unit 1, this is the TEKS that you are going to teach, like they break it down more for us and we could come up with lessons for that. It flows really well. I like that.

Lily's planning and teaching practices are certainly based on the norms and culture of her team and campus. She felt more comfortable knowing that her students received what all other seventh graders are receiving.

Both Julia and Kelly, the high-fidelity implementers, demonstrated the "I like it, so how do I make it work" attitude and reasoning perspective, which is more proactive than the critical yet passive reasoning. Such reasoning style showed a blend of action and creation, they creatively and progressively make the approach work in the classroom.

To resume activity in the classroom, Julia and Kelly's sensemaking reasons also included how their implementation and continuous sensemaking of the reform-oriented program's approach were "limited" but not "impeded" by institutional constraints and institutional norms and traditions. They were determined to make it work in their classroom and therefore, they looked beyond constraints. In order to reduce the interruptions, they continued to make sense of the program by focusing on their continuous plan to establish

a student-centered classroom. Subsequently, their reasons to make sense of the program implementation were based on their professional growth plan and expectation of establishing a student-centered classroom. The professional development program that focuses on a reformative instructional approach fit into their professional improvement progression.

Julia and Kelly also shared their thoughts about their vision for their successful implementation in the classroom. That is what they will observe and how they can gauge their effectiveness of the implementation. Although they did not give the details of how they are going to measure or quantify their effectiveness, they have a clear expectation of what the productive science classroom and student participation will look like in the classroom. For example, Kelly said,

> So, it is looking at the person as a whole. Whether they are more confident, whether they can problem solve with other people, whether they can communicate in a different kind of group, whether they can they can put themselves out there and be ok if they are wrong, that's what I am looking for, as well.

And Julia stated that,

> Things like… spending a day on it looking at the data, analyzing the data and really come up with the conclusion themselves, having the conversation with each other will put the information in their head in a way that it will never leave.

If a teacher has reasons to make sense of their professional development program so they can stay in action, what are some factors that make the difference in their implementation fidelity of the program's core intervention components? To answer this, the next part of this chapter will discuss why teachers' sensemaking and implementation practices in the classroom can be treated as reciprocal exchanges between actors (enactment) and their environments (ecological change) that are made meaningful (selection) and preserved (retention) (Weick, 1979; Weick, 1995; Weick et al, 2005).

Figure 11 shows that teacher sensemaking is a reciprocal relationship between environments that cause ecological change and the teacher's implementation (enactment). This figure is adopted from Weick (1979). As time progresses, the causal loop between environment or ecological change and enactment becomes less uncertain and teachers are able to select the more profitable and productive action-reaction causal loops. Eventually, certain causal loops will be preferred and retained. Based on the research question of this study, the relationship between teacher sensemaking and implementation is discussed in the ecological change and enactment (teacher implementation).

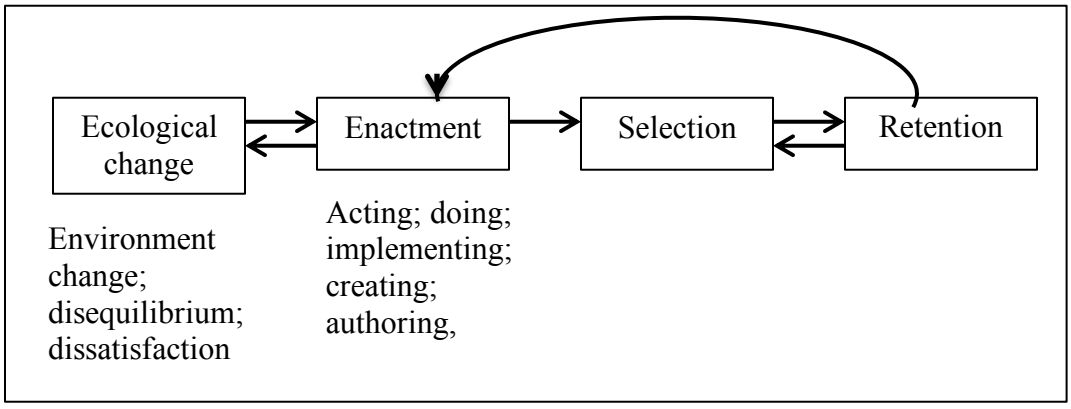


Figure 11. The relationship among enactment, organizing, and sensemaking (Weick, 1979, p. 132)

Ecological change.

Sensemaking starts with chaos or when the current state of the world is perceived to be different from the expected state of the world or when there is no obvious way to engage the world (Weick et al., 2005). In such circumstances, there is a shift from the experience of immersion in endeavors to a sense that the flow of action has become unintelligible in some way. Weick (1979, 1995) and Weick et al. (2005) called such

alteration in the flow of the sensemaker (also known as the social actor) as "ecological change." Ecological change can be summarized by the words of disequilibrium. These moments of disequilibrium provide the implementable environment for the teacher to make sense of the program's core intervention components.

The research revealed six common triggers of sensemaking instances that were shared by all teacher participants. They are, (i) the value of the professional development in their classroom, (ii) their emotions and feelings regarding the implementation of the core components, (iii) the relevance of the professional development program to students' needs, (iv) the relevance of the professional development to state standards, (v) the implementation network that operates within the school and, (vi) time constraints. What do these triggers of sensemaking instances mean in the context of teacher sensemaking and implementation?

The information, skills, and knowledge gained from the professional development is a complex mixture of quantity, ambiguity, and uncertainty of a variety of information that teachers are forced to process. As the load increases, people take increasingly strong steps to manage it (Weick, 1995). With the increase in complexity, the teacher will perceive an increase of uncertainty because a greater number of critical features of all core intervention components interact in a greater variety of ways.

Not only does the teacher face the high complexity and uncertainty of the information gained from the professional development, they also need to confront the lack of clarity or inconsistency of causality or intentionality in real classroom implementation – ambiguity. They need to tackle the ambiguity of how to translate and adopt the core intervention components that they learned in their professional learning environment into the real classroom. Undeniably, the professional learning environment does not match the teacher's own classroom environment. There are differences in audience, room set-up, the

facilitators, the conversation, and the interactions that teachers need to evaluate and take action when they are to implement the core components.

Ambiguity arises when teachers have to deal with ambiguous purposes where intention and causality cannot be specified clearly and the outcomes have fuzzy characteristics and implications (March, 1994 in Weick, 1995). For example, Alan dealt with ambiguity during his sensemaking and implementation. Ambiguity associated with Alan's implementation of a program means that the assumptions necessary for rational decision-making are not met (Weick, 1995). Thus, he turns to something more concrete or already in place. Extracting cues from all the factors, issues, and challenges from his environment, Alan critically analyzes them. However, the problem for Alan is not that the real world is imperfectly or incompletely understood and that more information will remedy that (Weick, 1995). The problem is that the information he has in hand does not resolve his understanding/misunderstanding.

Descriptions of conditions for sensemaking refer just as often to uncertainty as to ambiguity. The idea of uncertainty can be captured by ignorance, and unknown and imprecise extrapolations (Weick, 1995). Teacher lack the important information and frame of reference to transfer the core intervention components and their critical features into the classroom.

Therefore, the two common types of sensemaking occurring during teacher sensemaking are uncertainty and ambiguity. In the case of ambiguity, teachers engage in sensemaking when they are confused by too many interpretations; whereas in the case of uncertainty, they do so because they are ignorant or unaware of any interpretation (Weick, 1995). The six common triggers of teacher sensemaking instances affect what teachers notice and ignore the core intervention components as well as its critical features, and thus triggered their sensemking. They can either help or hinder the implementation.

The difference between the two low fidelity implementers (Alan and Lily) is that Alan knows and deeply believes that the critical features of the core intervention components will benefit his students. He was frustrated and overwhelmed as he pushed the student-centered approach out in his classroom. He struggles to implement the program with full fidelity due to his concerns that the program's content and prescribed activities are not aligned with the state standards. To overcome this issue, he uses different activities and invites other teachers outside his usual implementation network to implement just a few of the critical features at a time, ignoring the content of the program.

To sum up, when teachers encounter uncertainty and ambiguity; these are indications that they are trying to make sense of the program. They are trying to figure out what the program is, what they are supposed to implement or bring into the classroom? So, what's next?

Sensemaking is the reciprocal exchange of the actors (who enact) and their environment (where the ecological change happens). So, next is the action of implementation or the enactment, which is what teacher will do with the training they experienced from the professional development program.

Enactment.

Enactment or implementation is one of the most important parts of sensemaking of actor's (teacher's) environment or ecological change. I will discuss the importance of sensemaking and implementation using the question, "How do I know what I do until I see what I did?" emphasizing the teacher's role of doing and enacting during the sensemaking process. If counted, this question repeats the pronoun, "I," four times. These references to "I" are of the person who is doing the sensemaking, the sensemaker. Simple enough? Not

really. No individual ever acts like a single sensemaker (Weick, 1995). Identities are constructed and constituted through the process of interactions (Erez & Earley, 1993; Weick, 1995). Depending on who "I" am, the definition of "what is out there" will change.

Weick's theory of sensemaking and organizing showed the foundation of enactment, the action of implementation. Sensemaking is first and foremost the question of how does some "thing" become an event for the individual? Upon participating in teacher professional development, the teacher confronts the professional learning experience and their first question is, "What is the story here?" This question arises and brings the experience, which is the professional development program, into existence. Then, the next question follows. "What should I do with it?" By asking the next question, a force to bring meaning to the existence emerges. The teacher hopes to bring meaning that is stable enough for them to act in the future, continue to act, and to have the sense that they remain in touch with the continuing flow of experiences.

Weick et al. (2005, p. 131) stated that, "sensemaking unfolds as a sequence in which people concerned with identity in the social context of other actors engage ongoing circumstances from which they extract cues and make plausible sense retrospectively, while enacting more or less order into those ongoing circumstances." Weick (1995) explained this with the example of road construction. When a professional considers what road to build, they deal with a complex and ill-defined situation in which geographical, topological, financial, economic, community, and political issues are all mixed together. Once they have decided what road to build and go on to consider how best to build it, they may find problems they can solve by available resources. But, more than likely they will encounter the unexpected and find themselves in a situation of uncertainty. They have to pause. In any pause, "circumstances are turned into a situation that is comprehended explicitly in words and will serve as a springboard to action" (Taylor & Van Every, 2000,

p. 275). The professional will have to extract cues from the environment (new road) they created and take actions. In summary, only until the professionals take action of construction using the salient cues from road construction will it lead to the new roads. So, how does this apply to teachers' sensemaking of professional development program?

The case analysis and cross-case analysis found out that teachers' sensemaking of professional development is interconnected to their implementation. This means that teachers make sense of the program's core intervention components simultaneously while they implement it in their classroom. Equally important, the sensemaking and implementation processes are ongoing, interconnected, and parallel with each other. In fact, "enactment is one of the aspects that differentiates sensemaking from interpretation" (Maitlis & Christanson, 2014). Enactment of the program occurs while the teacher implements the PD program in their classroom. Instead of saying successful sensemaking leads to high fidelity (such as an event of implementation is an accomplishment of productive sensemaking), this research found that after the professional development program, teachers' sensemaking progresses concurrently as they try to implement the program in the classroom. Thus, to study teachers' sensemaking is not only to focus on how teachers make sense of the program; we must also study how they implement it in the classroom.

As long as the effort of program's implementation does not stop, teachers' sensemaking of the program will continue. As teachers implement the program's approach in their classrooms, they are creating the classroom environment where the act of implementation can happen. The term enactment or implementation contains within the actions of both teacher and the environment, and implies a co-creation of activities.

Over time, some activities of the enactments will prevail at the expense of others. During this process, teachers will be involved in some kind of arranging of the enacted or

implemented experiences to reduce their ambiguity and uncertainty. These are called "selection" and will be discussed below.

Selection.

After each round of implementation, the teacher extracts cues from their endeavors and selects useful as well as productive information to include in their next endeavor as they continue to make sense of the program approach. Weick (1995) stated that, "Only with ambivalent use of previous knowledge are systems able to both benefit from lessons learned and to update either their actions or meanings in ways that adapt to changes in the systems and its context" (Weick et al., 2005, p. 139). Weick's (1995) statement above can be summarized as "Selection." The enactment process incorporates the sensemaking activity of noticing and bracketing as the act of categorization. As such, the actor (teacher) begin to change the flux of circumstances into a more orderliness of situation and able to reduce the number of possibilities (Selection).

Teachers don't have to fully understand the program's approach to begin, but they will never achieve it without the act of "starting" an implementation. Plus, in sensemaking there is no end, as the end results are always evolving into the new beginning. Prior processes will feed into new processes and it starts all over again; sensemaking neither really starts nor ends. The teacher will eventually get familiar with the processes and environment and choose some of the ideal settings that they think are worth keeping. This process is called "selection" and it happens when teachers arrange and organize their enacted environment and experiences to reduce the uncertainties and ambiguities.

Each time teachers enact and create the environment, they become familiar with some uncertainties and ambiguity and get better at avoiding or solving them. Thus, teachers

get better at creating the "desirable" environment to make sense of the program and increase the implementation fidelity. Selection can be represented by some sort of causal loops, maps, or sequences that are built upon past experiences. Over time, certain selected causal loops will gain priority and consistency across different contexts. This causal loop will become the preferred causal loop and get "retained" in teachers' sensemaking activities.

Retention.

Retention is like the bank of all sensemaking process. It stores the successful sensemaking, including all the cues from the environment, the actions of implementation and enactment, and the creation of the environment. We store the preferred causal loop and it will usually act as another springboard for action.

To conclude, in order for teachers to make sense of the program, ecological change or disequilibrium occurring from the professional development is not sufficient. Enactment or teacher implementation drives everything else. With time and each trial, and the creation of "enact"-able environments of each implementation, teachers will get better at "selecting" the more productive action-reaction causal loop and learn to "retain" the preferred causal loop for the next action.

IMPORTANT FINDINGS

There are several unexpected and important findings arising from this study. One, teacher sensemaking and implementation should not be discussed separately; they progress side by side over time. Two, the research identifies teacher sensemaking orientation as

regards to their implementation fidelity. This research found that each individual teacher with a unique identity and working environment has different sensemaking patterns as they implement the reform-oriented practices. Three, the research found out that both teachers with high fidelity of implementation used scaffolding tool (such as CER) and students are clear of the procedures of the scaffolding tool that was adopted in classroom. Lastly, teacher sensemaking of ambitious teaching – ambitious sensemaking.

The interconnectivity of teacher sensemaking and implementation fidelity.

Case and cross-case analysis of the research found out that teachers' sensemaking of professional development is interconnected to their implementation. This means that teachers make sense of the program simultaneously while they implement it in their classroom. Disproving the hypothesis from pilot data and the four quadrants shown in Chapter 3 (see Figure 6), the implementation is not the product of sensemaking. Like the characteristics of generative learning (Franke et al., 2011; Jacobs et al., 2007; Stroupe, 2016), the sensemaking process and implementation process are ongoing and interconnected to one other. The graph in Figure 12 shows the average fidelity of implementation score of each teacher participant and their total instances of sensemaking recorded in the research.

Note that the more teachers talk the program into existence, the more instances they show of making sense of the program, and the higher their fidelity. The research suggests that as long as teachers sustain their efforts in implementing the program, teachers' sensemaking of the program will continue. Instead of saying productive sensemaking will lead to high implementation fidelity, this research suggests that sensemaking and implementation are continually improving alongside one another.

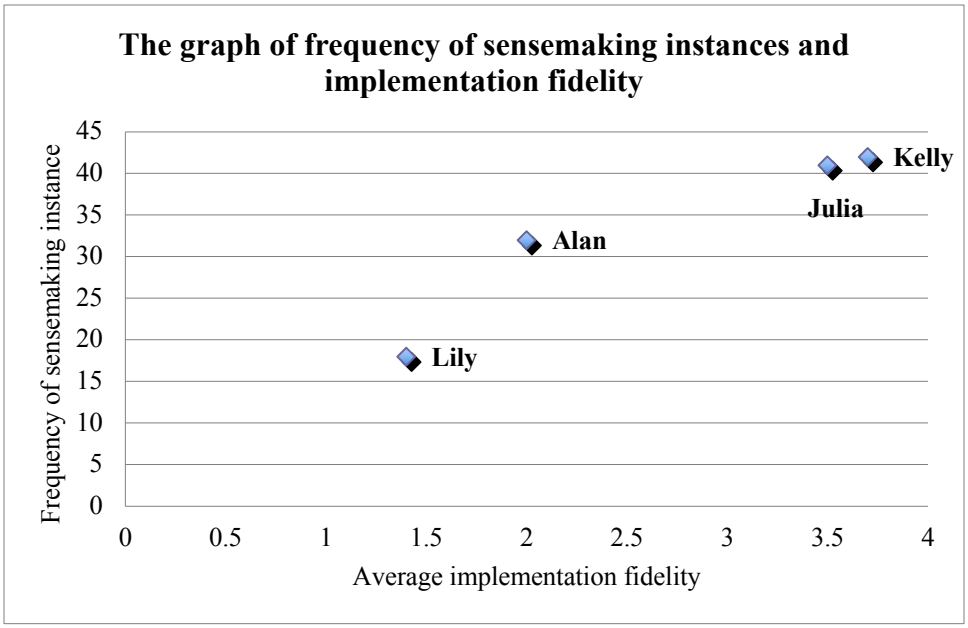


Figure 12. The graph of the relationship between teacher sensemaking and implementation fidelity.

Aware that this is a preliminary projection of an important finding; hence the relationship was shown in a dashed line. Note from the hyperbolic curve indicated the relationship between teacher sensemaking instances and implementation fidelity is positive. Also, as teachers become more skillful (high fidelity) at implementing the reform-oriented core components, their sensemaking processes become more stable with less increase in the number of instances. This is perhaps caused by what is explained as "selection" in Weick (1995). So, this research strongly suggests that more research is needed to study and explore the more comprehensive relationship between teacher sensemaking and implementation fidelity.

Teacher sensemaking orientation with regards to implementation fidelity.

Using case and cross-case analysis, the research identifies four types of teachers' implementation orientation as they make sense of the program. They are (i) passive distributive, (ii) critical evaluative, (iii) creative emergent, and (iv) transformative. Teacher participants with low fidelity of implementation are identified as having critical evaluative and passive distributive orientations. Teacher participants with high fidelity of implementation are identified as creative emergent and transformative orientation. Before we discuss the different sensemaking orientation of all teacher participants in more detail, the following are some general patterns that occur from the analysis.

In general, the low fidelity implementers tend to be insecure about their science abilities. Both Alan and Lily did not earn their degrees in science. Alan earned a business degree and Lily earned a degree in psychology. Alan explained that he is qualified to teach science based on his certification and his interest in science as he has a good logical apparatus to process scientific information. Lily, on the other hand, described how she can relate to students' needs and admitted that the program's content was too high level for her.

The high-fidelity implementers, Julia and Kelly, both have a solid science background. Kelly is very interested in space science and Julia in biology. They both spoke of how their specialty in science and science learning helped them to better support students' learning and classroom discussion. The high implementers feel more comfortable to let students explore because they can better grasp the situation of when to step back and let students explore, or step in to guide. Compared to Alan, Julia and Kelly feel more at ease to allow the students to do investigations, manipulations of data, and facilitate discussion. Although they have room for improvement in implementing the program's core components, they are more confident about their roles. On the other hand, Alan worried about his students' low motivation. He worried that if he let the students go on their own,

their learning would not be as effective. He believed that the students would not be able to make sense of the materials themselves.

In addition, the low-fidelity implementers (Lily and Alan) favored instructions that relied on a teacher-centered approach. Their classrooms evident the "information delivery system" rather than facilitation system to help students deepen their understanding (Stroupe, 2014). Their instructional practices are not aligned to the program's core intervention components in specific and the reform-oriented instructional approach in general. Over the course of the research, Alan got on board with implementing the program's core intervention approach.

The high-fidelity implementers (Julia and Kelly) favored the instruction that relies on a student-centered approach. In fact, Julia and Kelly participated in the professional development program with the goal of polishing their skills to establish a student-centered classroom. Thus, the core intervention components were not all unfamiliar to them. They struggled on a few certain critical features at first, but overall they were familiar with the student-centered instructional approach and the reform-oriented program's core intervention components.

Last but not least, school norms, school expectations, and the teachers' implementation network (departmental and grade-level teams) can reinforce or hinder the sensemaking and implementation of the program's core intervention components. The implementation networks of the low-fidelity implementers operate in school norms that focus on students' achievement and a teacher-centered instructional approach. Lily and Alan are from two different campuses that have different populations of students. Lily is teaching in a high-ranked middle school and Alan is teaching at a Title I campus. Yet, they both are teaching at campuses where students' achievement in district assessments and state tests are well monitored. Their grade- and departmental-level coworkers adopt a

teacher-centered approach, follow strict district timelines, and adhere to the state curriculum. Thus, they tend to default to a teacher-centered instructional approach because they feel more supported by their campus and co-workers. On the other hand, the high-fidelity implementers are teaching on campuses where a student-centered approach is a norm in teachers' implementation practices.

Passive distributive: Lily's sensemaking and implementation orientation.

Even though this is the second time attending the same reform-oriented program, Lily's implementation fidelity of its core intervention components was minimal. She describes the program as higher level and will not work for her and her students. She sees no need to change her current practices and thus she sees no need to make sense of the program. Very passively, Lily's sensemaking instances were mainly focused on the fact that the content was not relevant to her 7th-grade classroom. She hardly discussed the curriculum approach or its core intervention components. She shared that, "I do like (the program)! The only thing with the program is that I don't teach that stuff. But, the good thing is I take it to the 8th-grade teachers." This response indicates that the professional development program, which Lily attended twice, failed to bring significant change to Lily's classroom instructional practice.

Critical evaluative: Alan's sensemaking and implementation orientation.

This research categorizes Alan's implementation orientation whilst he makes sense of the PD program as "critical evaluative." Alan did not reject the MSS program. But, he is very critical and skeptical about implementing it as he faced challenges that he was

uncertain how to overcome. Not only does he see the implementation of the program as challenging, it is problematic, too. In general, Alan's sensemaking and implementation showed that he analyzed the program's core intervention components and his environment critically by how much it causes uncertainty as well as ambiguity in his current state of teaching practice. He evaluated and weighs whether the implementation is a worthwhile use of his valuable instructional time. Nonetheless, Alan trusts that the implementation of the program's core intervention components is the right movement to push forward. His struggles and frustration are real, but his ambitious determination is more powerful.

Creative emergent: Julia's sensemaking and implementation orientation.

Julia's sensemaking of the program was not limited to those intended by the professional developer. Instead, she also adopts Argument Driven Inquiry—ADI (Sampson et al., 2016) in her classroom to complement the productive science conversation evidenced in the core intervention components of the MSS program. She has creatively fused both programs' reform-oriented approaches and implements the blend of both in the classroom.

Since both the ADI instructional approach and the MSS curriculum approach highlight the essence of collaborative inquiry in science learning, these two approaches resonated with Julia's vision and beliefs of how science learning should be. So, she felt comfortable with both and implements them both, with one approach complementing another limitation. Julia fuses both approaches creatively so it works in her classroom.

The high implementation fidelity of MSS in Julia's science classroom can also be due to the fact that she has the flexibility and ownership of how she wants to implement in her classroom. Julia indicated that, "Just going to professional development, the more I am

able to personalize whatever I am doing, the more invested I am." This researcher believes that Julia's full implementation fidelity is emerging and will continue to progress. With time and experience, Julia's implementation and sensemaking of the core intervention components will transform.

Transforming: Kelly's sensemaking and implementation orientation.

The orientation of sense Kelly makes as regards her implementation fidelity is categorized as transforming practitioner. Kelly's exhibited the highest implementation fidelity; her classroom instruction practices and conversation evidenced the four core intervention components of the program's approach. This is pretty astounding considering that Kelly is a 5th-grade teacher who does not have to teach the content of the program – Planet Earth. Unlike Lily, who stopped when she saw that the content wasn't relevant, Kelly took what she could from the instructional approach and used it in her classroom.

When Kelly first implemented the MSS approach, she faced some difficulties and she requested to postpone her first classroom visit. She did not anticipate herself to be concerned about students' productivity during the activities. Later, after the first classroom visit, she shared that she had to work to create a social, productive, and safe community in her classroom so that the implementation of the program's core intervention components would be successful. The program's approach has triggered ambiguity in her current practice and classroom environment. She doubted if the implementation was going toward her desired goals. But, she decided to create one that supports her implementation. With such high fidelity of implementation, Kelly's sensemaking of the program is potentially a transformative one.

Teachers who share the same values, goals, and beliefs with the PD program are more likely to implement it in the classroom (Loucks-Horsley et al., 2010). Kelly's instance of sensemaking emphasizes how she values the reform-oriented approach of the program very much and how she appreciates the program as it helps her progress toward establishing a reform-oriented classroom.

The use of scaffolding tools.

With respect to the implementation of high fidelity implementers, distinctive use of tools was observed. Julia creatively combined the program with ADI instructional model in her implementation. She loves how MSS has improved her content knowledge and provide her a clearer sense of how students' ideas develop towards the big science ideas. She thinks it also helps her practices to focus on students' thinking and deeper conceptual understanding (noted that she improved in core intervention A and C). In the same spectrum, she thinks that ADI is a valuable tool that her scaffolds her instruction. It provides her a clearer guideline of procedures and tasks. She uses it to facilitate productive science conversation around student's science investigations.

Kelly, who has a transforming orientation of sensemaking and implementer, uses the CER strategy in her classroom. She models and adopts how CER is used in classroom discussion (small group and whole class discussion). With younger students (fifth graders) in her classroom, she thinks the CER strategy is a good tool that students can easily understand and accomplish. Despite CER strategy, she also institutes citizenship and community roles in her classroom to ensure students' conversations are able to put students' ideas out in public ready to be discussed and built on.

Tools in the lessons that maintained intellectual rigor publically represented students' ideas and forced students to incorporate key disciplinary ideas by requiring that they evaluate and to explain their thinking at length (Kang, Windschitl, Stroupe & Thompson, 2016, Reiser, 2004).). Thus the use of tools in reform-oriented instructional approach is essential and teachers need to experience how it can be done. Reiser (2004) stated that learners, tools, and teachers work together as a system. The scaffold tools can create opportunities, but whether learners capitalize on these opportunities is really depends on the expectations and practices established in the classroom by the teacher.

Teacher sensemaking of ambitious teaching.

With the continuous effort of research and literature in science studies, student learning, assessment, and curriculum, ideas about effective instruction become clearer (NRC, 2007; Windschitl, Thompson, & Braaten, 2009). However, traditional ways are still a norm in our classroom (Banilower, Smith, Weiss, & Pasley, 2006; Roth & Garnier, 2007). Half of the teacher participants' classrooms in this research are in traditional classrooms, which still use the instructional approach that is in general unresponsive to students' thinking and lack of disciplinary approach.

This research grounded in the logic that the changes in teacher practices or implementation of reform-oriented pedagogical practices in the classroom start from the teacher. Any professional development program of any type of educational reform initiatives will be filtered through teachers' sensemaking of their professional learning.

Teacher depth of learning envisioned in current educational reforms can only be realized through the ambitious form of teaching that is unlike the pedagogy seen in most classrooms (Windschitl, Thompson, & Braaten, 2009). Thus, teacher sensemaking of the

professional development program that aims for the ambitious form of teaching, such as implied in the program's core intervention components is a very important line of research. Thus, this research would like to suggest an initiation of research and study for sensemaking of ambitious pedagogical practices, or call "ambitious sensemaking." The sensemaking of ambitious pedagogical practices would like to focus on the exploration of how we can best support teachers so they can implement and make sense of the ambitious pedagogy introduced by their professional development program.

Ambitious science teaching aims to scaffold students' learning of science-as-practices as they act as epistemic agents in their learning (Stroupe, 2014; 2016). The four core intervention components in MSS program's evident the common critical features collaborative inquiry-based instruction as well as ambitious instruction. Looking at the results, a teacher who first attempts to make sense and implement the program can initiate his effort by (i) focusing on one core intervention component and a few of its critical features, (ii) make smaller changes over period of time, (iii) critically evaluate his environment, and (iv) uncertain and ambiguous of his roles and responsibilities to teach "ambitiously." Alan is unclear of the "end result" or how the "ambitious classroom" should look like with his group of students. This has created a foreground of ambiguity and uncertainty during his sensemaking and implementation.

Alan's sensemaking and implementation process of the ambitious pedagogical approach was initiated by critical features that emphasize on authentic science investigation with manipulation of tools and finding patterns in data. This research hypothesizes that these are the most noticeable features of reform-based instructional approach for the teacher who first attempts to launch ambitious science teaching.

How about the high-fidelity implementers? They are contrasted with Alan. The high-fidelity implementers (Julia and Kelly) improve the least on core intervention

component B. Their implementation fidelity scores showed that they improve more on the rest of three program's core intervention components. These core intervention components are, (i) core intervention component A: focus on conceptual understanding, (ii) core intervention components C: focus on students thinking, and (iii) core intervention components D: teacher reflection and metacognition of students' learning and own teaching. In common, these three core intervention components focus on students' ideas, thought process, interaction, and metacognition.

An expert like level of instructional practice is commonly assumed to be achievable only after years of classroom experiences (Windschitl, Thompson, & Braaten, 2009). The results showed that both the high-fidelity implementers have a clearer agenda of continuing to establish student-centered classroom. Julia admitted that she started her effort three years ago. After years of experiences in establishing classroom that focuses on collaborative inquiry and hands-on science investigation, the high implementers are focusing on self-improvement in looking at students' thinking and utilizing them in order to progress toward big science ideas and becoming a reflective practitioner.

From here, this research suggests that it is important that professional developers know and understand that teachers need to be supported in different phases as they make sense and implement the reform-oriented and ambitious pedagogical approach. The teacher who first initiates the ambitious teaching needs to be supported by how they can make sense of the student-centered approach and authentic science investigation, such as how they can facilitate collaborative science inquiry investigation as well as students' discussion of the data and results. When a teacher is emerging from this, then they can enhance their ambitious teaching practices to focus on how they can use students' ideas, work, and assessments as an input to their teaching practices in order to help students

progress toward the big science ideas. They will also need to be supported to become reflective practitioners.

IMPLICATIONS OF THE RESEARCH

This research intends to elaborate on how a teacher's processes of making sense unfold and how they influence his/her implementation fidelity. From the data analysis, 14 cues arise to trigger teacher sensemaking of the program's core intervention components that also align with ambitious pedagogical practices. Six of the triggers of teachers' sensemaking instances are common among all teacher participants. The common triggers of teacher sensemaking instances are (i) the value of PD, (ii) state standards, (iii) students' needs, (iv) emotions, (v) implementation network and (vi) time constraints. Four triggers are related to low-fidelity implementers; they are: (i) abundance of information gained from the program, (ii) roles and responsibilities to implement the program, (iii) setting and environment for implementation, and (iv) success measures of implementation. The others four trigger that related to high-fidelity implementers are, (i) availability and accessibility of instructional resources, (ii) accessibility to the expert, (iii) current progression towards the student-centered classroom, and (iv) availability of planning time during professional development.

Using the findings of the case and cross-case analysis, this research would like to continue the line of research of teacher sensemaking and implementation by suggesting "ambitious sensemaking." While ambitious pedagogical practices focus on the pedagogical and instructional approach in students' learning and classroom, ambitious sensemaking will focus on the effort to promote teacher's learning of reform-oriented practices, that is the sensemaking of ambitious pedagogical approach.

The discussion of teacher sensemaking cannot omit the vital role of the implementation. Aware that "ambitious sensemaking" is an initial stage of exploration, the research will provide the descriptions of some features that will promote teacher implementation practices, and thus the sensemaking of professional development program that aims for the ambitious classroom. Emphasizing the importance of enactment in teachers' sensemaking processes, this research identifies some of the implementable features and less implementable features of the professional development program.

Doing so, this dissertation aims to first, answer the critical need to structure teachers' learning opportunities combining these eight instances so that teachers are able to construct meaningful sensemaking as well as implementing the program core components in the classroom. Secondly, it aims to respond to the needs for teacher professional development to engage teachers in sustained sensemaking activities and increase the likelihood of implementing instructional practices aligned to its core components.

Implementable features.

Ambitious teaching involves risk-taking, more complex ways of relating to the subject matter and the learners than traditional approaches (Windschitl, Thompson, & Braaten, 2009). The teacher who is willing to challenge the norm, to change their practices to implement the reform-oriented core intervention components must be supported. A sustained support and follow up system is key since a teacher who is taking the initial steps to implement ambitious pedagogical practices will stumble into many uncertainties and ambiguities, it comes at the price of chaos and confusion. All teacher participants in this research agreed that their change does not come in easy, instant and spontaneous. The

teachers are wrapped with in-moment and day-to-day decision-making that can be stressful and overwhelming.

The implementable features promote ambitious sensemaking not only support teachers' sensemaking process, but also aid teachers' implementation of the program's reform-oriented instruction and ambitious pedagogical practices. It emphasizes the critical role of creating a platform of enactment, teachers' collaborative inquiry, and networked support system. The implementable features of ambitious sensemaking do not guarantee instantaneous full implementation; rather it supports and stimulates teachers to make sense, solve the problem, persevere and implement the program's core intervention components that evident reform-oriented instruction and ambitious pedagogical practices.

The opportunity of planning and collaboration time.

The high-fidelity implementers stressed the importance of planning time at the end of each day provided by the program's facilitator. In sensemaking, talk and communication are intertwined with action. Talk and action are treated as cycles rather than linear sequences. Talk occurs both early and late stage and so does action; either one can be the starting point to the destination (Weick et al., 2005). Action and talk is an "indistinguishable part of swarm of flux until talk brackets it and gives it some meaning, action is not inherently any more significant than talk, but it factors centrally into any understanding of sensemaking" (Weick et al., 2005, p. 412).

Therefore, it is important that a professional development program provides teachers with sufficient planning and collaboration time during teacher professional learning experiences. The time allocated will be especially supportive and accommodating as teachers can discuss, bounce ideas, plan, or map out the lessons. Although preliminary,

in certainly increased the likelihood of implementation in Julia's classroom. She continued such reflective practice in her instructional practices.

Social collaborative support system.

The two common types of sensemaking instances occur during teacher sensemaking are uncertainty and ambiguity (Weick, 1995). Ambiguity in teacher sensemaking means teachers encounter vagueness and confusion of multiple meanings create the program. Uncertainty, on the other hand, means that teachers encounter lack of clarity of the program. It is important the importance to clearly distinguish both as it has quite different remedies.

Weick (1995) suggested that ambiguity that is understood as confusion created by multiple meanings calls for social construction and invention. This means that teachers in networked groups can play a vital role in helping to reduce the ambiguity during teacher sensemaking. Indeed, sensemaking is influenced by many social factors. It can be any interactions with others on the campus and off campus. Teacher sensemaking is never solitary because of the intertwining of social and knowledge. The actions that teacher take is always contingent on others. To resolve ambiguity, the teacher needs "mechanism that enables debate, clarification, and enactment more than simply provide a large amount of information" (Weick, 1995).

So, in order to create an implementable environment and platform for the teacher to make sense and implement the core components, we need to put social construction and collaboration in a very fundamental place in teacher professional learning experiences. Such collaborative support systems at the campus, where all the teachers can work and talk

together. More profoundly if the professional development program and the facilitator set up a collaborative support system in place for the teacher (Loucks-Horsley et al., 2010).

The social collaborative group can be initiated by teachers and campus leadership and supported by the professional developers or the program's facilitators, such as regular and sustainable follow up and check-ins with the teacher. Being present and taking interest in teacher's practices will provide the teacher moral support and open another door for teachers to seek guidance and mentorship. The facilitator from the professional development program is a valuable asset to teacher sensemaking of the program and implementation. They provide the teacher the chances to seek advice, access to resources and materials, access to experts and many more than goes unnoticed often times.

On the other hand, uncertainty understood as lack of clarity created by insufficient information calls for more careful scanning and discovery. The facilitator from professional development program needs to sit down with the teacher to hash out what is lacking in the process of sensemaking. Depend on what is lacking, collaboration and actions need to be taken with the teacher if the sensemaking is to lead to high implementation fidelity. Being aware of what types of teacher sensemaking instances will remedy the situation more effectively, and, more importantly, how to improve teacher implementation fidelity of reform-oriented instruction as well as ambitious pedagogical practices.

Sustained self-inquiry group.

Uncertainty and ambiguity are essential components of sensemaking (Weick, 1995). However, what is the right amount? Kang, Windschitl, Stroupe, and Thompson (2016) suggested the importance of the appropriate level of epistemic and procedural

uncertainty for sensemaking and learning to be fruitful. In order for the teacher to make sense and take up the reform-oriented pedagogical practices that aim for ambitious instructional practices, the teacher needs to be supported with the environment and experiences that focus on "sustained self-inquiry" with a defined set of reform-based pedagogical practices (Windschitl et al., 2009). This "sustain self-inquiry" is a platform to foster both teachers' inquiry as well as networks where they can use the analysis of students' works as the basis of critique and change in practice. In order to sustain teacher self-inquiry, the teacher should be provided with a common frame of reference (such as clear protocol of practices, procedural guidelines, expectation, and rubric) as a tool for hypothesizing about the relationships between instructional decisions and student performances (Windschitl et al, 2009).

Less-implementable features.

The less-implementable features of teacher professional learning should be reduced if the sensemaking process and implementation practice are to be high in fidelity. The less-implementable features of the program hinder teacher sensemaking as well as teacher implementation of the program's core components.

The nature of the professional development.

As a program that consists the reform-oriented pedagogical approach, MSS has profoundly improved teacher content knowledge. Utilizing the four reform-oriented core intervention components of the program, the teacher is experiencing and observing their own sensemaking process of both the science content knowledge and pedagogical approach

of the program during the professional development. They saw and experienced how their sensemaking and learning can be done through conversation, collaboration, piecing together information or data to figure something out, and re-learning when ideas are incorrect. Teachers are also expected to implement the program that evident these reform-oriented pedagogical practices. However, teacher sensemaking and implementation are not a one-time deal.

This research thinks that although the MSS program consists of the features of ambitious pedagogical practices, it lacks the emphasis on continuous support and follow-up to promote teacher sensemaking and implementation process. Sensemaking is a cyclical process in which the end result is always evolving into the new beginning. As long as there is the implementation, the teacher will continue to make sense of the reform-oriented instructional approaches. With time and ongoing enactment, the teacher will find out the more useful cues from the environment they have created and become more skillful.

However, the MSS program did not provide sufficient follow-up and support systems to ensure teachers' continuity of implementation and sensemaking. Due to the nature of cascade and train-the-trainer model (Hayes, 2000; Griffin, 1999; Loucks-Horsley et al., 2010), teacher participants were not sufficiently supported when they went back to their classroom after the professional development. This research does not think that cascade model of teacher training is ineffective. Like all types of teacher professional development, it has its limitation and strengths (Loucks-Horsley et al., 2010). So, this research suggests a helpful enrichment to the nature of the professional development program – follow-up and support system.

For example, Alan lacked the information to launch as well as evaluate students' productive conversation. If the support and follow-up system were in place, Alan sensemaking will be promoted if the professional developers are aware of his concerns and

dilemmas. Although his dilemmas cannot be eliminated instantly, the articulation of what it is meant to work on the gap between idealized and realized pedagogy (Michaels, O'Connor, & Resnick, 2008) will help reduce Alan's stress. To support teacher sensemaking, learning, implementation, and improvement of teaching, the reform-oriented practices should not be viewed as the "best practices" in a static state (Lefstein & Snell, 2014). Ultimately, the professional developers need to ask critical questions about the practices: Who does the practice work for? Under what conditions? With whom as audiences? To surface tacit principles undergirding the practices in order to support teacher sensemaking and implementation.

Success measures of core intervention components are lacking.

Success measures of program implementation mean that teachers are able to perceive the end goals of their program's approach implementation. In general, teachers would like to see more concrete examples of the core components in students' learning, not vague assumptions that use adult learners as target audiences. This research revealed that if the success measures are lacking from the program, teachers have a hard time making decisions about what activities to implement and how to implement them. This means that the situation and expected end results have an inconsistent and vague relationship. Teachers find it hard to resolve the situation, as they have no way to assess the degree to which they are successful. Thus, they do not have a clear sense of what roles, responsibilities, and tasks to perform.

So, professional development programs need to ensure that not only the core components and its features are clearly communicated with the teacher, but it is also very vital that the goals and instructional tasks that are presented to teachers draw the explicit

connection to the program's core components. Sharing the rubric and rating scale can also be helpful to allow teachers to reflect on their current practice and their progression toward being skillful implementer sof the core components.

School norms and implementation networks.

In the case of low fidelity implementers, when conflicts happen between one's teaching approach and the PD's core intervention components, they make sense of the PD approach using the framework that is acceptable to their campus and implementation network. In other words, teachers tend to default to the practice that aligns with the school norms and culture. Why? It is easier since the social system and expectations are already well established. They are familiar with the routine and expectations rooted in the campus. Instead of creating the environment for implementing the core intervention components, it is much less stressful if the teacher can reproduce what is already available to them. If a teacher's implementation network and campus adopt the traditional teacher-centered practices or are not supportive of the reform-oriented core components, the teacher who initiates the implementation of a reform-oriented approach will find it extremely challenging to transform his classroom practices.

FUTURE RESEARCH

Building on this research, future research will continue to refine the framework of sensemaking. By refining the framework of sensemaking, it will help the researcher to pilot more constructs and items that can be used to explore teacher sensemaking. This will help

the researcher to move beyond general theorization to a more empirical linkage between the sense that teachers make and their implementation practices.

In addition, sensemaking is social and systemic. This research augments a call to look at the influences of multiple factors within and across systemic levels of environments when studying the implementation of a reform-oriented instructional approach. More importantly, take into account the dynamic systemic nature of the school, leadership, norms and standards, district coaches, and many more where interactions and influences of numerous parts and pieces are accounted for. This research suggests a social network research to explore the dynamic and networks of the teacher and his/her implementation. Another possible analysis methodology is complex adaptive system.

Implementation of any professional development program, especially the one that involves teachers changing their instructional practices, is not simply about compliance to a program's core components. In addition, implementation shortfalls are not just cases of individual rejection (like Lily) or capability. Rather, teacher implementation is a continuous process of evolution that involves the process of sensemaking (McLaughlin, 2006, p. 215). Therefore, future research is needed on how professional developers can better present, train, equip, and support teachers to enact or implement the core components. Teachers must be challenged as well as supported for them to implement and make sense of the program's core components.

The findings reported in this research helped justify the need for further research utilizing a constructivist perspective for a program's reform-oriented approach implementation. Implementation is not as simple as full compliance to the program's prescribed activities and lessons. It is the ability to make sense of the core intervention components and create an environment that supports the implementation of these core components. This research recommends a mixed methodology to further explore the

relationship between teachers' sensemaking and implementation practices. In this research and the cases it discusses, the qualitative methods allowed the researcher to describe perceptions and nuances of teacher sensemaking and implementation that would be difficult to ascertain through solely quantitative methods. The results of studies that combine both quantitative and qualitative results are thus more likely to be recognizably useful and more likely to be applied by local school leaders.

In addition, this research suggests longitudinal studies to explore how teachers evolve from passive distributive in their sensemaking and implementation orientation toward the transformative one. Focusing on a small sample size over extensive periods of time will provide more valuable insight into teachers' sensemaking orientation as regards their implementation orientation.

This research sees the important of future research and works to find a common ground of how professional developers can effectively support teacher sensemaking and implementation of reform-oriented and ambitious pedagogical approach. Some common ground that can be addressed across subject matters are, (i) acknowledge and understand that teacher enactment is essential for teacher sensemaking, (ii) teacher sensemaking and implementation of reform-oriented pedagogical approach involved in more than one phase, with each phase focused on different core components of the program, and thus, (iii) need different articulation, support, and motivation. These will bring a positive and promising implication to multiple subject matter areas to define and articulate particular practices teachers should enact to make instructional decisions that align with seven features of ambitious instruction.

CONCLUSION

Combining the case analysis with cross-case analysis, the research identified six common triggers of teacher sensemaking instances that are associated with all teacher participants; teacher participants that implement the program with low fidelity; and teacher participants that implement the program with higher fidelity. The research also found out that teachers' sensemaking of professional development's core intervention components is interconnected to their implementation.

The four core intervention components of the program evidence the common critical features of a reform-oriented instructional approach. Although not generalizable to all implementers and all professional development programs, the findings and implications of this research can be a good reference source to study how teachers make sense of the reform-oriented program and how they attempt to implement it in the classroom. Thus, the research suggests the importance of future additional research to study teacher sensemaking and fidelity of implementation in a larger sample size and in combination with the quantitative methodology.

Appendices

APPENDIX A: MSS'S PLANET EARTH WORKSHOP

	Monday: Sunlight	**Tuesday: Earth temperature**	**Wednesday: Atmosphere**	**Thursday: Geosphere**	**Friday: Earth surface**
SI	1. Understand how sunlight strikes the Earth over the course of the year 2. Explain the causes of observable seasonal changes in day length, shadow length, and temperature	1. Understand how earth materials warm and cool 2. Differentiate between heat energy and temperature 3. Explain the patterns and anomalies in Earth's temperatures	1. Explore the atmosphere as a system 2. Track transfers of matter and energy in various models 3. Investigate atmospheric conditions in various environments and how they change over time 4. Use models to explore the effect of warming and cooling gases on atmospheric pressure	1. Investigate the geosphere as a system 2. Learn about rock matter, mineral matter, rocks, and crystal and how they relate to one another 3. Explore the interactions that form sedimentary rocks, metamorphic rocks, igneous rocks and fossil 4. Design and evaluate models to represent the geosphere	1. Investigate the surface and interior of Earth 2. Learn about the ways plates move and what happens to Earth's surface as a result of those motions 3. Identify patterns and anomalies in map data 4. Build and evaluate a physical model of a tectonic plate 5. Develop questions about plates and plate boundary zones
TI	Consider the tradeoff of various models for helping students understand seasons	Consider how to help students make sense of phenomena with multiple contributing factors	Strategize about how best to teach about mechanisms for warming and cooling (conduction, radiation, convection)	Analyze the tradeoffs of different ways of teaching about the geosphere	
LI	Understand the complexities and demands of reading	Examine strategies that support reading in science	Practice making sense of data on maps and identify strategies for reading maps.	Identify supports for each dimension of a reading apprenticeship (personal, social, cognitive, and knowledge building)	Design the beginning of a reading apprenticeship to use with students during the first month of school
CC	Explore and understand common ideas students have about sunlight and seasons	Explore and understand common ideas students have about Earth's temperature	Explore and understand common ideas students have about Earth's atmosphere	Investigate students' ideas about rock and rock formation	

Notes: Science Investigations (SI), Teaching Investigation (TI), Literacy Investigation (LI), and Classroom Connection (C

APPENDIX B: TEACHER SURVEY

Thank you for participating in our survey. Your feedback is very important.

1. Gender: Female / Male (circle one)
2. Highest degree earned:
    a. BA/BS
    b. MA/MS
    c. Specialist
    d. Doctorate
3. Subject and grade level (Please specify if you teach more than one grade or subject).

    _____
4. What are you expert or major at?

    _____
5. How many years of teaching experiences do you have?

    _____
6. Please rate how do you view your own effectiveness as a science teacher:
    a. Superior – I am an outstanding teacher.
    b. Above average – I am confident about my teaching practices.
    c. Average – I am a typical science teacher.
    d. Low – I am not confident about my teaching practices and is in need of professional improvement.
7. In general, the major portion of your classroom instruction time is spent on:
    a. Textbook-based presentation than anything else.
    b. An equal amount of textbook-based presentation and activity-based instruction.
    c. More activity-based instruction than textbook-based presentation.
    d. Activity based instruction only.

Question 8: Please indicate how much do you agree / disagree with the statements.
*Circle **5**: I truly and 100% agree.*
*Circle **4**: I agree*
*Circle **3**: Neutral*
*Circle **2**: I disagree.*
*Circle **1**: I am 100% disagree and will not support this statement.*

8. Teachers perspectives on MSS course:

I will implement Making Sense of Science (MSS) course with high fidelity.	1	2	3	4	5
I agree with the philosophy of the MSS curriculum approach.	1	2	3	4	5
Overall, MSS course matches my beliefs about how students learn science best.	1	2	3	4	5

Overall, MSS course improves or strengthen my content knowledge as a science teacher.	1	2	3	4	5
Overall, MSS course improves my pedagogical and instructional skills as a science teacher.	1	2	3	4	5
MSS course allows me to reflect on my teaching practices.	1	2	3	4	5
MSS course allows me to reflect on my own process of learning science concepts.	1	2	3	4	5
MSS course allows me to appreciate students' tentative ideas or misconceptions.	1	2	3	4	5
I feel comfortable implementing MSS in my classroom.	1	2	3	4	5

Please feel free to justify your answer.

QUESTIONS 9 – 12: Teachers' Readiness level.
Rate your confidences to implement the following critical components of MSS course.
Critical component A: Focus on conceptual learning
Critical component B: Collaborative Inquiry and Sense-making
Critical component C: Focus on Students' Thinking
Critical component D: Reflection on Teaching and Learning

*Circle **5** if your current instructional practices are reflecting the feature.*
*Circle **4** if you are very confident and ready to implement the feature.*
*Circle **3** if you are somewhat confident and ready to implement the feature.*
*Circle **2** if you are not confident and not ready (at all) to implement the feature.*
*Circle **1**: if you are not sure what feature this is.*

9. **Teacher readiness level to implement critical component A: Focus on conceptual learning.**

Features of Classroom Teaching	**Scale**				
Teacher emphasizes conceptual understanding throughout lesson activities, prompts, questions, and suggestions.	1	2	3	4	5
Teacher publicly frames activities for students in terms of conceptual goals for science learning.	1	2	3	4	5
Teacher and lessons expose students to accurate and coherent science content.	1	2	3	4	5
Teacher provides opportunities for students to learn science vocabulary and use appropriate scientific language.	1	2	3	4	5

Please feel free to justify your answer.

10. Teacher readiness level to implement critical component B: Collaborative Inquiry and Sense-making.

Features of Classroom Teaching	**Scale**				
Teacher fosters sustained collaborative interaction among students to make sense of science ideas.	1	2	3	4	5
Teacher and activities create opportunities for students to investigate phenomena, make observations, and record data from hands-on activities.	1	2	3	4	5
Teacher invites and presses students to find patterns and anomalies in data and/or make connections among science ideas.	1	2	3	4	5
Teacher keeps conversations evidence-based, asking students to justify and explain in detail using data they have collected, something they have read, or other observations that make them think something is so.	1	2	3	4	5
Teacher uses multiple representations to help students engage in discussion of science ideas; identify and resolve content misunderstanding or inaccuracies; and/or achieve accurate, generalized understanding of concepts and relationships	1	2	3	4	5

Please feel free to justify your answer.

11. Teacher readiness level to implement critical component C: Focus on Students' Thinking.

Features of Classroom Teaching	**Scale**				
Teacher uses assessment tasks and questions that reveal student thinking and understanding.	1	2	3	4	5
Teacher listens to and reads student responses during and after lessons to monitor student understanding during instruction.	1	2	3	4	5
Teacher encourages students to explain their thinking using a variety of modes, such as writing, drawing visual representations, enacting ideas, using models and metaphors, etc.	1	2	3	4	5
Teacher consistently invites multiple, varied responses, both correct and incorrect.	1	2	3	4	5
Teacher adapts instruction to students' specific difficulties and thinking in the moment.	1	2	3	4	5

Please feel free to justify your answer.

12. Teacher readiness level to implement critical component D: Reflection on Teaching and Learning.

Features of Classroom Teaching	**Scale**				
Teacher considers tradeoffs among instructional alternatives in planning and implementing instruction.	1	2	3	4	5
Teacher helps students identify and resolve their own content misunderstandings or inaccuracies.	1	2	3	4	5
Teacher anticipates and acts to address or reveal common student misconceptions.	1	2	3	4	5

Please feel free to justify your answer.

APPENDIX C: TEACHER PROFESSIONAL DEVELOPMENT OBSERVATION GUIDE

Part A: Pre-Observation Information:
Date of observation:
Time of observation:
Numbers of teacher participants: _____(high school) + _____ (middle school)

Part B: Observation Information:
Part B is to see whether the core intervention components of the professional development program (MSS) and its critical features are evident during the teacher professional development. Please identify and describe how the core intervention components and its critical features are implemented during the teacher activities and training.

General / Overall	
Describe how the facilitator introduced the lesson. • What are the objectives? • What are the contents, investigations and activities? • Sessions and agenda.	
Describe how the facilitator concluded the lesson. • Representation (poster / chart / table)? • Homework. • Sunshine and blue.	
Focus on Conceptual Understanding	
A1: Teachers' talk and activities reflect conceptual learning goals underlying lesson.	(Yes / No). Please describe:
A2: Teachers develop understanding of core concepts and relationships.	(Yes / No). Please describe:
A3: Teachers have opportunities to read, write, and speak using appropriate scientific language, and to explore how to provide those opportunities for students.	(Yes / No). Please describe:
Collaborative Inquiry and Sense-making	
B1: Teachers engage in sustained conversations with each other to make sense of science ideas. Active participation by all or almost all teachers.	(Yes / No). Please describe:

B2: Teachers do hands-on or exploratory activities, observe scientific phenomena, and record data.	(Yes / No). Please describe:
B3: Teachers' talk focuses on patterns and anomalies in data and builds toward general level of conceptual understanding.	(Yes / No). Please describe:
B4: Teachers make and support claims with evidence-based reasoning, citing specific data or sources.	(Yes / No). Please describe:
B5: Teachers share/create and interact with public displays of data representations in whole group discussions; multiple representations are conducive to building conceptual understanding.	(Yes / No). Please describe:
Focus on Learners' Thinking	
Teachers analyze student understanding as evidenced in samples of student work.	(Yes / No). Please describe:
Teachers analyze assessment questions and identify features that reveal student thinking.	(Yes / No). Please describe:
Teachers understand specifics of and logical rationales behind common misconceptions.	(Yes / No). Please describe:
Teachers express their ideas in a variety of ways, using and translating among multiple representations.	(Yes / No). Please describe:
Multiple teachers generate answers to a question and give reasons for their answers.	(Yes / No). Please describe:
Teachers identify and discuss instructional strategies for avoiding and addressing specific student difficulties.	(Yes / No). Please describe:
Reflection on Teaching and Learning	
Teachers identify and discuss tradeoffs among instructional alternatives.	(Yes / No). Please describe:
Teachers articulate their own incorrect ideas and common student difficulties related to specific science topics.	(Yes / No). Please describe:

Summary:

APPENDIX D: CRITICAL FEATURES OF TEACHERS' PROFESSIONAL DEVELOPMENT

Program's critical intervention components	Observes critical features of teachers' professional development (What will teachers experience in the professional development?)
Focus on conceptual understanding	A1: Teachers' talk and activities reflect conceptual learning goals underlying lesson.
	A2: Teachers develop understanding of core concepts and relationships.
	A3: Teachers have opportunities to read, write, and speak using appropriate scientific language, and to explore how to provide those opportunities for students.
Collaborative inquiry and sense-making	B1: Teachers engage in sustained conversations with each other to make sense of science ideas. Active participation by all or almost all teachers.
	B2: Teachers do hands-on or exploratory activities; observe scientific phenomena, and record data.
	B3: Teachers' talk focuses on patterns and anomalies in data and builds toward general level of conceptual understanding.
	B4: Teachers make and support claims with evidence-based reasoning, citing specific data or sources.
	B5: Teachers share/create and interact with public displays of data representations in whole group discussions; multiple representations are conducive to building conceptual understanding.
Focus on learners' thinking	Teachers analyze student understanding evidenced in student work.
	Teachers analyze assessment questions and identify features that reveal student thinking.
	Teachers understand specifics of and logical rationales behind common misconceptions.
	Teachers express their ideas in a variety of ways, using and translating among multiple representations.
	Multiple teachers generate answers to a question and give reasons for their answers.
	Teachers identify and discuss instructional strategies for avoiding and addressing specific student difficulties.
Reflections of teaching and learning	Teachers identify and discuss tradeoffs among instructional alternatives.
	Teachers articulate their own incorrect ideas and common student difficulties related to specific science topics.

Table shows the essential features of the four critical intervention components of the teacher professional development program.

APPENDIX E: TEACHER CLASSROOM OBSERVATION REPORT GUIDE

Date of observation:
Time of observation:
Grade level observed:
Learning objectives:
Number of students:
Arrangement of classroom (please sketch it):

(i) Does the teacher introduce the lesson? How?

(ii) Does the teacher teach the science content as prescribe by MSS?
If no, how he/she modifies the lesson?

(iii) Where is the lesson within unit comparing to the prescribed pacing guide? If the teacher is teaching out of order from the prescribed lessons, how the scope and sequences of the lessons are being modified?

(C) Observable Critical Features (Instructional)

Part C is to see whether the core intervention components of the professional development program (MSS) and its critical features are evident during the lesson. Please identify and describe how the core intervention components and its critical features are implemented during the classroom instruction.

Core intervention components A: Focus on Conceptual Understanding	
A1: Teacher emphasizes conceptual understanding throughout lesson activities, prompts, questions, and suggestions.	(Yes / No). Please describe:
A1: Teacher publicly frames activities for students in terms of conceptual goals for science learning.	(Yes / No). Please describe:
A2: Teacher and lessons expose students to accurate and coherent science content.	(Yes / No). Please describe:
A3: Teacher provides opportunities for students to learn science vocabulary and use appropriate scientific language.	(Yes / No). Please describe:
Core intervention components B: Collaborative Inquiry and Sense-making	
B1: Teacher fosters sustained collaborative interaction among students to make sense of science ideas.	(Yes / No). Please describe:

B2: Teacher and activities create opportunities for students to investigate phenomena, make observations, and record data from hands-on activities.	(Yes / No). Please describe:
B3: Teacher invites and presses students to find patterns and anomalies in data and/or make connections among science ideas.	(Yes / No). Please describe:
B4: Teacher keeps conversations evidence-based, asking students to justify and explain in detail using data they have collected, something they have read, or other observations that make them think something is so.	(Yes / No). Please describe:
B5: Teacher uses multiple representations to help students engage in discussion of science ideas.	(Yes / No). Please describe:
B5: Teachers identify and resolve content misunderstanding or inaccuracies; and/or achieve accurate, generalized understanding of concepts and relationships	(Yes / No). Please describe:
Core intervention components C: Focus on Students' Thinking	
C1: Teacher uses assessment tasks and questions that reveal student thinking and understanding.	(Yes / No). Please describe:
C1: Teacher listens to and reads student responses during and after lessons to monitor student understanding during instruction.	(Yes / No). Please describe:
C2: Teacher encourages students to explain their thinking using a variety of modes, such as writing, drawing visual representations, enacting ideas, using models and metaphors, etc.	(Yes / No). Please describe:
C3: Teacher consistently invites multiple, varied responses, both correct and incorrect.	(Yes / No). Please describe:
C4: Teacher adapts instruction to students' specific difficulties and thinking in the moment.	(Yes / No). Please describe:
Core Intervention Components D: Reflection on Teaching and Learning	
D1: Teacher considers tradeoffs among instructional alternatives in planning and implementing instruction.	(Yes / No). Please describe:
D2: Teacher helps students identify and resolve their own content misunderstandings or inaccuracies.	(Yes / No). Please describe:
D2: Teacher anticipates and acts to address or reveal common student misconceptions.	(Yes / No). Please describe:

Summary:

APPENDIX F: TEACHERS CLASSROOM OBSERVATION RATING SCALES

Instructional (Pedagogical - Part C): Core intervention components and its critical features

A. Focus on Conceptual Understanding

Dimension	1 (Low)	2	3	4 (High)
A1a. Conceptual Learning Goals	Activities introduced and conducted without incorporating underlying science ideas.	Minimal explicit attention to science ideas that underlie procedures, hands-on activities, or computations.	Some explicit attention to science ideas that underlie some parts of the procedures, hands-on activities, or computations, but ideas remains tangential or secondary.	Teacher publicly frames activities for students in terms of conceptual goals for science learning. Teacher and materials emphasize conceptual understanding throughout lesson activities, prompts, questions, and suggestions.
A1b. Mapping Against Content Goals	Activity and discussion do not focus on the main content goals for the session.	Activity and discussion get to one or more goals but does not map fully against session goals; treatment of one or more may be superficial.	Activity and discussion get to all goals, but with some superficial attention to one or more.	Activity and discussion map well against content goals.

Dimension	1 (Low)	2	3	4 (High)
A2a. Accurate Content	Very little content is provided by teacher, or content provided exposes students to seriously deficient science content, misleading models or explanations, or confusing science information. Ends with no indication of student understanding.	Content provided by teacher exposes students to incomplete or inaccurate science content, weak models or explanations, or information that is somewhat unclear. Ends with weak evidence of student understanding.	Content provided by teacher exposes students to accurate science content, models, or explanations, and clear science information. Ends with more understanding than confusion about core concepts.	Content provided by teacher exposes students to precise, accurate science content with unusual clarity, and well-formulated, detailed models or explanations. Ends with substantial indication of accurate understanding.
A2b. Coherent Content	Science activities are not related to each other or to science ideas.	Science activities are minimally related to each other or to science ideas.	Science activities are related to each other and to science ideas.	Science activities are explicitly related to each other and to multiple, connected science ideas.
A3. Scientific Language and Literacy	Little or no scientific language is introduced or used by the teacher or students.	Scientific terminology or language is introduced or used by the teacher, but little or no attention is given to developing students' own use of scientific language.	Support is provided for students to develop some appropriate scientific terminology and language, and both teacher and students show some understanding of relevant scientific language.	Support is provided for students to develop appropriate scientific terminology, and use the varied languages of science. Both teacher and students consistently use language with precision, appropriate to context.

B. Collaborative Inquiry and Sense-making

B1a. Making Meaning through Discussion: Interaction	Students listen to teacher explanations of scientific phenomena, or read written explanations. Teacher may ask fact-based questions of individual students, evaluate answers, and move on to next question.	Students report out from group work or give answers to teacher questions, but do not explain reasoning or discuss differences between answers.	Students have opportunity to give answers and explain their reasoning in whole-group setting. Teacher may model consideration of ideas across several responses, and tends to resolve differences for students.	Students give answers, explain their reasoning, and discuss differences between answers in whole-group setting. Teacher helps identify and facilitate students' resolving differences among ideas among themselves. Students develop, clarify, and synthesize science understandings through extended discussion.
B1b. Making Meaning through Discussion: Building on Ideas	Students do not have access to each other's ideas (they are generally not expressed).	Students express their ideas but do not respond to or build on each other's ideas.	Students sometimes respond to and build on each other's ideas.	Students consistently respond to and build on each other's ideas.
B1c. Making Meaning through Discussion: Participation	Low student-to-student interaction; students do not participate verbally, or interact nearly exclusively with the teacher.	A very small number of active or dominant participants; IRE or dyadic interaction between students and teacher may dominate.	At least half of students interact with other students.	Most or nearly all students interact with one another.

B2. Inquiry and Observation of Scientific Phenomena: Investigation	Students have limited opportunity for hands-on activity and working with data.	Students participate in at least some key activities, but with little attention to recording or attending to observational data.	Students participate in key activities with some attention to recording or attending to observational data.	Students do extended hands-on activities, and generate and record observational data.
B2. Inquiry and Observation of Scientific Phenomena: Hands-on Investigation and Data	Students may read about hands-on or exploratory activities but do not do or observe hands-on activities or work with data.	Students observe hands-on or exploratory activities and see data being collected or worked with by teacher.	Students do limited hands-on or exploratory activities, participate in at least some key activities, and collect or work with data from investigations.	Students do extended hands-on or exploratory activities, or extended work with data from investigations.
B3. Finding Patterns and Connections	Teacher and activities provide little or no opportunity for students to see patterns in data or make connections among science ideas.	Teacher identifies patterns in data or makes connections among science ideas primarily by "telling."	Teacher uses some prompts, questions and suggestions in ways that invite students to find patterns in data or make connections among science ideas.	Teacher uses prompts, questions and suggestions in ways that press students to identify both patterns and anomalies in data, and/or make connections among science ideas.

B4. Justifying Claims with Evidence-Based Reasoning	Students make claims about phenomena but don't anchor them to evidence; students reason on other bases than evidence, accept one another's claims without pressing for evidence.	Students report observations and make erroneous claims, explanations, or arguments with vague reference to evidence.	Students discuss patterns and engage in some reasoning from evidence, but claims don't get to a level of generality.	Consistent reasoning from evidence (claims and justifications); consistent use of precise language for observations; talk builds toward accurate generalizations supported by evidence.
B5. Representations of Phenomena and Ideas	Lesson provides little opportunity to see data displays or visual representations of data or ideas, or uses visual representations primarily as props for "telling."	Students see visual displays and representations, but have little opportunity to interact with each other about them. Teacher	Students create or interact with displays and representations but not in a manner to support collective reasoning.	Teacher engages students in interacting with multiple displays of data and other representations to support collective reasoning and building conceptual understanding.

C. Focus on Students' Thinking

Dimension	1 (Low)	2	3	4 (High)
C1. Eliciting and Interpreting Students' Thinking	Teacher does not attempt to elicit or understand student thinking during lesson.	Teacher asks students what they observed, but not their thinking about it. Teacher tends to ask for reasoning behind incorrect answers only, which may be perceived as a negative evaluation.	Teacher elicits students' thinking and reasoning for both correct and incorrect answers, but does not ask further questions or discuss differences.	Teacher regularly asks/expects students to explain their thinking for both correct and incorrect answers; discussion illuminates similarities and differences in students' reasoning.
C1. Eliciting and Interpreting Students' Thinking: Interaction	Teacher telling dominates; lesson conducted in ways that actively limit or constrain student interaction.	Teacher elicits some participation, but permits a few to dominate or displays few moves for supporting interaction.	Teacher uses a variety of moves to elicit and support student interaction.	Teacher consistently makes moves that enable sustained student interactions around key concepts.
C2. Varied Ways to Demonstrate Understanding	Students answer questions but there are limited opportunities of any kind for students to demonstrate understanding. Forced choice or yes/no questions dominate.	Students are sometimes expected to share their answers verbally when asked; students who cannot easily articulate their thinking verbally are disadvantaged.	Some variety in the ways students can share answers to given questions (e.g., by showing, telling, drawing, or building), individually or as a group.	Multiple and varied opportunities for students to demonstrate understanding.

C3. Eliciting a Variety of Ideas	Very limited, teacher-directed Q&A. Teacher asks leading questions until a student gives correct answer, then moves on to next question. Teacher does not ask what students think about each other's answers.	Teacher asks whether other students agree with a classmate's answer only when answer is incorrect. Teacher turns to other students until someone gives correct answer	Teacher elicits multiple answers to a question before anyone evaluates answers but does not discuss any answer in depth or encourage students to consider and compare each other's answers. Teacher tells students which response is correct, or leads them to right answer.	Students generate multiple answers to a question and give reasons for their answers. Teacher elicits student explanations in response to both correct and incorrect answers and encourages students to appreciate the logic in incorrect answers and the 'trickiness' of the science
C4. Considering Students' Thinking in Instruction	Teacher does not respond to or may not notice emergent conditions, including student difficulties, boredom, or frustration; teacher holds to original lesson plan.	Teacher responds to student difficulties or ideas by re-explaining or repeating previous instruction, but does not noticeably modify instruction or activities, or fine-tune questions to students' ideas.	Teacher responds to student difficulties or ideas by making changes in instruction or activities rather than repeating previous approach.	Teacher responds to specific student difficulties and ideas by probing nuances of student understanding, posing follow-up questions based on student responses, and improvising and adapting activities as needed.

D. Reflection on Teaching and Learning

Dimension	1 (Low)	2	3	4 (High)
D1. Critical Analysis of Practice	Teacher does not justify lesson plans or implementations based on tradeoffs of instructional alternatives.	Teacher can articulate general reasons for pursuing lesson plans or implementations compared to alternative strategies.	Teacher can articulate specific reasons for pursuing lesson plans or implementations compared to alternative strategies.	Teacher considers tradeoffs among instructional alternatives in planning and implementing instruction, and can articulate multiple, specific considerations underlying decisions.
D2. Metacognition	Teacher does not attend to students' misunderstandings or difficulties.	Teacher corrects students' misunderstandings or shows them how to address difficulties.	Teacher identifies multiple students' misunderstandings or difficulties.	Teacher helps students identify their own misunderstandings or difficulties and reason through to correct solutions.

APPENDIX G: CRITICAL FEATURES OF TEACHERS' IMPLEMENTATION IN CLASSROOM

This table shows essential features of four critical intervention components of the MSS course for teacher classroom implementation.

Program's core intervention component	Evidence of teachers' implementation in classroom (What will students experience in the classroom)
Focus on conceptual understanding	A1: Teacher emphasizes conceptual understanding throughout lesson activities, prompts, questions, and suggestions.
	A1: Teacher publicly frames activities for students in terms of conceptual goals for science learning.
	A2: Teacher and lessons expose students to accurate and coherent science content.
	A3: Teacher provides opportunities for students to learn science vocabulary and use appropriate scientific language.
Collaborative inquiry and sense-making	B1: Teacher fosters sustained collaborative interaction among students to make sense of science ideas.
	B2: Teacher and activities create opportunities for students to investigate phenomena, make observations, and record data from hands-on activities.
	B3: Teacher invites and presses students to find patterns and anomalies in data and/or make connections among science ideas.
	B4: Teacher keeps conversations evidence-based, asking students to justify and explain in detail using data they have collected, something they have read, or other observations that make them think something is so.
	B5: Teacher uses multiple representations to help students engage in discussion of science ideas.
	B5: Teachers identify and resolve content misunderstanding or inaccuracies; and/or achieve accurate, generalized understanding of concepts and relationships.
Focus on students' learning	C1: Teacher uses assessment tasks and questions that reveal student thinking and understanding.
	C1: Teacher listens to and reads student responses during and after lessons to monitor student understanding during instruction.
	C2: Teacher encourages students to explain their thinking using a variety of modes, such as writing, drawing visual representations, enacting ideas, using models and metaphors, etc.
	C3: Teacher consistently invites multiple, varied responses, both correct and incorrect.
	C4: Teacher adapts instruction to students' specific difficulties and thinking in the moment.
Reflection on teaching and learning	D1: Teacher considers tradeoffs among instructional alternatives in planning and implementing instruction.
	D2: Teacher helps students identify and resolve their own content misunderstandings or inaccuracies.
	D2: Teacher anticipates and acts to address or reveal common student misconceptions.

APPENDIX H: TEACHERS INTERVIEW GUIDE

As the principle investigator, I wholeheartedly thank you for participating in my research and make a different in my study plan. Thank you very much for allowing me to observe your classroom teaching and for speaking with me today. The purpose of this interview is to explore how teacher sense making process is influencing his/her implementation fidelity in science classroom from constructivism perspectives.

With your permission, I would like to audio record the interview so that I can concentrate on what you are saying rather than on note taking. Your identity as well as the audio recording will remain private and confidential. All data (digital or hard copy) collected from you will be store securely and passwords protected. Is that okay?

Belief:

1. In general, what is the purpose of education?
2. What is the purpose of science education?
3. What is your view regarding your own ability in science?
    a. How prepare are you to teach science? What prepare you?
4. Who should control the learning environment?
5. What should be the relationship of teacher and students?
6. Under what condition is student learning most successful?
7. What motivates students to do their best in school?
8. What is your definition of effective teaching?
9. What personal characteristics does a successful teacher possess?
10. In your opinion, how should a teacher assesses student learning?
11. What is your definition of a good school?

Values:

1. What would you consider as the most important thing to teach in science? And why?
2. What are the messages you try to pass to your students through science teaching? And why?
3. (After classroom observation) Why did you teach science like this?
4. Were there any other alternatives? And why would you choose them? Or why it is so important to teach science that way?
5. What are your expectations about the professional development program? (Outcome expectancy - Fendt, 2010)

Emotion:

1. Overall, how do you feel the lesson went?

2. Overall, how do you feel during the initiation and implementation of the program? How do you feel when you begin to implement the program in your classroom? (also look at teacher self-efficacy, readiness, expectation)
3. Was today's lesson typical? How and how not?
4. Can you describe a typical lesson in your classroom?
5. How do you gauge students' progress?
6. What kinds of indicators do you use to gauge your effectiveness in teaching science?
7. Is there anything that gets in the way of your effectiveness as a science teacher? If so, what and why?

Context:

1. How long have you been teaching science?
2. Do you have any other roles at the school?
3. What kind of interaction do you have with your co-workers in your campus? (Shared sense-making)
4. What kind of interaction do you have with your administrators in your campus (Sense-giving)?
5. Do you have any access to any helps / guidance's from expert (either from campus, professional developers, or district)?
6. How do you describe your relationship with the expert? Who are they? (Sense making + sense giving)?

Fidelity of Implementation:

1. If someone asks you what is the professional development program, what would you tell them?
2. What did the lesson tell you about what the students learned and still need to know?
3. How do you decide generally if your students are progressing in science learning?
4. How do you anticipate and act to address common students' misconception / incomplete conceptions or tentative ideas?
5. What roles do "problem solving" play in the science classroom?
6. How do you support students in solving problem?

Policy:

1. How knowledgeable are you about state standard?
2. How knowledgeable are you about district and/or school policies?
3. How does your instructions reflect the state standard, district and school curriculum policies?
4. How do you feel about the state standard and curriculum policies apply in your district? Does it align with your teaching practices? Does it align with your teaching and learning philosophy?

APPENDIX I: TEACHER SELF-REPORT GUIDE

(i) Lesson plan (lesson plan guide is provided in the following page).
(ii) Teacher reflection.
(iii) Weakness and strengths of your lesson.
(iv) What critical intervention components of the teacher professional development program (MSS) that you have implemented in your classroom? Please justify your reason of implementation.
(v) What difficulties or hindrance you face or stumble into when you implement the critical features of the program?
(vi) What is your next step to overcome the difficulties?

Part A: Lesson planning (before classroom implementation).

A1: Learning objectives:
A2: Essential questions:
A3: Materials and resources:
A4: Describe the context / setting / set-up for this lesson:
A5: Describe the procedures / transition / flow of the lesson:
A6: Summary of the lesson:
A7: Task or assessment (Specified the purposes of task / assessment):

Part B: Teacher Reflection (after classroom implementation).

1. How do you support students' understanding? And why?
2. What common students' misunderstanding or tentative ideas you observed from students? What do you do and why?
3. Is there any alternative that you would try next time when you encounter the same students' misconceptions?
4. Does the lesson actually happen according to your plan? Why and why not?
5. What do you think students have learned in classroom today?
6. Do you think students understand the learning objectives you planned for them? How do you feel about their learning?
7. What do you think students have learned in classroom today? Do you think students understand the learning objectives you planned for them?
8. Weakness and strength of your lesson.
9. How do you feel about their learning?
10. What critical components of the teacher professional development program (MSS) that you implemented in your classroom? Please justify your reason of implementation.
11. What difficulties or hindrance you face or stumble into when you implement the critical components of the program?
12. What is your next step in order to overcome the difficulties?

APPENDIX J: STATEMENT ON RESEARCH WITH HUMAN PARTICIPATION

Detail & Update Page for IRB Study 2015-06-0026

View Original Application | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | View Summary | View Proposal/Consent Forms/Misc Docs

Study Number	2015-06-0026	PI Name	Anthony J Petrosino UT Austin RC Class 04/20/2015
Study Title			
Teachers' Fidelity of Implementation			
Dept Review Contact (DRC)		**Faculty Sponsor**	
Keffrelyn D Brown		Anthony J Petrosino	

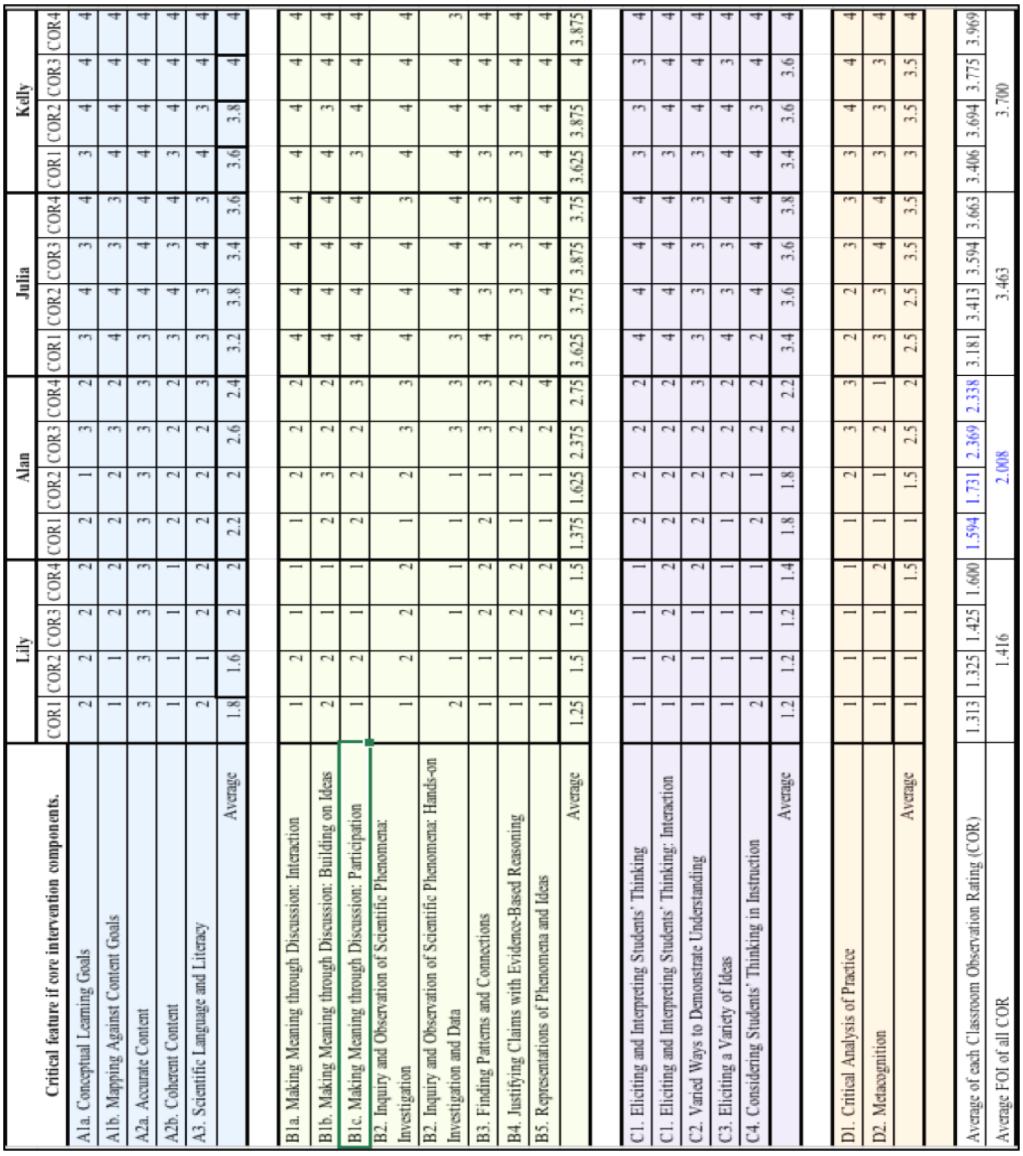
Type of Approval	Approval Start	Approval End
EXEMPT	06/16/2015	06/15/2018

Vulnerable Populations			
No Vulnerable Populations			
Risk Level	Minimal risk	**Waiver of Consent**	No Waiver Specified
Sponsor		OSP Number	
Submit New Action / View History			

Comments to: ORS Help | Office of Research Support |

APPENDIX K: CLASSROOM OBSERVATION RATING

Table shows the teacher Fidelity of Implementation (FOI) score of all classroom observation.



Critical feature if core intervention components.	Lily				Alan				Julia				Kelly			
	COR1	COR2	COR3	COR4	COR1	COR2	COR3	COR4	COR1	COR2	COR3	COR4	COR1	COR2	COR3	COR4
A1a. Conceptual Learning Goals	2	2	2	2	2	1	3	2	3	4	3	4	3	4	4	4
A1b. Mapping Against Content Goals	1	1	2	2	2	2	3	2	4	4	3	3	4	4	4	4
A2a. Accurate Content	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
A2b. Coherent Content	1	1	1	1	2	2	2	2	3	4	3	4	3	4	4	4
A3. Scientific Language and Literacy	2	1	2	2	2	2	2	3	3	3	4	3	4	3	4	4
Average	1.8	1.6	2	2	2.2	2	2.6	2.4	3.2	3.8	3.4	3.6	3.6	3.8	4	4
B1a. Making Meaning through Discussion: Interaction	1	2	1	1	1	2	2	2	4	4	4	4	4	4	4	4
B1b. Making Meaning through Discussion: Building on Ideas	2	2	1	1	2	3	2	2	4	4	4	4	4	3	4	4
B1c. Making Meaning through Discussion: Participation	1	2	1	1	2	2	2	3	4	4	4	4	3	4	4	4
B2. Inquiry and Observation of Scientific Phenomena: Investigation	1	2	2	2	1	2	3	3	4	4	4	3	4	4	4	4
B2. Inquiry and Observation of Scientific Phenomena: Hands-on Investigation and Data	2	1	1	1	1	1	3	3	3	4	4	4	4	4	4	3
B3. Finding Patterns and Connections	1	1	2	2	2	1	3	3	4	3	4	3	3	4	4	4
B4. Justifying Claims with Evidence-Based Reasoning	1	1	2	2	1	1	2	2	3	3	3	4	3	4	4	4
B5. Representations of Phenomena and Ideas	1	1	2	2	1	1	2	4	3	4	4	4	4	4	4	4
Average	1.25	1.5	1.5	1.5	1.375	1.625	2.375	2.75	3.625	3.75	3.875	3.75	3.625	3.875	4	3.875
C1. Eliciting and Interpreting Students' Thinking	1	1	1	1	2	2	2	2	4	4	4	4	3	3	3	4
C1. Eliciting and Interpreting Students' Thinking: Interaction	1	2	2	2	2	2	2	2	4	4	4	4	3	4	4	4
C2. Varied Ways to Demonstrate Understanding	1	1	1	2	2	2	2	3	3	3	3	3	3	4	4	4
C3. Eliciting a Variety of Ideas	1	1	1	1	1	2	2	2	4	3	3	4	4	4	3	4
C4. Considering Students' Thinking in Instruction	2	1	1	1	2	1	2	2	2	4	4	4	4	3	4	4
Average	1.2	1.2	1.2	1.4	1.8	1.8	2	2.2	3.4	3.6	3.6	3.8	3.4	3.6	3.6	4
D1. Critical Analysis of Practice	1	1	1	1	1	2	3	3	2	2	3	3	3	4	4	4
D2. Metacognition	1	1	1	2	1	1	2	1	3	3	4	4	3	3	3	4
Average	1	1	1	1.5	1	1.5	2.5	2	2.5	2.5	3.5	3.5	3	3.5	3.5	4
Average of each Classroom Observation Rating (COR)	1.313	1.325	1.425	1.600	1.594	1.731	2.369	2.338	3.181	3.413	3.594	3.663	3.406	3.694	3.775	3.969
Average FOI of all COR	1.416				2.008				3.463				3.700			

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