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FACILITATING COLLABORATIVE SCIENCE INQUIRY WITH SCRUM

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AMELIA COOK
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ADAPTIVE CLASSROOM PROJECT MANAGEMENT:
FACILITATING COLLABORATIVE SCIENCE INQUIRY WITH SCRUM

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BY

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Dr. Timothy Laubach, Chair

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Dr. Neil Houser

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Dr. Michael Richman

For Mom and Dad – so it goes. And for Uncle Drew, because – Rugby.

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Abstract

New standards such as *NGSS* require science teachers to shift the focus of classroom teaching to making sense of phenomena and designing solutions to problems, engaging in three dimensional learning, and developing 21st century skills such as problem solving, critical thinking, communication, collaboration and self-management. To achieve these goals, novel teaching and instructional management methods will be required to meet these new dynamic requirements. With the variety of challenges faced in the classroom, novice teachers stand to benefit from a management strategy to guide and organize their leadership efforts. This study is an autoethnographic reflection of how a pre-service science teacher utilized Scrum, an Agile Project Management delivery framework, to implement a collaborative project-based learning (PBL) inquiry science curriculum unit. Scrum roles, processes, and artifacts were incorporated into the PBL global climate change curriculum design and management strategies of the student intern. Researcher observations of variables in the learning environment that contributed to student collaboration were analyzed for patterns of significance. Scrum management had a significant impact on curriculum design and group communication which contributed to building a classroom community and creating a learning environment of positive educational outcomes and adaptability. The Scrum educational environment supported social learning, creativity, accessibility, engagement, and collaboration. These positive outcomes were the result of purposeful group management and sustained inquiry learning. Adaptive classroom project management based on components of Scrum was an effective method for a pre-service science teacher to facilitate student collaboration and a student-centered learning environment.

Chapter 1: Introduction

Historically, science education reform called for inquiry to be integrated into science classrooms; this was a new view of teaching and learning with the primary focus on the way students attempt to make sense of what they were learning, rather than how teachers should deliver instruction (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). These reforms called for teachers to create inquiry-based learning environments (Crawford, 2000) so to promote the development of inquiry abilities in students (Marx et al., 1997). These reforms supported shifting from a teacher-centered, knowledge-giver and student-receiver, to a learner-centered learning environment where teachers and students participate in learning as a partnership. Instructional strategies to promote and develop scientific inquiry are based on the idea that students learn science best when they are given an opportunity to do science in ways that represent authentic practices of scientists (Harris & Rooks, 2010; Minstrell & van Zee, 2000).

States developed their own science standards based on the following reform efforts: the *National Science Education Standards* (*NSES*; NRC, 1996) and the *Benchmarks for Science Literacy* (AAAS, 1993). Both reforms called for inquiry to be incorporated into science classroom instruction; however, many states regarded inquiry and content standards separately. Pruitt (2014) explained that this reduction of science as discrete pieces of knowledge resulted in state assessments that tended to focus solely on content. This juxtaposition led to a greater focus on content in science classrooms with little time spent engaged in authentic inquiry and science practice.

A new vision of quality science education began in 2011 with the release of *A Framework for K-12 Science Education* (*Framework*; NRC, 2012*),* which identifies key scientific practices and ideas all student should learn by the end of high school. The purpose of the *Framework* was to serve as a foundation for new K-12 science education standards to replace previous science education standards (*NSES* and *Benchmarks*). The *Framework* is based on a synthesis of the current research on how children learn science, implications for science instruction, the role of laboratory experiences in science instruction, the role of science learning experiences outside of school, assessments of science learning, and the knowledge and skill need to introduce students to engineering (NRC, 2012). The report articulates "a vision for science education in the 21st century and what students need to know to be considered scientifically literate citizens" (Pruitt, 2014, p.146).

The vision of the *Framework* reinforces what has been well accepted as the vision for science education in past reforms of *NSES* and *Benchmarks*, with one major addition, the introduction and definition of engineering and technology (NRC, 2012). The *Framework* calls for a move in science education toward a more coherent vision that includes building on the notion that learning is a developmental progression, focusing on a limited number of core ideas in science and engineering, and emphasizing that learning about science and engineering involves the integration of the practices needed to engage in scientific inquiry and engineering design necessary to construct knowledge of science ideas (NRC, 2012). It is recommended that science education be built around three major dimensions: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. The three dimensions will be discussed more extensively in Chapter 2.

A coalition of 26 states, managed by Achieve, led the development of K-12 science standards integrating the three dimensional recommendations in the *Framework.* The science standards, *Next Generation Science Standards* (*NGSS*)*,* are arranged in a coherent manner across disciplines and grades to provide students an internationally-benchmarked science education (NGSS Lead States, 2013). The *NGSS* were developed collaboratively with many stakeholders in science, science education, business, and industry in a process that underwent multiple reviews and drafts incorporating feedback from stakeholders and the public, allowing science education shareholders an opportunity to inform the standards (NGSS Lead States, 2013). The standards set the vision of the *Framework* into practice and established performance expectations for what students should know and be able to do with scientific knowledge. Performance expectations are a necessary and essential part of the standards and describe how students will demonstrate an understanding and application of the core ideas (NRC, 2012). The standards do not dictate curriculum or instructional method but support instructional flexibility (NGSS Lead States, 2013). Teachers at each grade level or content area have flexibility to arrange performance expectations in any order that suits the needs of students, local districts, or states.

The *Framework* and *NGSS* guidelines are not a federal mandate, nor supported, funded, or even researched by the U.S. federal government (National Science Teachers Association [NSTA], 2016). *NGSS* can be considered a national guideline of modern science standards for states to adopt and implement. However, not every state is adopting these guidelines. As of December, 2016, only 18 states have adopted *NGSS* (NSTA, 2016). Some states, because of the political climate and feedback from constituents, are either adapting their own standards based on the *Framework* and *NGSS* (Pruitt, 2014) or creating their own unique standards.

Oklahoma is one of the states that has drafted and is currently implementing their own new science standards (Oklahoma State Department of Education [OSDE], 2017). *Oklahoma Academic Standards for Science* (*OASS*) is similar in format and purpose to *NGSS*. The *OASS* was adapted from the *NGSS* and adopted and signed into rule June 2014 (Oklahoma State Department of Education, 2017). OASS was informed by previous reform documents (*A Framework for K-12 Science Education* and *Benchmarks for Science Literacy*), the *Next Generation Science Standards* (NGSS Lead States, 2013), and the state's previous science standards (*Oklahoma Priority Academic Student Skills for Science*; OSDE, 2011) (OSDE, 2013). The *OASS* is meant to be used as the comprehensive guide to provide education of scientific practice and subsequent scientific knowledge. Science education in Oklahoma reflects the same principles as *NGSS*, which are learning science by practicing science and applying science knowledge in authentic practice.

Implementing these standards will take three to four years to implement and will present many challenges transitioning to these standards including professional development, resources, educational materials, assessments, and teachers' understanding of both the knowledge of *NGSS* practices and application (Pruitt, 2014). The depth of knowledge required by *NGSS* and *OASS* exceeds standards of the past and adds an additional teaching strategy element of incorporating opportunities for students to engage independently and collaboratively in scientific practices.

"Teaching science as envisioned by the *Framework* requires teachers to have a strong understanding of the scientific ideas and practices they are expected to teach, including an appreciation for how scientists collaborate to develop new theories, models, and explanations of natural phenomena" (NRC, 2012, p. 256). Science education should include an emphasis on collaboration, as "science is fundamentally a social enterprise, and scientific knowledge advances through collaboration and in the context of a social system" (NRC, 2012, p. 27). The essential practices and competencies called for in the *Framework* require students to engage in science and engineering and to rely on skills of communication and collaboration. A science learning community that embraces a culture of collaboration and provides opportunities for peer feedback and deliberation supports the vision of science education called for in the *Framework* and *NGSS*. Research indicates that there are relatively few science classrooms at present that focus on scientific discourse practices and how teachers and students develop classroom learning community norms to promote these important collaborative skills (NRC, 2012).

The emphasis on student collaboration is echoed in the Partnership for 21st Century Learning (P21) organization's vision of the knowledge and skills all learners need to thrive the in the 21st century (P21.org, 2016). P21 is a nonprofit organization founded in 2002 comprised of collaborative partnerships among education, business, community, and government leaders to research and promote knowledge and skills essential to 21st century learning environments that will prepare students for the challenges of work, life, and citizenship, as well as, to ensure innovation in the economy and health of our democracy (P21.org, 2016). P21 stipulates that the "4Cs", creativity, critical thinking, communication, and collaboration, are essential to prepare students for the future (P21.org, 2016). These learning and innovation skills are being recognized as skills that separate students who are prepared for life and work in an increasingly global and informational based economy of the 21st century. Dede (2009) noted that "little time is spent on building capabilities in group interpretation, negotiation of shared meaning, and co-construction of problem resolutions" (p. 3) in K-12 curriculum. Plucker, Kennedy, & Dilley (2015) agreed and pointed out that collaboration is a critical skill for career and life success; however, the emphasis of collaboration in schools reflects traditional models of interaction and does not support 21st century competence.

There is ample evidence inquiry-based learning enables students to construct meaning from their learning, to engage in higher order thinking, to learn and retain content, and to gain higher levels of achievement (Minner, Levy, & Century, 2010; Von Secker, 2002). However, there is limited research for how to design instructional environments to promote students' understanding of scientific inquiry (Crawford, 2000) and how to implement authentic inquiry learning lessons (Crawford, Krajcik & Marx, 1999). These challenges are even more problematic for novice teachers (Huber & Moore, 2001).

Pre-service teachers lack the experience to provide authentic inquiry environments, the conceptions of how to be a scientific role model, and the scaffolding techniques to support inquiry discussions or creating models which affect the ability to engage students (Windschitl et al., 2008). Pre-service science teachers in Oklahoma are also tasked with an additional requirement to incorporate new science standards, *NGSS* and *OASS*, into their repertoire. Designing, implementing, and sustaining a learner-centered, inquiry learning environment is a challenge for experienced teachers, as is learning, adopting, and implementing a new teaching strategy outlined by *NGSS*. Additionally, novice teachers are concerned over managing paperwork, numerous changes in schedules, time constraints, placements, and classroom management (Watson, 2006). Teacher turnover is high with almost 50% of teachers leaving the profession in the first five years (Ingersoll & Smith, 2003). It is evident that the first few years of a pre-service teacher's career are difficult with many different constraints to manage, such as, meeting diverse stakeholder expectations and the needs of diverse learners and science standard objective goals with limited peer support due to the novel nature of *NGSS* standards.

Teaching science is a demanding, complex project that requires teachers to respond to numerous changing classroom conditions that shift from moment to moment (Brophy, 1988). Many novice (including pre-service) science teachers have limited resources to negotiate the demands of managing inquiry science and student collaboration due to their lack of experience. Harris and Rooks (2010) asserted that classroom management in inquiry science classrooms should be focused on creating student-centered learning environments. These environments support student reasoning around conceptual issues and complex problem solving, with effective teacher scaffolding to support student collaboration and communication around authentic tasks, and opportunities to participate in a scientific learning community (Harris & Rooks, 2010).

Our culture of education is a changing landscape of expectations, from new U.S Department of Education acts that often change with a new administration (No Child Left Behind, Every Student Succeeds), new standards such as *NGSS*, individual state standards, district policies, school policies, to classroom expectations that change with each hour and new student body makeup. Teachers must anticipate and manage change in every aspect of their career. Today's students are faced with adapting to change due to increasing global ecological changes (IPCC, 2013) and an interconnected global economy. Students in a post-industrial, information economy need skills to think critically, solve problems collaboratively, adapt to change, and prepared teachers to help them develop these skills.

Statement of the Problem

Science teaching and learning are at a critical point in the United States with the introduction of three dimensional learning and performance expectations outlined by the *Framework* and *NGSS*. Science teachers must shift the classroom focus to making sense of phenomena and designing solutions to problems. Krajcik (2015) identified this shift as a new challenge of developing a classroom culture that focuses on three dimensional learning in which many teachers are not prepared for this type of teaching. However, this new vision of science education will allow students to develop important 21st century skills such as problem solving, critical thinking, communication, collaboration, and self-management (NRC, 2012). To achieve these goals, novel teaching and instructional management strategies will be required to meet this challenge.

Inquiry teaching is not simple and challenges the most experienced teachers (Marx et al., 1994). The addition of implementing modern science standards in accord with *NGSS* requires adapting teaching strategies that equip the next generation of scientists with the skills they need to understand the increasing complexity and changes in science (Bowman & Govett, 2015), which is an important task for all teachers. *NGSS* are inquiry-based standards that require teaching strategies to promote a classroom culture of scientific practice and inquiry learning. The new vision of *NGSS* is a paradigm shift for science educators that moves instructional focus from the language of inquiry to that of practice with the inclusion of and parallel discussion of engineering practices (NRC, 2012).

Traditional teaching methods that conform to teacher-centered instruction do not align with this new paradigm and require adoption of a new approach to creating student-centered learning environments. Many teachers never progress from the survival stage of novice teaching where they rely on ineffective practices such as note taking and worksheets as busy work for students (Wong & Wong, 1998). Teachers in student-centered learning environments become a source of scaffolding that supports student integration and application of ideas as students assume accountability for their own learning where these students collaborate, communicate, and participate in learning communities of scientific practice in student-centered learning environments (Harris & Rooks, 2010).

Current pre-service science teachers will be some of the first generation of educational professionals to implement *NGSS* standards, which is another complicated issue to add to an already overloaded array of demands on a new teacher. Pre-service science teachers could benefit from a teaching strategy to plan, design, and implement curriculum in accord with *NGSS* inquiry disciplinary bundles that engages students in science practices and application of scientific knowledge in authentic problem solving. Organizing, planning, and implementing a teaching philosophy takes experience, which pre-service teachers lack, and therefore, require a guide or model to help manage their professional educational projects.

Teachers cannot implement their teaching philosophy without a management philosophy to guide the implementation (Brophy, 1988). The leadership roles and responsibilities of managing proper curriculum and learning outcomes is complex, dynamic, and unique to every class. Planning and adapting to change as it occurs are vital aspects of successfully managing a collaborative group. Teachers must also balance constraints of time, cost, changes of scope, expectations, quality, and value. Effective teaching requires good classroom management that intertwines management and instructional activities simultaneously in practice, requiring teachers to engage students in intellectually meaningful activities, maintain student interest, and scaffold student learning (Brophy, 1988; Harris & Rooks, 2010; Kounin, 1970). The teacher-student relationship is an important component of managing the learning environment and establishing a productive learning community as well (Piwowar, 2013). Teachers must establish a management system that supports student collaboration in inquiry science environments and enables continuous monitoring and responding quickly to changes in the environment. However, pre-service science teachers lack experience and need a model of purposeful management to assist with enacting *NGSS* inquiry curriculum, managing a student-centered learning environment, and sustaining a collaborative, scientific learning community.

Background and Need

Science education as envisioned by the *Framework* and *NGSS* requires teachers to have a strong understanding of the scientific ideas and practices they are expected to teach, including an appreciation for how scientists collaborate to develop new theories, models, and explanations of natural phenomena (NRC, 2012). Collaborative learning communities are an ideal environment to support student scientific discourse and participation in practices of science and engineering; however, research indicates that a limited number of classrooms focus on scientific discourse practices and lack emphasis on student collaboration and developing 21st century skills (NRC, 2012; Plucker et al., 2015).

Collaboration in the classroom can be achieved with project-based curriculum (Blumenfeld, et al., 1991). Project-based learning (PBL) is an instructional strategy that engages students in learning knowledge and skills through an extended collaborative process guided by an inquiry question that drives research and allows students to apply their acquired knowledge (Bell, 2010). Project-based curriculum shares design features that provide opportunities for students to engage in several key features of the *Framework* and the *NGSS*, including, but not limited to, constructing an explanation by engaging in sustained scientific inquiry to answer a challenging question, designing and implementing an investigation, reflecting and revising explanations based on evidence, communicating conclusions, and solving authentic, real-world problems.

Collaboration is an important instructional strategy used in PBL and a crucial 21st century learning outcome (Lee, Huh, & Reigeluth, 2015). Students learn by collaborating, constructing knowledge, and making meaning through iterative processes of questioning, active learning, sharing, and reflection in PBL environments (Blumenfeld et al., 1991). Although PBL curriculum has shown to be effective in the classroom, it can be a challenging and taxing method for teachers (Mergendoller & Thomas, 2001). Enacting PBL in science classrooms is not easy with teachers reporting common issues of time constraints, reluctance to release control to students, management complications, support of student learning, technology use, and assessment (Colley, 2008; Marx et al., 1997). Despite the management challenges accompanying this teaching method, PBL is an ideal vehicle to achieve student collaboration and the *NGSS* goals of sustained inquiry and applied science knowledge.

There are management challenges and limited resources to assist the implementation of a new teaching strategy incorporating inquiry and scientific and engineering practices while supporting collaborative science learning communities. Similarities in the process, artifacts, and roles between PBL, sustained inquiry, student-centered science classrooms, and project management methodologies exist, which indicates there may be some guidance for teachers to design, implement, and manage collaborative PBL curriculum utilizing project management methodologies. Modeling successful project management skills by the teacher may be helpful to students learning management and self-regulated learning skills, as well as, assisting teachers to navigate the many challenges associated with implementing PBL in the classroom, perhaps more so for a pre-service teacher. There are many similar integral components of project management and the process of the iterative learning cycle of PBL curriculum and *NGSS* teaching strategies.

Teacher usage of project management as a classroom management strategy appears to have been studied modestly despite the similarities between student collaboration, PBL, and student-centered inquiry learning objectives. A thorough literature review has not revealed any examples of project management practitioners in a secondary classroom setting. There is limited, if any, evidence in the literature that educational management methods have been emphasized as project management in education; however, these management methods share many of the same project constraints. Many other disciplines (engineering, architecture, business) teach project management in their college courses to prepare students to lead diverse groups and meet the requirements of professional management (Davidovitch, Parush, & Shtub 2006; Dicks, 2013; Lingard & Barkataki, 2011; Melnik & Maurer, 2003; Perera, 2009; Pope-Ruark, 2012; Pope-Ruark, Eichel, Talbott, & Thornton, 2011). Project management is not a traditional component of teacher education, but it shares many of the same classroom management variables including collaborative groups, time, cost, quality, objectives, and diverse stakeholder expectations.

There have been new developments in project management methods that evolved from software development, such as, Agile Project Management (APM) (Highsmith, 2010). These methods are designed to encourage creativity, self-directed engagement, high team collaboration, and agility to adapt to changes in a volatile market (Highsmith, 2010). Agile lifecycles are both iterative and story-driven with the primary focus of planning and executing functional features (Highsmith, 2010). This lifecycle reflects the emphasis *NGSS* puts on performance expectations because the goal of the iteration or learning cycle, curriculum unit, etc. is to construct functional knowledge that will be used to fit into a larger umbrella of knowledge and skills, which contribute enhanced functionality from learning over time. APM, *NGSS*, and PBL share a common assertion that knowledge (functionality) develops overtime through a reflective process of learning and adapting and iterative delivery of segments of knowledge. The values and outcomes of APM also reflect the desired learning outcomes of 21st century learning, especially the 4Cs, which are collaboration, communication, critical thinking, and creativity.

The *Framework* includes a new focus on scientific and engineering practices and incorporates engineering design to create solutions to solve problems (NRC, 2012). There are many overlapping elements of intent and purpose expressed in *NGSS* that reflect the process of APM, which is logical because APM is a management method for facilitating the engineering design process. Analogies can be made between iterative learning, PBL science curriculum, *NGSS*, and APM, specifically the Scrum APM framework, an adapted methodology based on APM values and principles.

There are several different frameworks and methodologies of APM; however, the Scrum methodology emphasizes techniques for managing creative, collaborative groups and allows for increased group autonomy. Scrum is a “management, enhancement, and maintenance methodology”, a set of tools and techniques to manage the process of a complicated and unpredictable progression of a project (Schwaber, 1997, p. 120). Scrum will be discussed more extensively in Chapter 2. It is worthwhile to investigate the applicability of an adapted APM model to facilitate student collaboration and the process of inquiry science while incorporating *NGSS* practices. An adaptive classroom project management model based on APM principles, using the Scrum framework, may help guide pre-service science teachers to create coherent *NGSS*-inquiry curriculum and maintain effective learning environments of collaborative problem-solvers.

There are many suggestions in the literature to design and plan PBL and some limited resources for project-based inquiry *NGSS* science curriculum (Iat.com, 2017) but little direction on purposeful, reflective management for collaborative groups and how to facilitate *NGSS* science teaching and learning. A review of the research suggests there is need for a coherent management model to create a learner-centered, collaborative environment that is conducive to inquiry science. Harris & Rooks (2010) highlighted a need for models of how teachers can successfully manage the complexity of inquiry instruction and the resources and constraints of the classroom setting. A prescriptive set of management techniques is not a suitable approach for preparing teachers to engage students in scientific practices due to the dynamic nature of science and the classroom environment.

Mergendoller and colleagues (2006) stressed that there is a need for more research into creating and managing PBL curriculum and related instructional strategies. They suggested there may be more to learn from business and industry about managing projects more effectively (Mergendoller et al., 2006). There are many elements of *NGSS* that reflect some artifacts and intentions of Scrum, such as, iterative cycles of producing functional features to incorporate into a coherent whole, estabilishing and managing creative and collaborative groups, and emphasizing community and personal accountability. It is logical to investigate the application of a group management (collaborative) methodology to facilitate a *NGSS* learning environment when these approaches share many of the same foundational principles.

There is some research in the literature describing APM methods (Scrum) used in college business courses (Pope-Ruark, 2012, 2015). Agile Learning Centers, "an expanding network of micro-schools leveraging agile management tools", advertise themselves as schools supporting a 21st century education are receiving more attention online but have yet to be formally researched (AgileLearningCenters.org, 2017). These centers use APM tools that are adapted for classroom use and advertise guiding principles of adaptability, agency, creative culture of a supportive learning community, visible feedback and sharing, and facilitating collaboration and learning. (AgileLearningCenters.org, 2017). It is evident others are interested in the applicability of APM principles to modern education and teaching strategies. The APM methodology and Scrum framework are iterative adaptive cycles that resemble a similar cycle of human learning, project-based learning curriculum, and sustained *NGSS* inquiry. Additional research is needed to investigate if a purposeful management model based on APM principles enables a pre-service science teacher to effectively facilitate a student-centered science classroom, intertwining management and instruction, to plan and implement a philosophy of teaching inquiry science in accord with *NGSS* and a philosophy of management that supports a collaborative, creative learning community.

Purpose of the Study

This purpose of this study was to examine how the participant researcher, a pre-service science teacher, utilized an adapted Scrum framework to guide the instructional management process to design and implement *NGSS*-inquiry science curriculum and to facilitate group collaboration in a student-centered, PBL environment. While there were suggestions for classroom and instructional management strategies for implementing collaborative inquiry science curriculum and project-based learning, a comprehensive management model was yet to be defined; hence, the need for this model had been highlighted (Harris & Rooks, 2010; Mergendoller et al., 2006). A review of the literature indicated teacher usage of project management in classroom environments had been researched modestly. However, project management and elements of management used in science teaching share many of the same management variables. The Scrum framework for Agile Project Management (APM) is a group management methodology that facilitates collaboration and development of progressive functionality, and reflects many of the same integral components of iterative learning, adapting to change, reflecting, and modifying processes as science inquiry teaching and learning and the phases of project-based learning.

This study utilized autoethnography, a qualitative research method that combines elements of ethnography, autobiography, and self-reflexivity (Chang, 2016) to analyze data from self-reflections and observations of the participant researcher. The participant researcher was a graduate student in science education who was involved in a semester-long student-teaching internship placement. The student-intern was a pre-service science teacher preparing to enter into professional practice following the internship. The pre-service teacher was tasked with designing and teaching curriculum aligned to *NGSS*, state (*OASS)*, and district (Advanced Placement) standards. The internship was under the supervision of the regular classroom teacher, referred to as the cooperating teacher (CT), and a university adviser. However, the teaching responsibilities and classroom management were the responsibility of the student intern with co-teaching assistance from the CT.

The curriculum for the research study was a project-based *NGSS*-inquiry unit in an Advanced Placement Environmental Sciences (APES) high school class of fifteen high school students in grades 9, 10, 11, and 12. The unit covered content related to climate science and the ecological impacts of change in Earth's climate system and was twelve class periods in length. Components of the Scrum framework were adapted and used to design and manage the unit's learning activity logistics and process, student management roles and responsibilities, and artifacts of learning. The unit was designed to progress through three collaborative iterative cycles, called sprints, with a culminating final collaborative project. The final project's format and message was decided by the students, produced as a collaborative effort by the entire class, and assessed according to the *NGSS* performance expectations (HS-ESS3-5, HS-ESS3-6) (a more detailed explanation of these performance expectations will be provided in Chapter 3).

Data were collected from the student-intern's curriculum development process, artifacts, and personal reflections to evaluate classroom project performance, student engagement and collaboration, and level of assistance the management model provided the pre-service teacher. The CT was an experienced mentor who assisted the student intern and participant researcher with evaluation of teaching effectiveness and interpreting management strategies throughout the project. This valuable insight from a knowledgeable other validated and reinforced the observational data of the classroom environment.

Pre-service science teachers lack experience and may benefit from a model of purposeful management to assist with enacting *NGSS*-inquiry curriculum, managing a student-centered learning environment, and sustaining a collaborative, scientific learning community. Collaboration and self-directed engagement is fundamental to APM (Highsmith, 2008) and may facilitate the same kind of results in a classroom setting. This study may contribute to the body of knowledge of managing science classrooms engaged in collaborative inquiry science learning and educational applications of the principles of APM. The process may develop a germinal theoretical framework for an adaptive classroom project management model that could be used as a planning tool or guide for pre-service science teachers. The research study may highlight new methods to implement *NGSS* teaching strategies that reflect engineering design principles. The adaptive classroom project management (ACPM) model is a tool intended for leadership in educational endeavors but may also serve as an instructional tool that contributes to the development of self-regulated collaborative learning and 21st century learning skills.

Research Question

The question guiding this research study was "How can a pre-service science teacher use Scrum, an Agile Project Management framework, to implement a *NGSS*-aligned PBL learning progression that facilitates student collaboration and a student-centered learning environment?"

Significance of Study

Scrum is a useful tool to manage collaborative groups. There are significant applications of this group management method in educational settings to facilitate collaborative sustained inquiry science. Scrum can be used by pre-service science teachers to design and implement *NGSS* aligned science curriculum with clearly defined performance expectations and social engagement of the learning group in scientific and engineering practices. This management method not only organizes collaborative groups but facilitates fluid communication and contributes to the development of a sense of community and relationships building among members of the group.

Definitions

Agile Project Management (APM) – opportunities created by the agile revolution and its impact on product development, the values and principles that drive agile project management, the specific practices that embody and amplify those principles, and practices to help entire organizations, not just project teams, embrace agility (Highsmith, 2010).

Agile Values – delivering value over meeting constraints, leading the team over managing tasks, adapting to change over conforming to plans. (Highsmith, 2010).

Backlog – prioritized list of requirements (capabilities, features, and stories) used for iteration planning in Scrum (Pham & Pham, 2012)

Crosscutting Concepts (CCC)– provide an organizational schema for interrelating knowledge from various science fields into a coherent and scientifically based view of the world, include patterns, cause and effect, scale proportion, and quantity (NRC, 2012)

Disciplinary Core Ideas (DCI) – fundamental ideas that are necessary for understanding a given science discipline, grouped into four domains: physical sciences, life sciences, earth and space sciences, and engineering, technology, and applications of science (NRC, 2012).

Science and Engineering Practices (SEP) – behaviors that scientists engage in as they investigate and build models and theories about the natural world and they key set of engineering practices that engineers use as they design and build models and systems (NRC, 2012).

Performance Expectation – statements of what students should know and be able to do at the end of instruction for a particular grade band or subject (NRC, 2012)

Product Owner – the guardian of the product vision and goals, manages stakeholder expectations, establishes clear project vision, develops backlog stories and priorities, and ensures backlog requirements are clear and visible to team (Pham & Pham, 2012)

Project-Based Learning (PBL) – teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, or challenge (Larmer, 2015)

Scrum – an agile method for project management, iterative method of developing products in an incremental fashion; gives authority to the development team to manage its own work and prescribes only a simple set of rules for the team to follow; an effective method for short projects or can break down long complicated projects into incremental, manageable modules, organized by sprints that deliver working increments of the final product, each next increment is built based on requirement specifications as well as modifications resulting from what was learned in the previous sprint (Goncalves & Heda, 2010).

Scrum Master – the modified project manager for the Scrum project, facilitates team, ensures nothing impedes team performance, and maintains adherence to Scrum practices, ensures Scrum is understood and enacted (Goncalves & Heda, 2010).

Sprint – project iteration cycle in which a useable, functional element of the final product is produced, consists of spring planning, daily stand up meetings, development work, sprint review, and sprint retrospective (Pham & Pham, 2012).

Sprint Planning – collaborative plan by entire Scrum team of the work to be performed in the sprint, decide what increment from the backlog will be delivered and what work will need to be completed to deliver increment for sprint iteration (Pham & Pham, 2012).

Sprint Retrospective – collaborative team meeting to discuss what worked and what did not work during the sprint, adjustments are made for the next sprint in response to this meeting, encourages peer accountability (Pham & Pham, 2012).

Sprint Review – held at end of a sprint to inspect and demonstrate product to product owner for feedback and make adjustments to the backlog (Pham & Pham, 2012).

Stand-up Meeting – also referred to as Daily Scrum, a short meeting at the beginning of every work day to keep team on track and evaluate performance (Goncalves & Heda, 2010).

Story – is a piece of a product that delivers some useful and valuable functionality to a customer, user oriented (Highsmith, 2010).

Story Card – simple medium for gathering basic information about the story, requirements, work estimates, expectations; (Highsmith, 2010).

Task – specific actions needed to complete story requirements generated by team (Pham & Pham, 2012).

Limitations

The student intern was a pre-service science teacher and project manager with limited experience planning or managing classrooms or utilizing management frameworks to meet project objectives or manage groups. However, this was the focus of this study, to evaluate how a pre-service teacher utilized a model adapted from existing management methodology from the business industry to meet professional educational expectations of managing an effective NGSS-inquiry learning environment.

Members of the learning community in this study were not familiar with APM nor Scrum, which required additional time to explain the process, roles, and artifacts, as well as, additional planning time for the CT and student researcher. There was limited information in the literature regarding APM or Scrum in K-12 classrooms. Thus, there were no best practices to guide the research design for this study.

The collaborating teacher and student researcher had limited experience with PBL curriculum while the students in the classroom of the research study had never participated in PBL-structured curriculum. Research shows that PBL is difficult to implement and can take an estimated three years before an experienced teacher is an effective PBL practitioner (Crawford, Krajcik & Marx, 1999). The unfamiliar nature of this teaching method took classroom time to explain and to adjust, which reduced the amount of classroom time for learning and reduced instructional effectiveness. Again, this was a limitation, but also an opportunity for the researcher to reflect on and observe the agility of the learning community to respond to changes in the learning environment and how much the management model assisted the pre-service teacher navigating unfamiliar curriculum, management challenges, and limitations of teaching experience and management.

Ethical Considerations

The Institutional Review Board (IRB) at the University of Oklahoma determined the research study met the criteria for exemption from a full IRB review (see *Appendix*). The research presented no more than minimal risk of harm to participants and involved no procedures for which written consent is normally required. Normal educational practices were followed in the classroom. Official permission was obtained from the school district, school site, and classroom teacher. An oral consent script was read prior to study initiation to inform the participants of the purpose and expectations of the study.

Chapter 2: Literature Review

Science teaching and learning in the United States are at a crucial juncture with the introduction of three dimensional learning and performance expectations outlined by the *Framework for K-12 Science Education* (*Framework*; NRC, 2012) and *Next Generation Science Standard* (*NGSS*; NGSS Lead States, 2013). Science teachers must shift the classroom focus from students primarily learning science concepts to learning how to use that knowledge with scientific and engineering practices, engaging in scientific discourse, making sense of phenomena, and designing solutions to problems. Krajcik (2015) asserted that a new challenge of developing a classroom culture, which focuses on three dimensional learning, is that many teachers are not prepared for this type of teaching. However, this new vision of science education will allow students to develop important 21st century skills such as problem solving, critical thinking, communication, collaboration, and self-management (NRC, 2012). To achieve these important, modern goals, novel teaching and instructional management strategies will be required to meet this challenge.

Science education as envisioned by the *Framework* and *NGSS* requires teachers to have a strong understanding of scientific discourse and practices, including the role of student collaborative problem solving. Teachers will need to create learning environments that incorporate opportunities for students to emulate how scientists collaborate to develop new theories, models, and explanations of natural phenomena (NRC, 2012). Research indicates that there are few science classrooms that currently focus on scientific discourse practices, emphasize student collaboration, develop 21st

century learning skills, or how teachers and students develop a classroom learning community that promotes these important skills (NRC, 2012; Plucker et al., 2015).

Collaboration is an important instructional strategy used in project-based learning (PBL) and a crucial 21st century learning outcome (Lee, Huh, & Reigeluth, 2015). Students learn by collaborating, constructing knowledge, and making meaning through iterative processes of questioning, active learning, sharing, and reflecting in PBL learning environments (Blumenfeld et al., 1991). Project-based curriculum has shown to be effective in the classroom; however, it can be challenging and taxing for teachers to manage (Mergendoller & Thomas, 2001).

Classroom management is a major concern for every teacher, even more so for novice teachers, and teachers utilizing inquiry-based science activities and PBL (Harris & Rooks, 2010; Hubert & Moore, 2001; Lawson, 2000; Mergendoller & Thomas, 2001; Watson, 2006). While there are suggestions for classroom management strategies for implementing inquiry science curriculum (Baker, Lang, & Lawson, 2002; Lawson, 2000) and project-based learning (Colley, 2008; Dickinson & Jackson, 2008; Marx et al., 1997), a comprehensive management model has yet to be defined; but, the need for this model has been highlighted by researchers (Harris & Rooks, 2010; Mergendoller et al., 2006). These management struggles are a challenge for experienced teachers; however, pre-service teachers have more of a disadvantage because of their lack of experience managing an educational environment (Windschitl et al., 2003).

A review of the literature indicated teacher usage of project management in classroom environments has been researched modestly without an obvious research focus or examples of K-12 classroom teachers as project management practitioners.

However, project management and elements of instructional and classroom management used in science teaching share many of the same variables, such as, diverse collaborative groups, time, quality, performance objectives, tasks, and diverse stakeholder expectations.

The Scrum framework for Agile Project Management (APM) reflects many of the same integral components of iterative learning, adapting, reflecting, and modifying processes as *NGSS* inquiry teaching and learning and the phases of project-based learning. Some courses in higher education have adapted Scrum to classroom use (Opt & Sims, 2015; Pope-Ruark, 2012, 2015), but there are virtually no studies of Scrum application methods in a K-12 science classroom that have been identified in the literature.

A pre-service science teacher, a science education student-intern, utilized Scrum, an Agile Project Management framework, to plan, design, and implement a *NGSS*-aligned PBL learning progression in a high school science class during a semester-long student teaching internship in an attempt to coalesce these seemingly related management and instruction variables into a purposeful management model. This study employed autoethnography as a tool to examine the experiences of the participant researcher to determine the magnitude of assistance Scrum was to the implementation of a *NGSS* aligned PBL learning progression and facilitation of student collaboration in a student-centered learning environment.

The literature review will address several areas related to the expectations of *NGSS*-inquiry science education, the educational value of student collaboration, and the challenges pre-service teachers face when implementing recommended science teaching strategies and managing science classrooms. The literature regarding Scrum, a potential management solution from the business industry, will be examined to explain the process, roles, and artifacts of this effective group management strategy, applications for classroom use, and the educational analogies to science teaching.

Inquiry Science Education

Inquiry science has been the hallmark of science education for many years (AAAS, 1993; NRC, 1996). Inquiry based instruction enables personal construction of meaning and can lead to higher achievement (Von Secker, 2002). Teaching science through inquiry leads students through a process to develop rational thinking skills and construct an understanding of science concepts to make sense of the world around them (Marek & Cavallo, 1997). Minner, Levy, and Century (2010) explained that the term inquiry, as it relates to science education, included three categories: activities of scientists (scientific investigations), how students learn ("actively inquiring through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists"), and the pedagogical approaches of teachers (designing "curricula that allow for extended investigations") (p. 476).

The essential feature common to all of these applications of the term inquiry is the foundational theory of Jean Piaget's model of mental functioning and intellectual development, which proposed individuals construct knowledge and meaning based on their experiences. Marek (2008) explained that the learning cycle model, is an approach to structure inquiry into sequential phases that reflect how children learn through the Piagtian processes of assimilation, disequilibration, accommodation, and organization. This model is divided into three phases: (a) the exploration phase is designed to give students an opportunity to assimilate data from exploration of a phenomenon and enter a state of disequilibrium when the new incoming information does not fit current schema; (b) the concept development phase follows the exploration and is a structured analysis and explanation of the data and introduction to a concept led by the instructor, which allows the student to accommodate the new information and become re-equilibrated; (c) the expansion phase then allows students to organize the new information with what they already know (existing schema) with opportunities to extend the concept in a new application (Marek, 2008). Lawson (1995) explained the history of the learning cycle can be traced to the work of Karplus and Thier (1967). The learning cycle has a long history and evolution from a "3E" to a "5E", and more recently a "7E" model, but the common thread among the different renditions of this model is that teaching science as inquiry means to give students an opportunity to explore and conceptualize a scientific phenomenon or problem, forcing them to come up with their own answers before giving them the solution (Alberts, 2000). There is ample evidence to support that claim that inquiry-based science teaching is effective (Abraham, 1997; Abraham & Renner, 1986; Marx et al., 2004; Von Secker, 2002); however, it is important to consider the learning environment in which the inquiry is taking place and the social role of learning.

Teachers need to combine inquiry learning activities with constructivist-oriented discussion so students can expand their existing knowledge and revise their understanding (Driver et al., 1994). Learning is an individual activity but does not happen in a vacuum. Driver and colleagues (1994) explained that cognitive psychologist Lev Vygotsky shared similar ideas of Jean Piaget about how children learn through constructing knowledge in a process of adaptation of cognitive schemes based on experiences in the physical environment, but placed more emphasis on the social context of learning and the role of an active, involved teacher. Social constructivism is the cornerstone of inquiry based teaching and learning (Chichekian, Shore, & Tabatabai, 2016). Scientific understanding requires social engagement to discuss and process shared problems. Scientific knowledge is "socially constructed, validated, and communicated", a process of "enculturation rather than discovery" essential to students developing scientific ways of knowing that require "intervention and negotiation", a "dialogic process" necessary to support and guide students to make sense of scientific concepts for themselves (Driver et al., 1994, p. 11). Learning is a social process that takes place in the context of culture, community, and past experiences and is enhanced when students work together on challenging tasks (Dickinson, 2008).

Emphasizing the social role of learning science and collaborative problem solving reflects the contemporary vision of science education reforms, such as the *Framework* (NRC, 2012) and *NGSS* (NGSS Lead States, 2013). The vision of the *Framework* reinforces what has been well accepted as the vision for science education in past reforms of *NSES* and *Benchmarks*, with one major addition, the introduction and definition of engineering and technology (NRC, 2012). The *Framework* calls for a move in science education toward a more coherent vision that includes building on the notion that learning is a developmental progression, focusing on a limited number of core ideas in science and engineering, and emphasizing that learning about science and engineering involves the integration of the knowledge of science (content) and the practices needed to engage in scientific inquiry and engineering design (NRC, 2012).

The addition of engineering practices is a new component to science standards and highlights an emphasis of complementing scientific practices with engineering and design (Bybee, 2014), which places science learning within a context of authentic problem solving, utilizing engineering design.

The *Framework* defines several guiding principles about the nature of learning science, which is heavily based on current educational research. The principles include: children are born investigators that develop their own ideas about the physical, biological, and social worlds and how they function and engage in scientific and engineering practices in early grades; a limited set of core ideas allow for deep exploration of concepts and time for students to develop meaningful understanding of these concepts through practice and reflection, core ideas are an organizing structure to support acquiring new knowledge over time and to help students build capacity to develop a more flexible and coherent understanding of science; understanding develops over time, across years, so instructional supports and experiences are needed to sustain students' progress; science and engineering require both knowledge and practice; classroom learning experiences need to connect with students' own interests and experiences for students to develop a sustained attraction to science; and that all students should have equitable opportunities to learn science and engage in science and engineering practices (NRC, 2012).

It is recommended that science education be built around three major dimensions: scientific and engineering practices (SEP), crosscutting concepts (CCC), and disciplinary core ideas (DCI). The practices of science and engineering describe behaviors that scientists engage in as they investigate and build models and theorize about the natural world and the set of engineering practices that engineers use as they design and build models and systems (NRC, 2012). Strengthening the engineering aspects of the *NGSS* will clarify for students the relevance of science, technology, engineering, and mathematics to their everyday life (NRC, 2012). Crosscutting concepts (CCC) are a way of linking different domains of science. They include patterns, similarity, and diversity; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; stability and change (NRC, 2012). Disciplinary Core Ideas (DCI) are ideas that meet at least two of the following criteria: (a) have broad importance across multiple disciplines or be a key organizing concept, (b) provide a key tool for understanding, (c) relate to the interest and life experiences of students or societal or personal concerns that require scientific or technological knowledge, and (d) be teachable and learnable over multiple grades at increasing levels of depth and sophistication (NRC, 2012). These concepts provide an organizational schema for interrelating knowledge from different fields.

The three dimensions of science education are an improvement and progression in the transition from inquiry to practice. The *Framework* (2012) explains that scientific and engineering practices include principal goals of science education that requires students to engage in scientific inquiry and reason in a scientific context. These practices minimize the tendency to reduce scientific practices into a single set of procedures, emphasize there are plural practices and not one scientific method, and provide clarity on elements of inquiry, more than what was previously offered (NRC, 2012). These concepts are similar to what was previously recommended in reform documents but requires incorporation into the three dimensional framework. Three dimensional learning emphasizes what students are expected to do with their science knowledge rather than what they should know (NRC, 2012). Disciplinary core ideas parallel content in previous standards with an included emphasis on engineering, technology, and applications of science. This stresses the reciprocity between science and technology and helps students recognize the interdependence of engineering, technology, science, and society (NRC, 2012). The *Framework* is drawn from what is known in the current research of science teaching and learning and lays the foundation for modern K-12 science standards.

The development of K-12 science standards, *Next Generation Science Standards* (*NGSS*) integrating the three dimensional recommendations in the *Framework,* arranged in a coherent manner across disciplines and grades, provide students an internationally-benchmarked science education (NGSS Lead States, 2013). With *NGSS,* students are led through a cyclical method of inquiry learning that requires them to ask their own questions and investigate impacts of their own personal investigations (Bowman & Govett, 2015). The standards set the vision of the *Framework* into practice and established performance expectations for what students should know and be able to do with scientific knowledge.

NGSS represents a paradigm shift in science teaching requiring students to meet performance expectations (PE), which are essential components of the standards. Performance expectations are statements that describe activities and outcomes that students are expected to achieve in order to demonstrate their ability to understand and apply the knowledge described in the DCI (NRC, 2012). These expectations specify what students should know, understand, and be able to do, supporting instruction and assessment by providing tasks that are measurable and observable (NRC, 2012). Performance expectations increase in sophistication at higher grade levels reflecting a "deeper understanding, more highly developed practices, and more complex reasoning" (NRC, 2012, p. 228). *NGSS* emphasizes that scientific and engineering practices are not teaching strategies, but indicators of achievement and learning goals. Performance expectations are meant to be accomplished at the end of instruction. Curriculum must be developed in a way that builds students' knowledge and abilities through practices and differentiated instruction toward meeting performance expectations.

The performance expectations of *NGSS* will require shifts in science teaching away from conventional teaching practices. Environments for learning science as envisioned by the *Framework* require teachers to adopt novel instructional strategies that facilitate a community conducive to scientific discourse, collaboration, and peer support and evaluation. Teachers need to have a strong understanding of the scientific ideas and practices they are expected to teach, including an appreciation for how scientists collaborate to develop new theories, models, and explanations of natural phenomena (NRC, 2012). Science education should include an emphasis on collaboration, as "science is fundamentally a social enterprise, and scientific knowledge advances through collaboration and in the context of a social system" (NRC, 2012, p. 27). The essential practices and competencies called for in the *Framework* and *NGSS* require students to engage in science and engineering practices such as engaging in argument from evidence and obtaining, evaluating, and communicating information that rely on skills of communication and collaboration. "Scientists collaborate with their peers in searching for the best explanation for the phenomenon being investigated" as do "engineers collaborate with their peers throughout the design process, with a critical stage being the selection of the most promising solution among a field of competing ideas" (NRC, 2012, p. 52). A science learning community that embraces a culture of collaboration and provides opportunities for peer feedback and deliberation supports the vision of science education called for in the *Framework* and *NGSS*. Research indicates that there are relatively few science classrooms at present that focus on scientific discourse practices and how teachers and students develop classroom learning community norms to promote these important collaborative skills (NRC, 2012).

Modern science education advocates for learning environments that provide opportunities for students to inquire and make sense of phenomenon, construct knowledge by engaging in scientific and engineering practices to discuss, collaborate, and refine processes to solve problems or design solutions. Performance expectations establish what we currently value in our scientific practices and culture. *NGSS* performance expectations clearly define what competencies students should have at the end of instruction. These objectives are observable and measureable tasks that can be used to assess learning. Performance expectations are knowledge benchmarks in a long-term learning progression with increasing levels of understanding and skill. This type of science education relies on a learning environment of regular discourse and collaboration, a community of collaboration to cultivate and strengthen our society's ability to solve problems with the knowledge obtained in science class.

Student Collaboration and Classroom Learning Communities

Collaboration among learners is an essential component of inquiry learning (Bell, Urhahne, Schanze & Ploetzner, 2010). Bell and colleagues (2010) utilized Duit & Treagust's (1998) work to explain that social constructivist theories indicate that knowledge emerges by a "collaborative search of problem solutions in communities with distributed information among its members" (Bell et al., 2010, p. 4). Collaborative learning is central to Vygotsky's (1978) construct of the zone of proximal development in which he believed an individual's cognitive growth requires assistance from a more knowledgeable other to provide support to accomplish tasks that are out of the individual's current range of ability. With more experiences the individual's learning will progress as a result of continued cognitive development and social interaction (Doolittle, (1997).

The emphasis on student collaboration is mirrored in the list of skills established by the Partnership for 21st Century Learning (P21) organization all learners need to thrive the in the 21st century (P21.org, 2016). P21 is a nonprofit organization founded in 2002 comprised of collaborative partnerships among education, business, community, and government leaders to research and promote knowledge and skills essential to 21st century learning environments that will prepare students for the challenges of work, life, and citizenship, as well as, to ensure innovation in the economy and health of our democracy (P21.org, 2016). P21 stipulates that the "4Cs", creativity, critical thinking, communication, and collaboration, are essential to prepare students for the future (P21.org, 2016). These learning and innovation skills are being recognized as skills that separate students who are prepared for life and work in an increasingly global and informational based economy of the 21st century.

Collaboration in the classroom can be achieved with project-based curriculum (Blumenfeld, et al., 1991). A recent study (Harris et al., 2015) suggested that project-based curriculum that incorporates science practices along with disciplinary content can help students achieve next generation science and 21st century learning outcomes. Project-based curriculum shares design features that provide opportunities for students to engage in several key features of the *Framework* and the *NGSS*, which include but are not limited to, constructing an explanation by engaging in sustained scientific inquiry to answer a challenging question, designing and implementing an investigation, reflecting and revising explanations based on evidence, communicating conclusions, and solving authentic, real-world problems. Students learn by collaborating, constructing knowledge, and making meaning through iterative processes of questioning, active learning, sharing, and reflection in PBL learning communities (Blumenfeld et al., 1991). Collaborative learning projects are an important contribution to the development of 21st century skills of collaboration, critical and creative thinking, and complex problem solving (Bell, 2010; Gokhale, 1995; Johnson & Johnson, 1994).

Project-based curriculum can be referred to as problem-based learning, project-based learning, project-based science, and other similar labels but will be collectively referred to in this study as project-based learning (PBL), which commonly share a method of inquiry that emphasizes cooperative learning and student construction of artifacts that demonstrate what is being learned. Students construct knowledge individually through inquiry as well as collaboratively to research and create projects in PBL environments (Bell, 2010).

PBL is a student-centered, inquiry-based pedagogical approach for facilitating knowledge construction (English & Kitsantas, 2013). Students engage in solving real-world problems similar to what will be expected of them as adults in PBL. This form of learning is a comprehensive method of learning environment design that incorporates the following five main features: (a) a driving question or problem to be solved, (b) student exploration of driving questions through inquiry process in an authentic, real-world context in which they learn and apply concepts of the discipline, (c) a collaborative learning environment of learning partnerships (d) students and community members learning technologies that scaffold student learning during the inquiry process to assist students to engage in activities beyond their current abilities, and (e) student created artifacts of learning that are publicly shared to answer the driving questions (Blumenfeld & Krajcik, 2005).

Larmer, Mergendoller, & Boss (2015) explained the "gold standard" PBL model includes three main features: student learning goals, essential project design elements, and project based teaching practices. They stated student learning goals are the center of any well designed PBL unit in which students learn to apply knowledge to the real-world, solve problems, answer questions, and create high-quality products. Student goals include the development of key success skills to think critically, solve problems collaboratively, and self-management (21st century skills) in PBL environments. Essential design elements of successful project include; a challenging problem or question, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and communicating learning through a public product. Teaching practices that are included in the "gold standard" PBL model reflect the emphasis of the role of the teacher as a partner in learning, a guide. Teaching practices are framed around a project and include; design and plan; align to standards; build the culture; manage activities; scaffold student learning; assess student learning; and engage and coach (Larmer et al., 2015).

Students become accountable for their own learning and actively engage in constructing knowledge and making meaning in PBL (Mergendoller et al., 2006). PBL has been shown to positively affect student content knowledge, high levels of student engagement, increased motivation to learn, and initiative to use learning resources (Barron, et al., 1998; Bartscher, et al., 1995; Belland, et al., 2006; Brush & Saye, 2008; Mergendoller, 2006; Penuel & Means, 2000). Teachers that utilize PBL can create student-centered learning environments that engage students in sustained inquiry and promote collaboration.

Teaching science with PBL supports sustained inquiry and collaborative problem solving of authentic, real-world problems and reflects the contemporary vision of science education reforms, such as, the *Framework* (NRC, 2012) and *NGSS* (NGSS Lead States, 2013). Although, project-based curriculum has shown to be effective in the classroom, it can be challenging and taxing for teachers (Mergendoller & Thomas, 2001). PBL implementation is not easy in classrooms with common issues of time constraints, reluctance to release control to students, management complications, support of student learning, technology use, and assessment are reported by science teachers when they attempt to enact project-based science (Colley, 2008; Marx et al., 1997). Mergendoller (2001) found that teachers reported difficulties associated with striking a balance between the need to maintain order in the classroom and the need to allow students to work on their own projects. PBL is an ideal vehicle to achieve student collaboration and *NGSS* goals of sustained inquiry and applied science knowledge and practice; however, there are management challenges to this teaching method.

Challenges of Pre-Service Science Teachers

Pre-service science teachers are expected to create learning environments of sustained inquiry and meet the challenge of modern science education reform outlined by *NGSS*. Science teachers will need extensive professional development to achieve this level of science learning for their students (Lee, Miller, & Januszyk, 2014). There is limited research for how to design instructional environments to promote students' understanding of scientific inquiry (Crawford, 2000) and many teachers struggle implementing authentic inquiry learning lessons (Crawford, Krajcik & Marx, 1999). This challenge is even more problematic for novice teachers (Huber & Moore, 2001). Novice teachers lack experience to provide authentic inquiry environments, conceptions of how to be a scientific role model, and scaffolding techniques to support inquiry discussions and creating models which affect the ability to engage students with modern pedagogy (Windschitl et al., 2008).

Many teachers encounter classroom management problems in inquiry teaching with unique challenges to modify instruction to meet individual student needs (Baker, 2002). Additionally, novice teachers are concerned over managing paperwork, numerous changes in schedules, time constraints, and placements, and classroom management (Watson, 2006). Teacher turnover is high with almost 50% of teachers leaving the profession in the first 5 years (Ingersoll & Smith, 2003). Classroom management is the most common concern expressed by beginning pre-service teachers and the reason many teachers leave the profession (Malmgren, 2005). Pre-service science teachers are faced with many challenges upon entering into professional practice.

Facilitating inquiry science is a concern for many science teachers; futhermore, many novice science teachers may not be prepared to be effective inquiry facilitators (Crawford, Krajcik, & Marx, 1999; Harris & Rooks, 2010; Lawson, 1995; Windschitl et al., 2008). While there are suggestions for classroom management strategies for implementing inquiry science curriculum (Baker, Lang, & Lawson, 2002; Lawson, 2000) and project-based learning (Colley, 2008; Dickinson & Jackson, 2008; Marx et al., 1997), a comprehensive management model has yet to be defined. But, the need for this model has been highlighted by researchers (Harris & Rooks, 2010; Mergendoller et al, 2006).

Colleagues Harris and Rooks (2010) skillfully explained the pervasive nature of managing the classroom and provided an important pyramid model framework to consider key management areas for inquiry learning in science classrooms. They emphasized managing the classroom to facilitate student inquiry learning is a considerable challenge for teachers. This article was published before *NGSS* but their instructional recommendations reflect the same interconnected nature of "science-as-practice" perspective for science instruction emphasizing "instruction should integrate doing and learning through four strands of scientific practice" (p. 229). The four strands include: (a) know, use and interpret scientific explanations, (b) generate and evaluate scientific evidence and explanations, (c) understand the nature and development of scientific knowledge, and (d) participate productively in scientific practices an discourse (Harris & Rooks, 2010). The authors elaborated on Mergendoller and colleague's (2006) work to explain the term pervasive management: "a view of classroom management that goes well beyond maintaining classroom order….intertwined with instruction and involves sustained support for student learning" (p. 230). Effective instruction in inquiry science teaching involves initiating and "maintaining student interest and engagement, enacting intellectually meaningful activities, and scaffolding student learning", strategies that require both instruction and management (p. 230).

Harris and Rooks (2010) identified common areas of pervasive management required for inquiry science teaching including: instructional materials, science ideas, students, tasks, and the social context, which is the classroom community of the learning environment. These areas are interconnected and impact the effectiveness of one another by how each area is managed. Changes in one area of management will affect the other areas. The management areas are arranged in a pyramid model with classroom community at the apex. This position indicates the "vital importance of managing the overall social context in which science instruction takes place" (p. 231). The pyramid model illuminates the nature of a student-centered classroom as interdependent areas of management critical to inquiry-based science learning. Management interactions function in inquiry learning environments by enlisting students in scientific practice and providing context for using scientific knowledge and skill as students build understanding and collaborate in the scientific community.

Harris and Rooks (2010) provided suggestions for managing inquiry science based on the current research for each of the following areas of the management interaction pyramid model: students, instructional materials, tasks, science ideas, and classroom community. Students in inquiry science classrooms experience higher demands to participate and to be personally responsible for learning, which requires the role of teacher to become a competent source of scaffolding to facilitate collaboration and scientific practices. Instructional materials need to be flexible to meet the needs of diverse students and utilize technology that supports student learning and reflects modern uses and practices of technology in professional science. Tasks must be authentic in inquiry classrooms to engage students in a "manner similar to how scientists conduct their work" (p. 234).

The learning objectives of students should be clearly defined to communicate intent, purpose, and relevance of learning tasks which will contribute to student learning and engagement. Science ideas need to be sequenced in a progression of understanding key science concepts. The learning progression should create a storyline that enables students to follow the logic of the lesson (Reiser, 2014). Managing the classroom community is a vital aspect of inquiry science. Collaboration, discussion, and communication are foundational to the classroom partnerships between teachers, students, and classmates. Teachers need to create the conditions in the learning environment that fosters collaboration and participation in scientific practices. Students need to relate to each other and expect a respectful interaction as they engage in learning partnerships within the classroom community. Pervasive management in inquiry science is dynamic and will look different in every classroom and therefore a prescriptive set of management techniques is not useful to engage students in scientific practices. Models of management are needed to assist teachers to navigate the complexity of inquiry instruction and diverse learning environments (Harris & Rooks, 2010).

The leadership roles and responsibilities of managing proper curriculum and learning outcomes is complex, dynamic, and unique to every class. Planning and adapting to change as it occurs are vital aspects of successfully managing a group. The social context of the inquiry learning environment is vital to learning and is interconnected and interdependent with other management areas of tasks, students, instructional materials, and science ideas. Teachers must also balance constraints of time, cost, changes of scope, expectations, quality, and value. Effective teaching requires good classroom management that intertwines management and instructional activities simultaneously in practice (Brophy, 1988; Kounin, 1979).

Research in effective science classroom management supports this idea of intertwined instruction and management (Harris & Rooks, 2010). Teachers who approach classroom management as a process of establishing and maintaining effective learning environments tend to be more successful (Brophy, 1988). Successful teachers are those who intentionally and proactively organize the classroom environment, communicate and maintain high expectations for behavior, social and intellectual engagement, seek to build positive relationships with students and promote self-management (Crawford, 2004). Effective teachers manage with procedures that demonstrate how people are to function in the classroom.

Teachers must anticipate and manage change in an ever changing landscape of education. Pre-service teachers lack experience planning for, navigating around, and responding to change. This inexperience makes it difficult for pre-service science teachers to maintain student-centered learning environments of sustained inquiry that are necessary to equip students with the skills to collaboratively problem solve in the 21st century. Novice teachers are lacking experience in many domains of teaching expertise including designing curriculum of sustained inquiry that engages students in collaborative problem solving (Crawford, 2000). Pre-service science teachers could be more effective with a purposeful, organized management strategy, like a model that supports iterative cycles of learning in collaborative, creative, student-centered learning environments, with tools to respond to and learn from changes in the environment and expectations.

Many of the challenges of classroom management are solved when students are interested and engaged in activities. Inquiry science encourages student engagement, particularly PBL science that incorporate collaborative learning. Cooperative learners develop the skills of leadership, communication, decision making, and conflict management; skills they need of future success (Wong & Wong, 1998). PBL is an ideal vehicle to maintain learning communities of sustained inquiry and intertwines teaching practices of instruction and management to produce 21st century learning outcomes. The teacher-student relationship is an important component of managing the learning environment and establishing a productive learning community as well (Piwowar, 2013). However, teachers cannot implement their teaching philosophy without a management philosophy to guide the implementation (Brophy, 1988). Establishing a collaborative learning community with clear expectations and rules for how people are to function in the classroom are essential to effective teaching.

It is evident that the first few years of a pre-service teacher's career are difficult, with many different constraints to manage: meeting diverse stakeholder expectations, the needs of diverse learners, and science standard objective goals with limited peer support due to the novel nature of *NGSS*. There is a need to learn more about managing educational projects more effectively and examples from the business industry may be helpful (Mergendoller et al., 2006). A management methodology that balances the pervasive management areas in Harris and Rook's (2010) pyramid, responds to changes in the interconnected management system, and emphasizes a community of learners would create the conditions for effective inquiry science teaching and learning.

Classroom Agility

Project management is undergoing a major transformation as it is used in information and technology industries (Cervone, 2010). Traditional project management was developed during an era of industrial, machine economy and is evolving to manage information systems. Computer science and innovation is driving a systems approach development. Agile project management (APM) is an outgrowth from agile software development (Highsmith, 2010). A group of project management experts wrote the Agile Project Management "Declaration of Interdependence" in 2005 to communicate the following objectives of highly successful teams: increase return on investment by focusing on value; deliver reliable results by engaging with stakeholders frequently and sharing ownership of the project; expect uncertainty and manage for it through iterations, anticipation, and adaptations; unleash creativity and innovation and create environments where individuals can flourish; boost performance through group accountability for results and shared responsibility; and improve effectiveness and reliability through situationally specific strategies, processes, and practices (Pham & Pham, 2012). Some advantages of APM include simplicity, short iteration, broadly based ownership of project, and management methods that enforce extensive communication and collaboration.

This is a leadership-collaboration management style that creates social architecture that enables organization and teams to collaboratively face volatility in their environment (Highsmith, 2010). Highsmith (2010) stated:

> In the chaordic age, success will depend less on rote and more on reason, less on the authority of the few and more on the judgement of the many, less on compulsion and more on motivation, less on external control of people and more on internal discipline. (p. 50)

Participatory decision making and service leadership are the essence of APM. Many of these same elements are similar to the propositions in the modern reformation of science education with emphasis on performance expectations, collaboration, and the role of teacher as a partner in learning rather than a disseminator of information.

Complex Adaptive Systems (CAS) theory has reshaped scientific and management thinking (Highsmith, 2010). A CAS, be it biological or economic, is an ensemble of independent agents who interact to create an ecosystem whose interaction is defined by the change of information, whose individual actions are based on some system of internal rules, whose agents self-organize in non-linear ways to produce emergent results, and whose agents exhibit characteristics of both order and chaos and evolve over time (Cervone, 2010; Highsmith, 2010). Adaptive development process reflects an organic, evolutionary, envision, explore, adapt, approach that does not begin with a single solution, but with multiple potential solutions. It explores and selects the best solution by applying a series of fitness tests and then adapting to feedback. The APM delivery framework consists of a five phase cycle and supporting practices: envision, speculate, explore, adapt, reflect, and expand (Highsmith, 2010). These phases resemble the practice of science and the cycle of constructing knowledge, an iterative process of adaptation.

There are many examples of APM methods in industry and one in particular that has been shown to be an effective tool to manage creative, collaborative groups: Scrum. The word scrum is usually used to reference a method to restart play in rugby that requires a team to join together in an orchestrated, seemingly chaotic, effort to gain possession of the ball. Ken Schwaber (1997), a software developer and one of the original creators of Scrum, explained that the Scrum methodology is an intentional metaphor for the game of Rugby because the two share many characteristics: the context is set by the playing field (environment) and rugby rules (controls); the primary cycle is moving the ball forward (progress); rugby evolved from breaking soccer rules – adapting to the environment; and the game does not end until the environment dictates. Schwaber (1997) explained that the methodology, which encourages flexibility and tolerance for changes in the environment, may be the most important factor in achieving success. Scrum was designed incorporating an assumption of chaos and unpredictability in the environment and developmental process to utilize control mechanisms to promote flexibility. This approach reflects the process of evolution that favors those that operate adaptively within a complex environment and requires flexibility for teams to create order under rapidly changing circumstances. Operating and producing order close to the edge of chaos is where creative and divergent thinking occurs which gives the team a competitive and useful advantage (Schwaber, 1997).

Schwaber & Sutherland (2012) explained that Scrum is “founded on empirical process control theory, or empiricism”, and employs an “iterative, incremental approach to optimize predictability and control risk” (p. 137). Schwaber and Sutherland described the three pillars to empirical process control as transparency, inspection, and adaptation, and how each is integral to Scrum. Transparency requires features in the process be visible to those responsible for the outcome with a clearly defined “common standard” and shared understanding of expectations. Inspection requires frequent collaborative review of artifacts and progress towards a goal to detect variances in quality expectations. Adaptation requires adjustments be made as soon as possible in accordance with changes in the environment or when components of the process diverge from accepted standards and the artifact does not meet expectations. Scrum practices include formal opportunities to engage in inspection and adaptation while the Scrum framework provides the transparency and common language on which the collaborative group operates (Schwaber & Sutherland, 2012).

Scrum is an agile method, a collaborative framework to facilitate cross-functional, diverse team progress and project management. The scrum process is an iterative method of developing products in an incremental fashion that gives authority to the development team to manage its own work and prescribes only a simple set of rules for the team to follow. Scrum methodology supports an environment of learning in response to project progression and environmental changes that enable team members to engage in creative, divergent thinking to solve problems (Schwaber, 1997). Scrum is an effective method for short projects or for long complicated projects broken down into incremental, manageable units, organized by sprints that deliver functional increments of the final product with each next increment built based on requirement specifications as well as modifications resulting from what was learned in the previous sprint (Goncalves & Heda, 2010). Schwaber (1997) described Scrum has the following characteristics: flexible delivery dictated by the environment; flexible schedule that is responsive to changes during the project; small teams; frequent reviews of team progress; collaboration; and object oriented team focus of clear expectations (Schwaber, 1997). The method is growing in popularity and has been effectively used to manage many diverse collaborative projects in higher education and courses that facilitate collaborative service-learning projects as well (Opt & Sims, 2015; Pope-Ruark, 2012, 2015).

There are three essential features of scrum: roles, processes, and artifacts. The Scrum team is cross-functional team composed of three main roles: a Scrum Master (SM), Product Owner (PO), and the Development Team (usually referred to as simply, Team). The PO is responsible for communicating with all project stakeholders to clarify and communicate project objectives and quality expectations. The PO works with the SM to create a list of requirements for the project, the backlog. The SM fulfills the leadership role for the Team, similar to the conception of PM. However, the SM is a vital functional role responsible for removing barriers from the Team's productivity, communicating progress with stakeholders, and ensuring quality expectations are met.

Scrum artifacts include the backlog, which is a prioritized list of requirements described by functionality or performance expectation and referred to as the project epic, and a burndown chart, which is a graph representing the progress of the project and the amount of work left to do. The project Epic can be thought of as what the project can expect to look like from an audience's or user's perspective, or in other words, the story of the project. Scrum is an iterative cycle that moves through definitive phases. Schwaber (1997) referred to Scrum phases as: pregame (planning and defining expectations and sequence), game (managing variables in iterative sprints to create functionality that evolves through an adaptive learning process), and postgame (review of deliverable and integration, retrospective of lessons learned). Essential Scrum processes include sprint planning, daily scrum stand up meetings, and a review and retrospective phase.

The roles, artifacts, and process of the Scrum method are team-centered and focused on maximizing creative productivity with the ability to respond quickly to changes in project constraints. This group management method cultivates a collaborative, supportive environment and reflects many of the principles of *NGSS*-inquiry and student-centered, collaborative learning environments. There is significant implications that Scrum may be a worthwhile method to adapt to classroom use. The Scrum framework provides mechanisms teachers can utilize to facilitate group collaboration, plan, design, and implement curriculum in an iterative cycle that mirror the learning process and investigative process of science inquiry.

There is a new project to help facilitate teachers' implementation of *NGSS* by designing curriculum to follow a storyline. Storylines are statements that describe the context and rationale for *NGSS* performance expectations and function as an engaging, anchor phenomenon to design a coherent curriculum unit (nextgenscience.org). Storylines is a curriculum development process that uses *NGSS* standard bundles; groups of standards arranged together to create the endpoints for units of instruction (nextgenscience.org). The *Next Generation Science Storylines Project* is a movement to fill the current void of curriculum materials that reflect the new *NGSS* vision (nextgenstorylines.org) and also reflect the recommendations of utilizing a coherent storyline in inquiry science teaching and PBL design. This curriculum development approach is very similar to the iterative cycle of building incremental functionality of Scrum; a spiral of increasing functionality and productivity.

It is logical to consider management of the science inquiry process in a similar manner as the Scrum method, as they are designed around the same adaptive principles and collaboration. The essential roles, artifacts, and processes of Scrum are similar to the "gold standard" of the PBL model, pervasive management areas, teaching strategies, and objectives of collaborative inquiry science learning communities.

Summary

Today's pre-service science teachers will be the first generation of teachers tasked with designing and implementing *NGSS* science curriculum. The new standards are a paradigm shift for science teaching that will require professional development and training for all teachers, pre-service and veteran, to prepare them to elevate teaching to *NGSS* expectations. This task alone is a daunting assignment for an experienced teacher, and an additional challenge to add to an already full array of responsibilities for the pre-service teacher. PBL is an ideal vehicle to achieve 21st century learning outcomes and support collaborative scientific learning communities; yet, this model has the reputation of being difficult to manage and assess. Harris and Rooks's (2010) pyramid model of the components of pervasive management areas of inquiry science reflect similar essential elements of inquiry science and PBL and emphasize the important role of the teacher to establish and maintain a learning community that develop and support the norms of scientific practices. This can be an overwhelming set of expectations for a pre-service science teacher.

There has been limited research on the ways Scrum may be used in K-12 classrooms. The Scrum methodology reflects many of these same management principles of inquiry learning and teaching and collaborative PBL learning communities. More importantly, the Scrum methodology shares the same iterative cycle of adaptation and collaborative learning and provides guidance on managing and cultivating self-organizing collaborative groups. Scrum has been shown to be effective at managing collaborative groups and may have the same effect in the classroom. The roles, processes, and artifacts of Scrum align with the phases and purpose of PBL and support inquiry science teaching strategies to meet performance expectation.

Meeting the expectations of a first year science teacher is challenge, but may also be an opportunity to achieve a novel, modern vision of an authentic student-centered learning environment conducive to inquiry science. Pre-service teachers have the advantage of limited experience in the classroom with little time to become dependent on traditional teaching methods and have an advantage of the increasing prevalence of technology. While pre-service science teachers are faced with many challenges related to implementing science inquiry curriculum and classroom management, the modern call for science teaching reformation presents a juncture where traditional teacher-centered strategies are no longer applicable and a path for novel teaching methods are essential for cultivating a 21st century learning environment.

Chapter 3: Methodology

Introduction

When I began my student teaching internship and met my cooperating teacher (CT) we discussed the idea of using Scrum to teach a curriculum unit. My CT was not familiar with the term Scrum but became interested as I explained how I thought it could facilitate student collaboration in inquiry science. My CT's reaction to Scrum was typical of most people. Many people are unfamiliar with Agile Project Management and Scrum. I have been doing research on Scrum for about three years and during that time I have only met three people familiar with the methodology. The first, my husband, introduced Agile to me from an engineering perspective. Agile is becoming a prominent management idea in the business industry, applicable to professional engineering projects, which is how he learned of it. During a discussion of what I was learning in my science education graduate courses he described to me how much the learning cycle sounded like the Agile project management methodology of which he was just learning.

This conversation was early in my educational program, while I had begun field observations in a few local science classes. Most of these classes had the reputation of being an inquiry science classroom, and many of them had awesome inquiry activities, but I always felt the classrooms were mostly teacher-centered with inactive students responding to direction, some students not engaged at all. The mentor teachers were excellent educators and expressed the drive of standardized testing focused most of their classroom time on covering required exam content. Many explained that student-centered inquiry is not always understood by administration or parents, looks chaotic, and can be difficult to assess and manage. One of these teachers said many of their colleagues would agree inquiry science is the goal, “in theory”, but in the classroom, it was “a different story”. This call for student inquiry was echoed throughout my university education courses but only in my science education classes did I experience a group that practiced a culture of inquiry.

I struggled to apply what I was learning of human learning and the expectations of how to guide that process, with what that looked like in a classroom, specifically the crazy reality of a high school classroom. I had many questions throughout my university program related to questions such as: What does a culture of inquiry look like in a high school classroom? What would it take as the classroom leader to meet curriculum objectives and facilitate student collaboration? The night I heard about Agile it was hard for me to sleep. I began researching project management the next day.

A few years later, through my children’s school friends, I met a software engineer that was an Agile practitioner and strong supporter of the methodology. I found researcher Rebecca Pope-Ruark’s work on Scrum in her university technical writing classes. She refers to herself as RPR in her writings, as will I. RPR shared her story of learning about Agile through an engineering perspective and the subsequent research of the Scrum methodology in her classroom. Her methods of teaching her students how to collaborate and mange projects was exactly what I was looking for. Even though the subject matter was not science, her teaching made sense. She was facilitating a learning community of sustained inquiry and productivity. I shared this article with the software engineer. After some consideration he agreed with her methods and expressed excitement of the idea of Agile in the classroom. His thoughts were, if the analogies could be made between Agile and education and you could get a student team doing Agile, this could be a big idea. He mentioned there are many different Agile approaches and suggested I look into the Agile delivery framework, Scrum, because it was a system of simple rules to facilitate creative group collaboration. This study is a reflection of that journey to discover management methods that facilitate inquiry science learning and student collaboration as recommended by the *Next Generation Science Standards* (*NGSS)*.

Pre-Service Science Teacher Agility – An Autoethnographic Investigation

This thesis is a study of my experiences as a science education student intern. The semester-long internship was an immersive preparation for my professional practice. I was tasked with many of the same professional expectations that will be expected of me as an in-service teacher with support from a cooperating classroom teacher (CT) and a university supervisor who also served as my thesis adviser. This support system made it possible for me to experiment with my managerial approach to meeting these expectations. Based on my prior knowledge of Scrum, I had a desire to investigate if it was an appropriate and applicable management methodology for collaborative inquiry science in a high school environment. These experiences are the focus of this study. I will relate my observations and reflections of managing the leadership process with Scrum to lead a collaborative learning group. The human dynamics that are involved with managing an educational group are diverse and sociological. My story will follow an autoethnographic narrative using grounded theory as a tool of constant comparative reflection, to identify significant themes and relationships, and to analyze the results of my management efforts in the classroom environment.

Autoethnography, is a qualitative research method that combines elements of ethnography (the study of people in a cultural context), autobiography (the telling of one's own story), and self-reflexivity (the inward attention to one's thinking, feeling, and behavior) (Chang, 2016). It is used to analyze self-reflection and observations of the participant researcher. Autoethnography requires that the researcher be visible, active, and reflexively engaged, which reflects a "self-conscious introspection guided by a desire to better understand both self and others through examining one's actions and perceptions in reference to and dialogue with those of others" (Anderson, 2006, p. 382). This type of self-reflective research has significant applications in educational research.

Star (2010) stated autoethnography is a valuable tool to explore the "space between the self and practice" and to examine the complex and diverse realm of education. Engaging in an individual self-analysis can have "purposeful implications for the preparation of teachers and school leaders" (p. 1), which can lead to greater understanding and transformative pedagogy. Education is fundamentally a social practice as evident in its central artifacts such as curriculum. Star (2010), quoting Schubert (1986) stated, an "individual seeks meaning" amidst present events, past experiences, and possible future scenarios,

> based on the sharing of autobiographical accounts with others who strive for similar understanding, the curriculum becomes a reconceiving of one's own perspective on life. It also becomes a social process whereby individuals come to greater understanding of themselves, others and the world through mutual reconceptualization. (p.2)

The relationships between teachers and students is critical to the learning environment and requires teachers to take a "critical stance towards social relations" to generate authentic personal knowledge of educational beliefs and ideologies and how that knowledge informs personal teaching philosophy and pedagogy and helps teachers be more effective (p.1). An autoethnography is an ideal method to analyze my experiences in an educational leadership position utilizing Scrum for group management and collaboration in a high school science classroom.

There are two variations of autoethnography, evocative and analytic (Anderson, 2006). Anderson (2006) described that evocative autoethnographers espouse a storytelling narrative of subjective emotional experiences as the goal of their research and scholarship and reject traditional realist and analytical epistemological assumptions and conventional sociological analysis. The author offers an alternative practice that is "consistent with qualitative inquiry rooted in traditional symbolic interactionism" (p.374).

Anderson (2006) characterized analytic autoethnogrpahy as

> ethnographic work in which the researcher is (1) a full member in the research group or setting, (2) visible as such a member in the researcher's published texts, and (3) committed to an analytic research agenda focused on improving theoretical understandings of broader social phenomena. (p.375)

These characteristics reflect my research intent and provide a platform to share my experiences of Scrum as a management tool with other educational practitioners. This research method allowed me to analytically examine my reflections of the experience. This analysis may contribute to the theoretical knowledge of management features and methods for collaborative inquiry science. The data from classroom observations and my personal reflections will be reported in accord with Anderson's (2006) recommendations of the five key features of analytic autoethnography which include: (a) complete member researcher (CMR), (b) analytic reflexivity, (c) narrative visibility of researcher's self, (d) dialogue with informants beyond the self, and (e) commitment to theoretical analysis. These elements characterize my role and objective as an educational researcher.

A complete member researcher (CMR) in analytic autoethnography refers to the immersive role of the researcher in the social world under study (Anderson, 2006). This role is more than a research participant and observer, but a more "analytic and self-conscious participant" who gains an understanding by functioning as a member and researcher and as a result of engagement and dialog with the group (Anderson, 2006). Anderson explained that analytic reflexivity is a very important contribution to autoethnography, as the CMR embodies a reciprocity of influence between themselves and the group. The CMR creates a representation of group experiences, but is also involved in and influenced by the creation of those experiences; they share and "co-create" meaning and group experiences (Anderson, 2006, p. 379). Analytic autoethnography requires the researcher to be visible and active in the text they are creating. This visibility reflects the CMR's personal investment in the study group. The researcher is not an inactive bystander, but actively engaged in co-creating the social space in which they occupy and study, which should be related in the data.

Another advantage to using autoethnography to analyze this educational study is Anderson's key element requiring the author to engage in dialogue with others in the field to validate the data and avoid "solipsism's", "author saturation", or the potential for self-absorption (Anderson, 2006, p. 386). This dialogic element differentiates analytic from evocative autoethnography, because the author reaches beyond self-experience and grounds their data within a disciplinary field (Anderson, 2006). As a student intern and pre-service science teacher, this dialogue with my CT and university advisor is crucial and fundamental to my preparation for professional practice. The final, and defining characteristic of analytic autoethnography is that the purpose of the study is not to provide just an "insider's perspective" but to use the data to "gain insight into "some broader set of social phenomena", to "reformulate and refine theoretical understanding" (Anderson, 2006, p. 387). The context of this data is important to provide generalizability for other educators, a thick description of the research environment. Merriam (1998) explained that a thick description in qualitative research should provide enough information for the reader to determine if their situation is similar and relevant. Analytic autoethnography is an ideal method to relate and analyze my journey into educational management and classroom agility.

Setting

The study took place in a high school Advanced Placement Environmental Sciences (APES) classroom during my student internship (student teaching placement) in the spring semester. The high school teacher of this class designs curriculum in accord to College Board recommendations. College Board is a not-for-profit organization that provides Advanced Placement (AP) programs for high school students in preparation for the successful transition to college and offers courses that reflect college expectations (collegeboard.org, 2017). College Board describes the AP

Environmental Science course as an equivalent of a one-semester introductory college course in environmental sciences. Students engage with interdisciplinary scientific principles, concepts, and methodologies required to understand the interrelationships of the natural world. The course requires students to identify and analyze natural and human caused environmental problems, evaluate the risks associated with those problems, and examine alternative solutions for resolving or preventing them (collegeboard.org, 2017). Students enrolled in this course can take a comprehensive exam at the end of the year and earn college credit with a satisfactory score.

The APES class had been meeting since the beginning of the fall semester, and I joined them at the beginning of the spring semester. The high school enrolls about 2,000 students each year and is located in an Oklahoman suburb.

Participants

This study was a blend of opportunity, creativity, and curiosity. The individuals that joined me for the journey of this study reflect that amalgamation. I had the good fortune of an insightful university adviser (UA) that placed me with a cooperating teacher (CT) that was willing to give a student intern some autonomy and creative leverage in the classroom. The CT with whom I was placed was an eleven year veteran high school science teacher and the reigning "Teacher of the Year" in the school district. My CT was passionate about science and the environment and was involved in many community projects. The teacher had a history of creating learning opportunities and engaging students outside of the classroom in service learning projects including gardening projects and recycling programs. My placement with this CT provided me an opportunity to experiment with my educational and instructional management strategy when the time came to design, implement, and manage my own curriculum unit. This study is a result of taking that opportunity to reflexively analyze educational applications of Scrum with an experienced and open-minded mentor CT and an adept, supportive UA.

The APES class was chosen for this study because it was the only class section of the CT's with unique curriculum, which allowed us to keep the other non-APES class sections on the same schedule and curriculum. The APES section was a small class that included fifteen students, seven boys and eight girls, in grades 9 through 12. Students varied in age from fourteen to eighteen years old. There were no students with exceptional needs nor English language learners. The student body was diverse ethnically and academically. There were students with high, medium, and low grade point averages and an array of skills.

Research Process

Earth's climate is warming and there will be significant ecological impacts and disruptions to human systems from this change (IPCC, 2013). Understanding the science of these changes, the human contribution to this problem, and potential solutions were curricular objectives in the APES class and included on the AP exam. Climate change was usually taught around the middle of the spring semester, which was enough time for me to become familiar with the classroom setting, procedures, and students and resultantly became the focus of the curriculum unit I would design and implement for the class.

Curriculum design.

There are three essential features of Scrum: roles, processes, and artifacts (see Figure 1). I was the Scrum Master [with some Product Owner (PO) responsibilities], my CT was the PO, and the students were the Team. The PO was responsible for communicating with all project stakeholders to clarify and communicate project objectives and quality expectations (AP and *NGSS)*. The PO and SM worked together to create a list of requirements for the project, hereafter referred to as the backlog. The SM fulfilled the leadership role for the team, similar to the conception of project manager. However, the SM was a vital functional role responsible for removing barriers from the team's productivity, communicating progress with stakeholders, and ensuring quality expectations were met.

The Scrum process was an iterative cycle that moved through definitive phases of: (pregame) initiating and planning to define expectations and sequence; (game) sprints of iterative cycles to build features (knowledge) that evolved through an adaptive learning process; and (post game) a review of student artifacts, integrated into the final product (body of knowledge), and a group retrospective discussion of what was learned and suggestions to improve the process. Three iterative sprints were used to design the curriculum sequence. These cycles also included daily stand-up meetings, another essential Scrum process. All study participants (CT, student intern, and students) participated in daily stand-up meetings to discuss what was accomplished, what was planned, and what, if any, potential barriers to productivity were present.

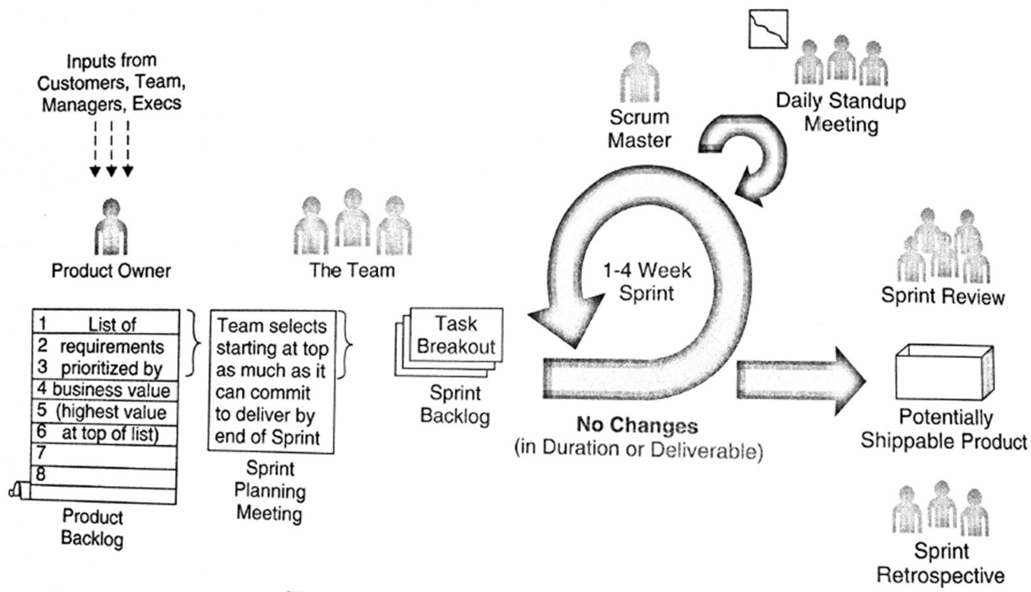

*Figure 1***.** Scrum Process Flow. Reprinted from *Making Sense of Agile Project Management (*p. 214), by C G. Cobb, 2011, Hoboken, New Jersey: John Wiley & Sons, Inc. Copyright 2002-2010 Rally Software Development Corp. All Rights Reserved

The curriculum included an important Scrum artifact, the backlog, which was a prioritized list of requirements described by functionality or performance expectation. The desired outcome of the projects is referred to as the project epic. The project epic could be thought of as the "product" what the project could be expected to look like from an audience's perspective, the story of the project. Science concepts were assembled into incremental groups that contributed sections of the story and project epic. A burndown chart is another important Scrum artifact, but was not included in this study in an effort to keep the process simple and limit the amount of unfamiliar tasks required of study participants.

I was responsible for designing and implementing curriculum aligned to *NGSS* that provided students an opportunity to engage in scientific and engineering practices and collaborate with their peers. To accomplish these objectives I decided to use PBL as an instructional tool. PBL is a student-centered, inquiry-based pedagogical approach for facilitating knowledge construction (English & Kitsantas, 2013). Students engage in solving real-world problems similar to what will be expected of them as adults in PBL. This form of learning is a comprehensive method of learning environment design that incorporates the following five main features: (a) a driving question or problem to be solved; (b) student exploration of driving questions through inquiry process in an authentic, real-world context in which they learn and apply concepts of the discipline; (c) a collaborative learning environment to find solutions that include teacher, students, and community members; (d) learning technologies that scaffold student learning during the inquiry process to assist students to engage in activities beyond their current abilities; and (e) student created artifacts of learning that are publicly shared to answer the driving questions (Blumenfeld & Krajcik, 2005).

Larmer, Mergendoller, & Boss (2015) explained that student learning goals are the center of any well-designed PBL unit in which students learn to apply knowledge to the real-world, solve problems, answer questions, and create high-quality products. Student goals include the development of key success skills to think critically, solve problems collaboratively, and self-manage (21^{st} century skills) in PBL environments. Teaching practices that are included in the "gold standard" PBL model reflect the emphasis of the role of the teacher as a partner in learning, a guide. Teaching practices are framed around a project and include: design and plan; align to standards; build the culture; manage activities; scaffold student learning; assess student learning; and engage and coach (Larmer et al., 2015). Scrum reflects this same sequence of management objectives and is also driven by a driving storyline. I used Scrum throughout the experience to start the design process, to sequence my unit curriculum and processes, to keep myself organized to contend with the diversity of expectations, and to manage the group of students once we began the project.

The first thing I had to do was prepare a list of requirements for the curriculum unit and organize them according to highest value. My inputs came from my CT, my UA (my science university adviser), *NGSS*, APES exam objectives, and inquiry science pedagogy utilizing a PBL framework. This input provided expectations of quality in the form of science education performance expectations and three dimensional learning activities, and requirements from my CT regarding APES testing objectives, resource and time constraints. Critical science concepts were derived from *NGSS* performance expectations (HS-ESS3-5, HS-ESS3-6) and the United States Global Change Research Program's (USGCRP) (2009) climate literacy guide. I also had inputs of a definitive time frame and schedule dynamics from the CT. The curriculum unit could not be more than two-weeks' worth of classroom time (ten school days) and must include an opening debate.

The debate was an activity the CT had included for climate change units in previous classes and knew this would be an important academic element of the unit. The APES class was also responsible for a school-wide recycling program. Once a week they collected recycling from campus and brought it to the curb for city collection. This is a regular occurrence during class time and a schedule variable to include in the planning process. The unit was taught during the spring semester which also included standardized testing and a lot of extracurricular activities. Absences and departmental requirements are part of the landscape of dynamic variables teachers must manage every day. I was enthusiastic to include these variables into my Scrum puzzle.

The planning phase involved my curriculum design process and collaboration with the CT to establish expectations, learning objectives, activities, sequence. The final "product" for the project was the *NGSS* performance expectation (PE) for high school, Earth and space science, weather and climate, Earth and human activity (HS-ESS3-5) which states that "students who demonstrate understanding can: Analyze geoscience data and the results from global climate change models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems" (*NGSS* lead states, 2013). *NGSS* describes the observable features students should demonstrate by the end of instruction include: students organize data (graphs) from global climate models and climate observations over time that relate to the effect of climate change on physical parameters or chemical composition of the atmosphere, geosphere, hydrosphere, or cryosphere; students analyze the data and identify and describe relationships within the datasets that include changes over time on multiple scales and relationships between quantities and data; students use their analysis to describe climate change of the present or past on a physical parameter and predict the future effect of climate change on that parameter, as well as describe whether the change is irreversible, identify one source of uncertainty in the prediction and describe the variations and limitations of uncertainty in their prediction (*NGSS* Lead states, 2013). This PE is based on three dimensional learning from the science and engineering practice of analyzing and interpreting data, the disciplinary core idea of global climate change, and the crosscutting concept of stability and change.

The unit was built around a student challenge to collaboratively create a presentation to explain to a public audience the science of climate change to demonstrate this PE. The presentation was the culminating final collaborative class project. The final project's format and message was decided by the students, produced as a collaborative effort by the entire class, and assessed according to the *NGSS* observable features of the PE. The CT and I collaborated on a rubric to assess the presentation. Students needed to construct knowledge of climate science concepts and climate literacy to achieve this PE. The process of knowledge construction was broken down into driving research questions students would answer collaboratively. These activities were broken down into three sprints that incrementally created segments of the final presentation. The three sprints were designed in accord with the basic learning cycle of exploration, team introduction, and concept application (Marek & Cavallo, 1997). The anchoring phenomenon was global climate change.

The instructional sequence took me a very long time to design. I had to work the unit within a classroom timeframe and I have a tendency to overcomplicate my work, which was a struggle. I had to take a break and work on a university assignment after I spent weeks struggling with how and what science concepts to include. My research for my university class assignment led me to Brian Reiser's (2014) *Designing Coherent Storylines Aligned with NGSS For The K-12 Classroom,* which explained how to design curriculum with a similar cycle of sustained inquiry storyline and how to create that storyline with *NGSS* PEs. This resource would have undoubtedly improved my curriculum; however, I did not find this resource before my project was underway.

The team of students worked in groups for each sprint to create an artifact that communicated their scientific understanding of the driving questions of the sprint. Each artifact created was used as a functional feature of the final project. The three sprints were organized around the following driving questions and activities:

Sprint 1.

Driving Question: Climate Issue - What is the public perception of climate change? Why is it considered a controversial issue?

Three Dimensions: SEP: Engaging in argument from evidence; DCI: ESS3.D Global Climate Change; CCC: Cause and effect, systems thinking, stability and change

Objectives: Students will be able to identify and defend public perspective of the main arguments for and against anthropogenic climate change. Student will understand different perspectives of a complex scientific issue.

Instructions: Students will work in small groups to research and build a case for three public climate change perspectives: climate change is not occurring; climate change is occurring but humans are not the cause; climate change is occurring and humans are the cause. Students will formally debate their cases and will be scored with a ballot scoring sheet.

Student Groups: Three groups were chosen by the CT according to class performance and attendance history. Members were chosen purposefully to balance attendance, gender, and academic performance.

Student Deliverable: Case documents with references and citations. Personal notes and reflections of debates. Begin building model for major components of climate change presentation. Class discussion following debate.

Sprint 2.

Driving Question: Climate Issue – What are the components of Earth's climate system?

Question A: Earth Systems - How do Earth's major systems interact? What is the main source of energy for the Earth? How does energy and matter transfer among Earth's materials and living organisms? What changes in Earth's systems are occurring and how are those observations obtained?

NGSS Performance Expectation: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks and interactions that cause changes to other Earth's systems (HS-ESS2.2).

Three Dimensions: SEP: Developing and using models, analyzing and interpreting data; DCI: ESS2.A - Earth's Materials and Systems; CCC: energy and matter, structure and function, cause and effect, stability and change

Objectives: Students will be able to use a model to describe how variations in the flow of energy into and out of the Earth's systems result in changes in climate.

Instructions: Students will work in small groups to research and incrementally build a model to answer the driving questions (A, B, and C) of Sprint 2. Groups will create models with the medium of their choice within the resources of the classroom. The model will be used in the final collaborative presentation. Each group will present, explain, and interrelate their model increments from Sprint 2. A list of required terms will be added to the project shared folder for students to include in the models and/or the presentation. A scoring rubric will be available on the shared project folder to guide their presentation.

Student Groups: Students expressed a desire to choose their partners after Sprint 1. They were given autonomy to choose their own three groupings.

Student deliverable: Model of Earth systems

Question B: Climate Systems - What regulates weather and climate? What are feedback effects or loops? What are greenhouse gases, concentrations and their duration in the atmosphere? What changes in Earth's systems impact climate or are they the result of climate change?

NGSS Performance Expectation: Use a model to explain how variations in the flow of energy into and out of Earth's systems result in changes in atmosphere and climate (HS-ESS2-4).

Three Dimensions: SEP: Developing and using models, analyzing and interpreting data; DCI: ESS2.D - Weather and Climate; CCC: energy and matter, structure and function, cause and effect, stability and change

Objectives: Students will be able to create a model and analyze geoscience data to make the claim that one change on Earth's surface can create feedbacks that cause changes to other Earth's systems.

Instructions: Students will work in small groups to research and incrementally build a model to answer the driving questions (A, B, and C) of Sprint 2. Groups will create models with medium of their choice within the resources of the classroom. The model will be used in the final collaborative presentation. Each group will present, explain, and interrelate their model increments from Sprint 2. A list of required terms will be given to students to include in the models and/or the presentation. A scoring rubric will be given to students to guide their presentation.

Student Groups: Students expressed a desire to choose their partners after Sprint 1. They were given autonomy to choose their own three groupings

Student Deliverable: Model of climate system

Question C: Global Climate Change - How do people model and predict the effects of human activities on Earth's climate? What is the evidence of anthropogenic climate change? What is the role of scientist's uncertainty? Is today's warming different from the past? What are the projections for future climate change and impacts?

NGSS Performance Expectation: Use a computational representation to illustrate the relationships among the Earth systems and how those relationships are being modified due to human activity (HS-ESS3-6).

Three Dimensions: SEP: analyzing and interpreting data, engaging in argument from evidence; DCI: ESS3.C – Human impacts on Earth Systems, ESS3.D – Global Climate Change; CCC: Cause and effect, systems and system models, stability and change

Objectives: Students will be able to use a computational representation to build a model to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Instructions: Students will work in small groups to research and incrementally build a model to answer the driving questions (A, B, and C) of Sprint 2. Groups will create models with medium of their choice within the resources of the classroom. The model will be used in the final collaborative presentation. Each group will present, explain, and interrelate their model increments from Sprint 2. A list of required terms will be given to students to include in the models and/or the presentation. A scoring rubric will be given to students to guide their presentation.

Student Groups: Students expressed a desire to choose their partners after Sprint 1. They were given autonomy to choose their own three groupings

Student deliverables: Model of global climate change

Sprint 3.

Driving Question: Communicating Global Climate Change -What is climate change and why should we care? Is it effecting our area? What are the effects? What should we expect in the future?

NGSS Performance Expectation: Analyze geoscience data and the results from global climate change models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems (HS-ESS3-5).

Three Dimensions: SEP: analyzing and interpreting data, engaging in argument from evidence; DCI: ESS2.A – Natural Resources, ESS2.D, ESS3.C – Human impacts on Earth systems, ESS3.D - Global Climate Change; CCC: Cause and effect, systems and system models, stability and change

Objectives: Students will be able to analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

Instructions: This lesson begins with class discussion and each group describing their thoughts of the three most important messages from their research and models. The class will discuss each group's model with opportunities to give and receive constructive peer feedback. The class will discuss what geoscience resources they utilized for model building. The class will explore geoscience resources, focusing on IPCC and the National Climate Assessment to become knowledgeable of the scientific bodies that study climate change and the regional climate assessment and projections for our local region. Model revisions can be made after data review and feedback. Whole-class collaboration will follow to design, construct, and final presentation. The final presentation will be assessed with a rubric.

Student Groups: Students worked together as one collaborative unit.

Student deliverables: Cumulative class presentation with clearly defined message from Sprint 1, and the three models representing earth and climate systems and global changes from Sprint 2, and predictions from analysis of geoscience data about local climate change impacts with a description of uncertainty.

The project began with an initial planning meeting between the SM and Team to determine what tasks needed to be performed to meet the requirements of the project epic. These tasks were organized onto the backlog chart as stories, functional segments that contribute to the epic. Stories were written on sticky-notes and organized into three different categories: backlog, work in progress (WIP), and done. The Teams were given autonomy to decide what stories they would commit to for the first sprint. The teams would collaboratively break down the story further into tasks that needed to be accomplished to complete the story. This step was team driven, organized and implemented as the team deemed necessary.

The SM's role throughout the unit was to support productivity and provide resources for the Team once the sprint began, as well as to serve as a guide and learning partner. The Team worked through phases of implementing, inspecting and adapting (control and monitoring) until the end of the sprint when the entire Scrum team (PO, SM, and Team) reviewed the final sprint artifact and provided feedback for improvement. Students collectively decided when the artifact met the expectations set forth by the group. A sprint retrospective meeting was held after each sprint to communicate and identify components of the process that did or did not work and make adjustments in these variables for the next sprint.

Materials

Important materials required in this project included access to technology and internet for researching the driving questions. Our students utilized computers loaned from the high school's library and the school's Wi-Fi network. Google classroom was a platform the class was using for lecture notes. Instructions were given on how to utilize Google's document and group chat features. Google classroom was used as a collaboration tool and learning platform throughout the project. There were no hard copy documents handed out to students. Excessive use of copy paper is discouraged in the CT's classroom and every effort is made to model sustainable decision making. Instructional expectations and class calendars were communicated electronically through Google Classroom. Butcher paper, markers, colored pencils, and various sizes and colors of sticky notes were provided for students to create backlog charts, tasks, and posters.

Data Collection

The focus of my research question was how I could use Scrum to manage a collaborative science inquiry unit of my design. Daily personal reflections and classroom Scrum observations were recorded to collect data of my assessments of project status, educational goals, and management tasks, as well as student status on planned project activities, goals, and barriers to productivity. Daily classroom observations of the impact of Scrum methods (roles, processes, artifacts) in the learning environment included physical student activity, grouping, and personal work space arrangements, student involvement in group project management, productivity, and social engagement, demonstrated student inquiry science activities, educational outcomes and learner attitudes, classroom management of the learning environment, and teacher instructional activities.

I maintained detailed daily field notes during the research project of classroom observations related to student collaborative behavior. My observations were guided by behavioral responsive indicators to the instructional management decisions of Scrum methods. These data were compiled and assembled an autoethnographic chronological narrative that described the learning environment. This narrative was reviewed at the end of each sprint and analyzed for recurrent themes.

Data Analysis

One of Anderson's (2006) elements of analytic autoethnography requires the researcher to demonstrate a commitment to theoretical analysis. Data from the Scrum learning environment were compiled daily into an auto ethnographic narrative and analyzed at the end of each sprint following a retrospective group meeting using constant comparative strategies of grounded theory. The phenomenon of study was how Scrum methods effected my ability to manage the implementation of a *NGSS* aligned PBL collaborative inquiry science curriculum unit. Grounded theory provides a constant comparative method of analysis to generate emergent theories from the data that account for the data (Charmaz, 2006). Grounded theory does not prescribe a definitive set of research steps, but requires the researcher to constantly review data and make adjustments to the research process if necessary. This method reflects a similar iterative adaptive cycle of Scrum and provided a functional tool of analysis throughout the study which also assisted my reflexive facilitation of the Scrum process. With methods of coding, memo writing, and theoretical sampling, I determined emergent themes. Open coding was used to identify significant concepts and discrete incidents of significance which were further analyzed to determine relationships among these emergent concepts in a theoretical coding process (Charmaz, 2006). These data were further analyzed through selective coding and memo writing to determine a main theme that could explain a pattern of behavior in the data (Glaser, 1978). Emergent themes were compared theoretically, evaluated, and then summarized to define a core categorical theme.

Evidence of student collaboration and contributing factors were identified and analyzed. Patterns in student collaboration and emergent themes in relation to the classroom learning environment were analyzed and triangulated from multiple data sources, including dialog with other informants (Anderson, 2006). This analysis was reviewed by the CT and UA to discuss and validate any patterns of significance. A comprehensive review of these data were compiled and analyzed to deduce categories of meaning and a theoretical understanding of how Scrum elements affected my ability to facilitate a collaborative inquiry science learning environment.

Chapter 4: The Science Scrum!

Introduction

I began this journey with an elementary understanding of Scrum as an Agile Project Management (APM) methodology, but I knew enough of the Scrum methodology to recognize the overlapping theoretical foundations between the management methodology and inquiry science teaching and learning. Thus, they share an adaptive cycle of social learning. Inquiry science classrooms can be a challenge for teachers to implement and manage (Windschitl et al., 2008). There are suggestions and teaching strategies to assist teachers with this challenge (Baker, Lang, & Lawson, 2002; Lawson, 2000). However, a pre-service science teacher has additional challenges when they enter the classroom and may be underprepared to offer authentic inquiry learning experiences in their classrooms.

New modern science standards, *NGSS*, are designed to incorporate scientific and engineering practices into classrooms and promote 21st century learning outcomes of communication, collaboration, creativity, and critical thinking. *NGSS's* three dimensional learning to meet performance expectations is a new way of teaching that will require teachers to reevaluate their teaching strategies (Krajcik, 2015). Inquiry science curriculum including project based learning (PBL) has been shown to help students achieve next generation learning (Harris et al., 2015), but it can be challenging for teachers to manage (Mergendoller & Thomas, 2001). Pre-service science teachers will be some of the first challenged to implement new standards, try novel teaching strategies, and contend with the other traditional challenges of being a novice teacher.

My student teaching internship provided an opportunity to be creative and to take a risk with my management methods. I followed a purposeful group management strategy, Scrum, an Agile Project Management delivery framework, to design, plan, and implement a curriculum unit of global climate change in the AP Environmental Sciences (APES) of my cooperating teacher (CT). I documented the experience with extensive field observations and personal reflections of Scrum methods including roles, processes, and artifact and how they affected my ability to facilitate collaborative science inquiry. These qualitative data were compiled with analytic authoethnography (Anderson, 2006) to provide a chronological story and context, a thick description of the research environment (Merriam, 1998). The autoethnographic narrative was coded after each sprint to identify variables in the learning environment that contributed to student collaboration. Those variables were compared to one another as new patterns emerged to identify relationships. The assembled chronological narrative was created throughout the duration of the study and analyzed with a constant comparative method (Glaser & Strauss, 1967). Emergent themes from the data were identified through a process of open, theoretical, and selective coding and then compared to current theoretical (Charmaz, 2006) management recommendations for inquiry science teaching and the Scrum methodology in education. These themes are reported in a chronological order of emergence, relationship, and core concepts.

Facilitating Collaborative Science Inquiry with Scrum

Collaboration was evident throughout the unit. Instructional practices, classroom community, student use of technology, positive educational outcomes, and an adaptive learning group were all variables that contributed to student collaboration and were a result of Scrum methods. Instructional practices that are in accord with Scrum methods facilitate collaboration by design. Educational objectives and activities engage Scrum roles, activities, and artifacts which required collaboration to reach educational expectations. These practices established routine social engagement and support. A positive, supportive classroom community emerged as students cycled through the learning progression. Regular communication and engagement with technology enabled the learning group to cultivate a collaborative community. Students engaged in this environment which resulted in positive and sometimes unexpected educational outcomes. The iterative curriculum unit experienced many disruptions to the learning environment and changes in project variables, yet the group remained productive and met their project objectives and academic expectations. The adaptive classroom community was a result of educational leadership with intentional social management strategies and iterative collaborative sustained inquiry.

Cultivating collaboration and community with scrum curriculum.

Collaboration was a significant element in the Scrum facilitated curriculum unit. Scrum significantly impacted my instructional process and role in the learning group. The Scrum process workflow enabled me to establish a cyclical learning sequence and regular routine of group meetings to discuss productivity, goals, and problems. Designing curriculum and learning activities around a collective class “product” assisted with aligning activities to *NGSS* standards. *NGSS* performance expectations are written to clearly define what a student should be able to do following the instructional unit and is a logical final goal of an educational Scrum unit. Scrum enabled groups to engage in three dimensional learning by encouraging collaboration, engaging in scientific and engineering practices such as scientific discourse, and creating and modifying models. Cross cutting concepts were a natural component of the Scrum process requiring students to consider and engage in systems thinking and analysis. DCI's were easy to incorporate into an iterative cycle to construct learning progressions. The DCI packages were designed to be increments in a cohesive storyline that built the knowledge necessary to answer the driving question and demonstrate performance expectations of the unit.

Expectations of the learning community were communicated through Google classroom (rubric, assignments, and calendars) and regular collaborative rituals of planning and feedback. Students worked together to break down driving questions into tasks and shared the responsibility for completing those tasks. Expectations were co-created and communicated with backlog charts and collaborative technology. Student autonomy was supported by using Scrum to plan educational activities in which students made decisions and collaborated without direction or prodding from instructors. Following a Scrum methodology ensured that I collaborated often with stakeholders to establish quality expectations and received regular feedback after every cycle. Clear expectations and group objectives were the focus of every classroom day. Collaboration was a natural result of Scrum facilitated science inquiry.

Scrum prepared me to deliver project based learning (PBL) in an organized way. I was able to provide students with clear expectations at the beginning of each sprint, and incorporate the five main features of a PBL unit: (a) a driving question or problem to be solved, (b) student exploration of driving questions through inquiry process in an authentic, real-world context in which they learn and apply concepts of the discipline,

(c) a collaborative learning environment of learning partnerships (d) students and community members using learning technologies that scaffold student learning during the inquiry process to assist students to engage in activities beyond their current abilities, and (e) student created artifacts of learning that are publicly shared to answer the driving questions (Blumenfeld & Krajcik, 2005). Scrum enabled me to engage in teaching practices of "gold standard" PBL that reflect the emphasis of teacher as a partner in learning, a guide. Scrum methods mirror PBL teaching suggestions: design and plan; align to standards; build the culture; manage activities; scaffold student learning; assess student learning; and engage and coach (Larmer et al., 2015).

There was significant scaffolding required throughout this unit; however, fulfilling the role of Scrum Master enabled me to provide scaffolding as needed on an individual basis and focus on my role as a functional partner in the learning process. As a Scrum master I was responsible for removing barriers to productivity and learning. I was free to move through the room without being busy with other tasks. Students were self-managing tasks and resources which freed up much of my time to focus on coaching. Much of the scaffolding that students required related to management or research tasks. Some students needed help breaking down a goal into discrete, functional tasks. The Scrum process required groups to engage in self-management, which required communication and allowed for peer scaffolding and also ensured their individual self-management skills were developed and improved as a natural result.

Regular stand up meetings enabled me to have multiple opportunities of formative assessment with the students. The stand-up meetings were to maintain productivity, visibility, and peer feedback and accountability. When Scrum is applied in an educational setting, the accomplishments, goals, and barriers are oriented according to learning goals. So, regular formative assessment is naturally built into the process.

As students became familiar with the stand-up meetings, they started using these opportunities to ask for help on a concept or task and many times the other students would answer their questions or offer suggestions and feedback. These meetings facilitated students' self-reflection and assessing their own learning goals. There was a significant amount of questioning within groups and limited conceptual questions asked of the instructors. Group members relied on one another to help them understand science concepts and construct explanations.

Scrum supported collaborative teams to self-manage tasks and gave students autonomy to decide how to accomplish learning goals. Scrum also required social engagement within groups to meet objectives and facilitated regular communication and constructive feedback. When management decisions were made collaboratively, the groups shared the responsibility and were accountable to each other. This self-organization and collective focus on achieving a shared educational goal established a positive learning community.

Teams collectively decided to create team names and many students assumed helpful roles during the process to assist the team to organize and collaborate without direction. Students practiced taking alternative perspectives and empathizing with others. Conversations during class time reflected alternative perspectives and scientific discourse, which was facilitated in a positive and constructive way. Students felt challenged and safe to express feelings of confusion and frustration. Support systems developed to assist members who were absent or needed direction.

Relationships were a significant factor in cultivating community. The CT had built a supportive classroom environment prior to the study. I was welcomed into their learning group and felt immediately comfortable. The students came to know me pretty well and were curious about the research project. They were interested and supportive. Practicing Scrum together for the unit deepened those relationships between instructors and students and also other students. Students showed evidence of developing community by co-creating creative environments, contributing to one another's learning, and supporting absent group members. We set up and established a physical location for a common meeting area that we regularly visited when beginning each day. We held daily stand-up meetings in the same physical location in the classroom every time. This location in the center of the back of the room resulted in the central meeting place where students would organize in groups. This centrality was not planned but could be a result of the community building and shared ritual of communication as a central activity that tied in all other classroom activities

Communication tools.

Technology was a key tool of communication during the unit. The students enjoyed working with technology and used it in creative, collaborative ways that I had not planned. MacBook Air computers were available in our classroom for students to use during their research. These computers were new and many students were excited to work with them. Technology was a critical feature in my curriculum plan but was not an instructional focus.

Students were expected to manage their own research tasks and productivity with Google classroom tools. There were not specifications on what to do with these tools, but instruction was given on how to use the tools. Google classroom was a platform of communication between instructors and students and became a central feature to the unit. Students utilized Google a great deal to share and collaborate outside of the classroom. The ability to have a shared folder and documents was helpful to many students. Utilizing features of Google classroom contributed immensely to collaboration. Many students commented they had communicated during the evening through Google to work on their research and cases. One team member mentioned how much Google helped them keep all of their team members informed of what was going on and what need to be done when someone was absent. Twice during the unit absent students came to class completely caught up. They met with their groups online during the evening, communicated, and work on their projects. They were ready to join the class when they returned and did not need to discuss with the CT what was missed during the absence.

One group seemed to be having difficulty with the content in Sprint 2 and knowing what to do, but they were productive and stayed engaged with technology. This group used technology to clarify content misconceptions with the CT. The group's use of technology kept them engaged and assisted them to work through the problem. Technology supported differentiated instruction in the unit. Students that were typically characterized as the "quiet" students were able to contribute in nonverbal ways which enabled them to contribute and be productive. Each student had a different way to access and contribute to the learning progression with technology. Some contributed to research tasks and resources, some organized presentation scripts, and others found related graphs and models. Many students used technology as an assistive teaching tool for other group members. When there were questions the group could not answer, they would search for a video or resource for explanations. The student would check these explanations by the CT or engage in dialog to deepen the concept. The majority of the time learning was self-directed by students.

The teams took initiative and used technology for productivity. Students planned ahead when they were going to be absent and met other team members online during the evening to work on projects. The students enjoyed working with technology and used it in creative, collaborative ways that I had not planned. Two students suggested a need to have the backlog chart online in a digital format so they could engage with it outside of class and had planned the initial steps to create an interactive digital backlog app. These students were excited to use their interest in computer technology to design something useful for the group. The use of technology was related to all collaborative themes in the Scrum learning environment and was a significant contribution to the group's ability to collaborate.

Educational outcomes and adaptive classrooms.

Scrum created an environment that supported extensive social learning, creativity, accessibility, engagement, and collaboration. Students would observe processes that were successful or resources others were using and adapt their own processes to become more successful. The Scrum educational environment provided access to more diverse knowledgeable others. The teachers were not the only source of guidance, other students became instructional partners. The Scrum process supported the use of the diverse skills by students, whether it was artistic creativity, leadership, scholarship, etc. There were many opportunities for students to use their individual strengths to contribute to the success of the group. Embracing the diversity of skillsets in the classroom increased the learning opportunities of all students, because it differentiated the modes of learning.

Scrum processes differentiated instruction to fit the needs of learners. The educational Scrum environment enabled me to respond quickly to barriers of productivity. All students were able to engage and contribute in significant ways because there were many different ways for them to access the learning group. I was concerned about the quiet students a few different times throughout the unit that they were excluded from the group or did not speak up when they had questions or issues. However, with the use of collaborative tools to communicate electronically as well as creative opportunities to contribute, this sometimes ignored population made significant contributions to the group.

Students were given autonomy to meet academic performance expectations. This created an environment of divergent, creative thinking. Some students shared poetry, some created innovative methods to manage sticky note tasks and backlog charts, others created colorful and engaging scientific charts and graphs by hand that were very artistic and well done. Students were creative in their ways to communicate scientific data that was engaging, informative, and accurate. One group devised a method to assist their presentation of their global climate change model. The group had strategically placed talking points on the back of a poster to refer to as they were holding up the poster and explaining their work. This was a creative idea that added to the professionalism of the presentation. Students showed motivation, initiative, and self-direction to research topics beyond what was required of them or expected.

Scrum provided a platform for students to delve deeper into subjects of interest. Final expectations were clear, but how they achieved them or the path they took to reach the goal was self-directed. Students many times went above and beyond our requirements for the assignment. Sometimes even beyond my own knowledge of a subject with initiative to research the literature and share information with the group. Students began to self-direct their own extended learning into diverse, yet related subjects of interest.

Student engagement was high throughout the unit. There was one instance a student sat alone, withdrawn from the group, but engaged in a research task. The student did not stay alone for an extended time before the group requested his contribution to the group discussion and he gladly joined them. There were no other examples of students disengaged or not actively contributing to a group effort. Students physically self-organized themselves facing one another, were often standing or leaning into their conversations. I witnessed one student use their cell phone twice, briefly during class, in the entirety of the eleven day unit. This is highly unusual for most classes. Students regularly check their phones even if they are not actively using it during class. However, during this curriculum unit, most students did not glance at their phones!

Dynamic variables such as time and changes in schedule were planned with processes that regularly encouraged re-evaluating the schedule and making adjustments according to group consensus and a shared group accountability for meeting quality expectations. Time constraints were a significant factor in every sprint. Regularly scheduled recycling days reduced four class periods by half, as well as testing, and absences impacted the amount of class time available. The unit had to be completed within a two week period. The unit consisted of eleven days of instruction with four half days due to recycling schedule. The unit also included four major days of absences, a week long break in the middle of the unit, and location disruptions, which in only five full days of instruction. About 45% of the unit was during “normal”, uninterrupted classroom conditions. The remaining 55% of the time was characterized by disruptions to the learning environments and limiting resource factors. The three sprints averaged less that two full days of uninterrupted class time per sprint.

Sprint 2 was chaotic returning from a long break, and with many changes to the schedule, expectations, and physical learning environment. Many students were absent and the class was displaced to another classroom for a day which caused disruptions in productivity and some students expressed negative emotions during this time. Curriculum was also changed mid cycle to accommodate student schedules. I made the decision to combine the elements of climate science (Earth systems, climate systems, and global climate change) into one sprint after re-evaluating the schedule. These were initially planned to be sprints of their own with the class investigating each climate science element. I tried to design the sprint to encourage students to rely on one another to explain some of the concepts and the class to work together to stitch the concepts into a cohesive storyline to gain some schedule flexibility. Some students were hesitant to initiate activities when we started the sprint, and I believe most of this stemmed from a lack of clear expectations.

Scrum enabled us to establish a central location to gather daily and communicate as a group with purposeful focus on achieving group success. The process also enabled us to keep a regular routine. Daily stand-up meetings allowed the class to stay on task and adapt to disruptions in the learning environment including time and resource constraints. Barriers that were discussed in these meeting were shared by the group and several of the meetings became resource planning. Students and instructors shared management tasks throughout the unit. Routine, shared meetings contributed to collaboration by giving students an indication of expectations and a framework to communicate in a productive way. Collaboration was not interrupted with classroom disruptions. Rather, through the Scrum process, the learning group adapted and remained productive, and the final results of the unit exceeded expectations.

Chapter 5: Scrum in Education

Introduction

New standards such as *NGSS* require science teachers to shift the focus of classroom teaching to making sense of phenomena and designing solutions to problems and developing 21st century skills such as problem solving, critical thinking, communication, collaboration and self-management. To achieve these goals, novel teaching and instructional management methods will be required to meet these new dynamic requirements. With the variety of challenges faced in the classroom, novice teachers stand to benefit from a management strategy to guide and organize leadership efforts.

I began this investigation curious how to apply Scrum to implement sustained inquiry science. A classroom of your own can be daunting to pre-service teachers. There are many educational demands and expectations, as well as classroom management decisions that are complex and dependent upon the classroom context. The purpose of this study was to examine how a pre-service science teacher utilized a Scrum framework to design and implement *NGSS*-inquiry science curriculum and to facilitate group collaboration in a student-centered, PBL environment. My desire to try this approach was to merge the attempts to meet professional expectations with strategies that also created a student-centered learning environment through sustained collaborative science inquiry. Scrum components of roles, processes, and artifacts were incorporated into a global climate change curriculum unit in an AP environmental sciences high school class. As a participant observer, I recorded indicators of student collaboration in field notes and observations. The autoethnographic data were analyzed at the end of each cycle to identify patterns of behavior as a result of my Scrum methods. These patterns were compared and evaluated to determine core concepts evident in student collaboration in an inquiry science learning environment maintained by Scrum.

Discussion

Scrum processes focused the outcome of the project in terms of group success and productivity. Emergent themes from our Scrum classroom room included evidence of collaboration and community through processes of group planning and management that were components of the curriculum design. The curriculum was designed with purposeful social intention. Students were required to communicate in person on a regular basis, share the same goals, and manage their own activities. Engaging in successful and productive collaboration contributed to positive behaviors that developed a sense of community among the group. The community was cultivated through regular collaboration to solve collective problems. Muzafer Sherif's (1961) famous Robbers Cave experiment, conducted during his tenure at The University of Oklahoma, illustrates what was observed in this study; superordinate goals contribute to group cohesion and reduces intergroup conflict because compelling goals were shared by the group and required the collaborative efforts of all to achieve success.

The community was a result of regular communication. Technology was a critical role to supporting diverse methods of communication. The technology we used extended the ability to communicate outside the classroom and provided a supportive platform for collaborative documents and folders. Technology was the fabric that wove the emergent variables, Scrum curriculum and community, to support student collaboration in the study.

The functional foundation laid by the interactions among Scrum curriculum, community, and technology created a learning environment of positive educational outcomes and adaptability. Students were given autonomy to meet group objectives. Student autonomy is important for educational outcomes. Ryan and Deci's (2000) self-determination theory hypothesized that human motivation is a function of extrinsic and intrinsic motivation that depend on three basic psychological needs: competence, relatedness, and autonomy. They explained that if these universal needs are met, people will function and grow to optimize their inherent potential. The social environment is critical to nurturing these needs and has significant implications to educational environments (Ryan & Deci, 2000). The Scrum educational environment supported autonomy, social learning, creativity, accessibility, engagement, and collaboration. These positive outcomes were the result of purposeful group management and sustained inquiry learning.

Despite my feelings of the curriculum being too complicated and frustration for not providing clear expectations after adjusting our plan during Sprint 2, the groups impressed me with their commitment to productivity and scientific integrity. Students that complained of frustration and confusion were usually doing so in response to a desire for scientific accuracy and helping the team be successful. There was never a situation of one student who chose to do nothing and not engage with the group. Every student was an active participant in group activities. Many students commented on how much they relied on technology to get work done and enjoyed engaging with peers in multiple capacities. Many student expressed feeling pressured during the sprints; however, they exceeded our expectations with their artifacts.

Utilizing Scrum to design, plan, and implement a *NGSS* aligned PBL-learning progression enabled me, a novice science teacher, to facilitate student collaboration in an inquiry science classroom. Several elements of the inquiry science learning environment that relate to student collaboration were impacted by Scrum. Despite disruptions in the learning environment of location change, student absences, and time constraints, we maintained our regular stand-up meeting and daily research activities as planned. The groups made adjustments for missing team members and created a collaborative environment in response to changing conditions.

Agile values, scrum educational methods, collaborative inquiry science.

Incorporating Agile values into education created a learning culture of collaboration. The Scrum framework connects components of science inquiry management areas to actions that create opportunities of community building. Scrum enables a shared management of responsibilities of the learning group. Students and teachers work together to succeed as a group. The Scrum framework created a foundation for a positive social context and community, a secure place to share feelings and grow.

After more recent conversations with agile professionals and further research into suggested resources, I have learned of other organizations making this same connection between Agile and education. There were not many mentions of educational applications of Agile Project Management nor Scrum applications online, and no examples in the literature of K-12 classroom applications when I began this research project a few years ago. Recently, I discovered Agile Learning Centers, the Scrum Alliance, EduScrum and the Agile in Education (AIE) organization.

The *Agile in Education Compass* by (AIE) (see Figure 2) was recently published. The AIE website stated the compass was developed in a collaborative meeting during the spring of 2016. They wrote:

> Together we are the discoverers of the world and ourselves. The world is no longer predictable and learning needs to be more adaptive, connected, and interdependent. Education can respond to this constantly changing landscape with agility. Through our journey, new paths unfold to reveal learning authentic to us. We invite you to use this compass to navigate the unfolding opportunities. (www.agileineducation.org, 2016)

The AIE *Compass* is star-shaped and its triangular points are similar to the Harris and Rooks (2010) inquiry science learning environments management pyramid (see Figure 3).

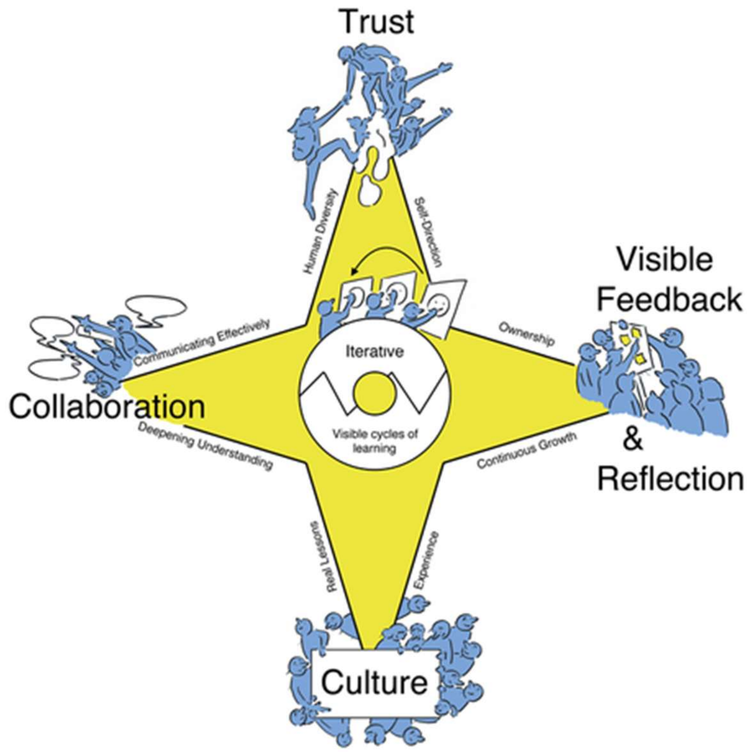

Figure 2. Agile in Education Compass. Reprinted from Agile In Education, by S. Young, 2016, Retrieved April 16, 2017, from http://www.agileineducation.org/.

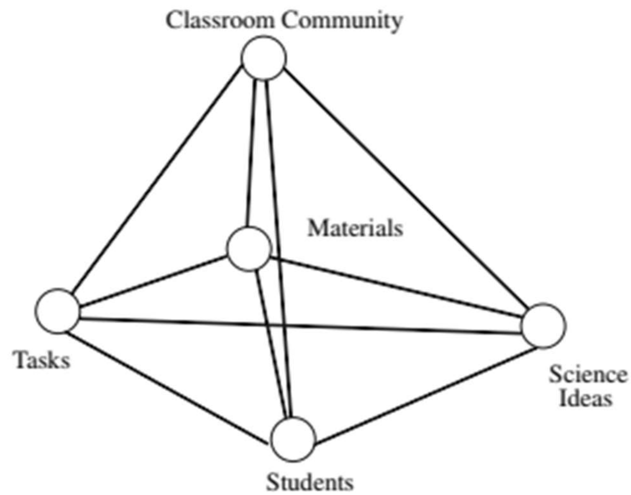

Figure 3. Inquiry Science Learning Environment Management Interactions
Reprinted from "Managing Inquiry Based Science", by, C.J. Harris & D. L. Rooks, 2010, *Journal of Science Teacher Education, 21*(2), 231.

Harris and Rooks (2010) identified common areas of pervasive management required for inquiry science teaching including: instructional materials, science ideas, students, tasks, and the classroom community, which is the social context of the learning environment. These areas are interconnected and impact the effectiveness of one another by how each area is managed. Changes in one area of management will affect the other areas. The management areas are arranged in a pyramid model with classroom community at the apex. This position indicates the "vital importance of managing the overall social context in which science instruction takes place" (p. 231). Management interactions function in inquiry learning environments by enlisting students in scientific practice and providing context for using scientific knowledge and skill as students build understanding and collaborate in the scientific community.

Harris and Rooks (2010) suggested students in inquiry science classrooms experience higher demands to participate and to be personally responsible for learning, which requires the role of teacher to become a competent source of scaffolding to facilitate collaboration and scientific practices. Instructional materials need to be flexible to meet the needs of diverse students and utilize technology that supports student learning and reflects modern uses and practices of technology in professional science. Tasks must be authentic in inquiry classrooms to engage students in a "manner similar to how scientists conduct their work" (p. 234). Classroom community is the apex of the pyramid to reflect the "importance of the social context in which science instruction takes place" (Harris & Rooks, 2010 p. 231). Managing that apex is difficult. Facilitating the learning environment is an important management task on which Scrum may provide some guidance.

The classroom community we created in this study is reflected by the blue star centered in the middle of the germinal model for Adaptive Classroom Project Management (ACPM) (see Figure 4). I aligned the AIE *Compass* with the inquiry science management pyramid, placing the center of the *Compass* at the top of the classroom community apex. Envision the *Compass* Trust point as (North) directed toward the materials point on the foundation of the pyramid. This aligns Visible feedback & Reflection with science ideas, Culture with students, and Collaboration with tasks. Imagine the *Compass* folding its points down with the apex of the pyramid holding up the middle of the *Compass*. The sides of the *Compass* become connections between the apex and between the points of the base of the pyramid. The force that supports the union of these models is the iterative learning progression (learning cycle) and purposeful management of the group (Scrum). This force creates a cyclical motion between the elements in the *Compass* and the pyramid.

The characteristics of that action in the classroom can be explained the connections between the points. The pyramid is designed to illustrate the inter-connected, inter-related, and interdependent relationships between the management areas. Scrum is the tool to facilitate group management of those areas. Between each of the four cardinal directions on the *Compass* there are two lines, one line (A) connects to the center (iterative, visible cycles of learning), and the other (B) connects to the next point. The (A) line is a management strategy that supports building the classroom community. The (B) lines represent a management strategy that defines expectations between the points of management variables (materials, science ideas, students, tasks). These spheres of influence are inter-connected, related, and dependent on one another, and reflect a nested system of the ecological development of humans (Bronfenbrenner, 1979). Scrum management contributes strategies that promote a classroom community and define responsibilities to meet the expectations of the group as they cycle through learning progressions. Figure 4 represents this emergent theory.

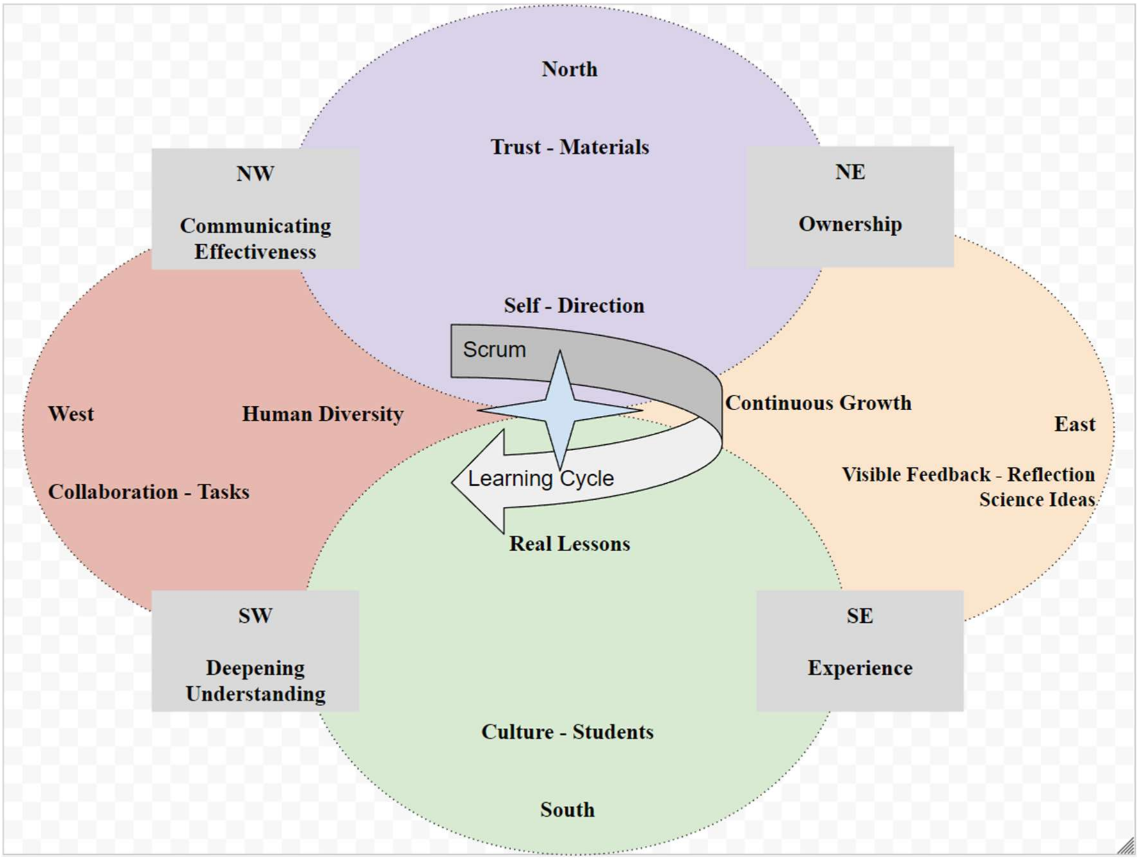

Figure 4. Adaptive Classroom Project Management

The social context utilizing Scrum management in a science inquiry classroom is described from this merging of management models. Scrum provides a method to manage groups by facilitating a project environment that supports self-direction, continuous growth, authentic learning, and embraces human diversity. This management apex represents uniting two management strategies, one focused on science inquiry learning environments and one on group management. Combing the two models represent similar emergent theories from my experience utilizing Scrum to facilitate a science inquiry classroom. Management considerations are the overlapping areas between the spheres of ACPM (see Figure 4) of the four cardinal directions. These areas are management expectations of the members in the inquiry science environment. Each cardinal direction includes a sphere of the interrelationship between a major management practice and inquiry science classroom variable. The shape of the center blue star is the classroom community experience.

Teachers modeling and developing project management agility in the learning community create an adaptive classroom. To explain this process starting at North, materials (resources such as technology and each other) in the science inquiry classroom are managed by the learning group through relationships built on trust. Practicing ownership in the learning process reflects an earned trust to utilize classroom resources as the group determines. The materials are utilized and managed by the group through practices of visible feedback and reflection engaging with scientific ideas and assessing how the group is meeting agreed upon objectives. The east direction provides *NGSS* opportunities for students and teachers to engage in scientific discourse and collaboratively solve problems with clear performance expectations. These experiences enable the learning group to create a culture focused on students and authentic learning. Students that engage in their own culture of learning deepen their understanding of the problems they are collaboratively working on. Students collaborate and identify tasks the group needs to accomplish to meet expectations. Utilizing the diversity of human skills to accomplish group tasks can encourage divergent thinking and creativity, which may lead to unexpected innovations. Effective communication is a management practice that will improve productive collaboration and contribute to a cycle of trust and effective management in the science inquiry learning environment.

The impetus to facilitate this learning environment comes from the curriculum and designing a learning sequence in a coherent storyline the group collaborates to co-create. Members of the learning group move through a process of self-organized management of expectations while co-creating a shared understanding of quality expectations and a system of support to achieve collective success. Iterative curriculum that moves a group through a cycle of incremental learning encourages student engagement and is an effective vehicle to facilitate collaboration through project-based learning. Collaboration in inquiry science is a product of relationship and community building. Scrum facilitates this process and has significant applications for education.

Limitations

There are many limitations to this study. Most importantly, my limited experience teaching and managing classrooms and practicing Scrum. I made teaching decisions based on research and dialogue between myself and my professional learning community. There is no doubt an experienced teacher or Scrum practitioner would have made different choices and would have many helpful suggestions. By my calculation about 45% of the unit was during “normal”, uninterrupted classroom conditions. The remaining 55% of the time was characterized by disruptions to the learning environments and limiting resource factors. These factors impacted the effectiveness of the curriculum. However, this study was focused on how a pre-service science teacher could plan to manage collaborative inquiry science and contend with dynamic, complex variables. Scrum provided guidance for this. Experienced teachers may see more effective uses of Scrum in education.

The classroom and cooperating teacher were not familiar with PBL nor Scrum which led to confusion and impacted the effectiveness of the teaching method. Effective management would increase with extended experience with Scrum. The classroom in this study was an elective environmental sciences class that had been studying human pollution and impacts to biodiversity throughout the year leading up to this curriculum unit. The class also included a small number of students in a popular teacher's classroom. The student to teacher ratio was eight to one with two instructors. Quality, functional technology was available. The students were aware of the research project. The combination of these factors set the stage for what many would consider ideal classroom conditions and could explain the high student collaboration and engagement

The curriculum incorporated several *NGSS* performance expectations and driving questions. There were many complex science concepts and disciplines included to meet these expectations. I believe the unit was over complicated with multiple performance expectations for this unit. Many of the Earth science, weather and climate concepts could be addressed in units of their own. The students ranged in age and intellectual development and may not have been able to understand all the content. Scrum enabled me to formatively assess the students often and we adjusted accordingly in this study. However, implementing Scrum with more streamlined curriculum could be more effective to teach the method and give the group time to become familiar with it.

Recommendations for Future Research

There are many interesting features of Agile values and Scrum applications to inquiry science teaching and learning that could be researched. A primary focus could be more documented experiences of Scrum and Agile methods in the classroom to refine methods, establish best practices, and develop instructional resources. To what extent do these methods help other teachers? Is Scrum appropriate in other disciplines?

Assessment is regularly cited as a challenge to assess in inquiry and PBL classrooms. Implementation of *NGSS* is raising many questions about assessment as well. Research is needed in these areas as it is, but does Scrum offer any assistance to assessment? Project burndown charts are another important feature of Scrum that I was not able to utilize in this study. The burndown chart graphically analyzes group progress based on amount of work completed and how much is left to accomplish within a timeframe. The data for this analysis are from a value system that is assigned to project stories and tasks. Including a regular public review of an evidence based analysis of performance could have significant applications in an inquiry science classroom.

Because I am an unexperienced researcher, those with a better sense of the literature landscape would have an illuminating opinion of where these ideas align. A more thorough review of the literature and a theoretical analysis of Scrum educational methods and analogies is necessary. A more thorough theoretical explanation of the proposed adaptive classroom project management (ACPM) compass would be illuminating. There are many more layers to investigate regarding group management through iterative cycles of learning and adapting.

The learning of science was evident in the final presentation of Sprint 3 of this study. There were observable and measureable tasks related to the performance expectation. However, not every student had the opportunity to construct their own scientific understanding of the unit judging by the remaining student questions. The novel instructional method and science education standards and my inexperience as a teacher limited the ability to formally assess achievement. Student achievement metrics would further evaluate the effectiveness of Scrum as a teaching strategy.

Scrum was an effective tool for a novice teacher to facilitate collaborative inquiry science. The methodology provided purposeful iterative strategies and a few simple rules to maintain a culture of learning and adapting. My interpretation of Scrum is amateur and I have had no formal, professional training by credentialed Scrum practitioners. I will be refining my teaching strategies in my future classes. More research needs to be done that is informed and designed by knowledgeable Scrum practitioners.

Conclusions

This experience was highly collaborative from a professional perspective planning and designing curriculum to a classroom leadership perspective facilitating science inquiry. I believe with more practice managing with Scrum and more experience with inquiry science in the classroom, these methods could be an effective strategy to facilitate student collaboration in inquiry science. The stand-up meetings and regular opportunities for discussions of the group's intent and purpose enabled the learning community to respond to change with agility. Scientific and engineering practices were regularly practiced with scientific discourse, peer feedback, and collaborative decision making. This study included many opportunities to develop 21st century skills of creativity, critical thinking, communicating, and collaborating.

The emergent themes from my experience using Scrum to facilitate student collaboration in a student-centered classroom can be described quite well by the merger of AIE's compass (see Figure 2) and the Harris & Rooks (2010) pyramid (see Figure 3) of pervasive management in inquiry science environment, in the ACPM developmental model (see Figure 4). Using Scrum to inform my management decisions in the classroom resulted in a personal deeper appreciation and awareness of the social context as a critical factor in the learning process. Scrum methods established an environment of regular communication and clear expectations. The learning group built a community through practicing rituals of communicating progress and reflecting on performance, supporting group success, and co-creating social purpose. Collaboration and engagement was a constant element in my Scrum classroom. *NGSS* curriculum, achievement objectives and performance expectations were a natural fit for Scrum methods, because the Scrum process required the learning group to engage in scientific and engineering processes. This is logical since Scrum is a delivery framework for Agile project management values as a software engineering management tool. A scrum classroom engages the entire learning group and cultivates a *NGSS* culture of inquiry.

Not all data were positive in this study. Some students were confused and frustrated at times with these methods and many of these negative elements could erode a learning culture if not corrected and student frustration was allowed to increase. However, Scrum enabled me to identify the barrier, make a course correction, and respond quickly when this occurred in our classroom. My purpose was intentionally reflective and my focus was not absorbed with running the classroom; I was able to be free to move through the room and identify barriers because the group was sharing the responsibilities of the classroom. The barriers were easy to identify because the group regularly discussed progress. Students contributed more to the discussion as they became more familiar with the processes and felt their contribution was valued. Students regularly expressed their feelings; communication was a critical tool.

This further exemplifies the benefit of merging Scrum group management methods to iterative cycles of learning, a culture of inquiry emerges from a positive, productive community. This framework may assist educational leaders to facilitate an adaptive, collaborative learning group and maintain growth through reflective management processes. Facilitating collaboration in science education with purposeful management harnesses the power of shared learning and creates a community of learning.

Collaboration is critical to establishing a culture of inquiry and is achieved through shared management of group responsibilities. Managing an inquiry science classroom is complex and requires a strategy that reflects the purpose of science, which is the quest for knowledge (Renner, 1982) through an iterative cycle of collaborative learning and adapting. Managing science inquiry with Scrum facilitated relationship and community building, which is a critical element to effectively manage inquiry science. The positive relationships enlisted students to help manage the mutual goals of the classroom.

There are clear leadership responsibilities of classroom teachers; our purpose is not to just teach the concepts of a discipline but to orchestrate the learning of a group. Learning is the shared goal assumed by the group but not always understood and embraced. Scrum allowed me to put purposeful group focus on our progression toward a shared learning goal. That goal became our conversation and social context through Scrum rituals and striving for one another's well-being. The classroom is full of diverse cross-functional students with an array of skills, many of those skills are still developing, and they may not even know they possess. This is a valuable resource for educators. Scrum enables students to choose their role in the social context and find out how they can contribute to the group. Productivity is inevitable if you make the entire group's goals the focus of the classroom.

The classroom is an unpredictable and highly dynamic social environment. Managing that environment requires a purposeful social intention. Scrum management reflects the game of Rugby. This study showed me this metaphor applies to the science inquiry learning environment as well. The game (classroom) is controlled by the environment (social context). There are rules (expectations and pedagogy) that control the game. The purpose (learning) of the primary cycle is to move the ball (progress). Players on the learning team co-create expectations of group intentions to move the ball and progress. Scrum enables the group to share and collaborate action toward a well-defined learning goal to score knowledge. Regular practice improves a Rugby team's ability to score in the game, conceivably a classroom learning environment facilitated by Scrum would improve the knowledge and collaborative skills of the group. Scrum was a helpful tool to assist my abilities as a novice science teacher to facilitate collaborative inquiry science.

Scrum in education is a tool to orchestrate the social context of the classroom. This perspective reflects the interconnected and interdependent nature of society and education. As our world is becoming more unpredictable (IPCC, 2013), our learning needs to be adaptive and responsive to the unexpected. Students need opportunities while they are in school to collaboratively learn to solve the problems they face as a community. Collaborative and adaptive learning builds relationships of trust, shared responsibility of management and resources, and focus on growth. It may be possible that learning environments which embrace and employ Agile values will help move our perception, an outdated worldview that is inadequate to contend with the reality of our collective global problems (Houser, 2005), to intentional collaboration and ecological responsibility. Educators can respond to this dilemma with an adaptive classroom and project management agility.

References

Abraham, M. R. (1997). The learning cycle approach to science instruction. *Research matters-to the science teacher*, *9701*.

Abraham, M. R., & Renner, J. W. (1986). The sequence of learning cycle activities in high school chemistry. *Journal of Research in Science Teaching*, *23*(2), 121-143.

Agile Learning Centers. (2017). Retrieved from http://agilelearningcenters.org

Alberts, B. (2000). Some thoughts of a scientist on inquiry. *Inquiring into inquiry learning and teaching in science*, 3-13. American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

Anderson, L. (2006). Analytic autoethnography. *Journal of Contemporary Ethnography*, *35*(4), 373-395.

Baker, W. P., Lang, M., & Lawson, A. E. (2002). Classroom management for successful student inquiry. *The Clearing House, 75*(5), 248-252.

Barron, B. J., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., & Bransford, J. D. (1998). Doing with understanding: Lessons from research on problem-and project-based learning. *Journal of the Learning Sciences*, *7*(3-4), 271-311.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House, 83*(2), 39-43.

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: Models, tools, and challenges. *International Journal of Science education*, *32*(3), 349-377.

Belland, B. R., Ertmer, P. A., & Simons, K. D. (2006). Perceptions of the value of problem-based learning among students with special needs and their teachers. *The Interdisciplinary Journal of Problem-based Learning*, *1*(2), 1-18.

Blumenfeld, P., & Krajcik, J. (2005). Project-based learning. In R. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (p. 17). Cambridge: Cambridge University Press.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3-4), 29. doi:10.1080/00461520.1991.9653139

Bowman, L., & Govett, A. (2015). Becoming the change: A critical evaluation of the changing face of life science, as reflected in the NGSS. *Science Educator, 24*(1), 51-61.

Bronfenbrenner, U. (1979). *The ecology of human development*. Cambridge: Harvard University Press.

Brophy, J. (1988). Educating teachers about managing classrooms and students. *Teaching and Teacher Education, 4*(1), 1-18. doi:10.1016/0742-051X(88)90020-0

Brush, T., & Saye, J. (2008). The effects of multimedia-supported problem-based inquiry on student engagement, empathy, and assumptions about history. *Interdisciplinary Journal of Problem-Based Learning*, *2*(1), 4.

Bybee, R. (2014). NGSS and the next generation of science teachers. *Journal of Science Teacher Education, 25*(2), 211-221. doi:10.1007/s10972-014-9381-4

Cervone, H. F. (2011). Understanding agile project management methods using Scrum. *OCLC Systems & Services: International digital library perspectives*, *27*(1), 18-22.

Chang, H. (2016). *Autoethnography as method*. New York: Routledge.

Charmaz, K. (2006). *Constructing grounded theory*. Thousand Oaks, CA:Sage.

Chichekian, T., Shore, B. M., & Tabatabai, D. (2016). First-year teachers' uphill struggle to implement inquiry instruction: Exploring the interplay among self-efficacy, conceptualizations, and classroom observations of inquiry enactment. *SAGE Open*, *6*(2), 2158244016649011.

College Board. (2017). Retrieved from http://apcentral.collegeboard.com

Colley, K. (2008). Project-based science instruction: A primer: An introduction and learning cycle for implementing project-based science. *The Science Teacher, 75*(8), 23.

Crawford, B. A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching, 37*(9), 916-937. doi:10.1002/1098-2736(200011)37:9<916::AID-TEA4>3.0.CO;2-2

Crawford, B. A., Krajcik, J. S., & Marx, R. W. (1999). Elements of a community of learners in a middle school science classroom. *Science Education, 83*(6), 701-723. doi:10.1002/(SICI)1098-237X(199911)83:6<701::AID-SCE4>3.0.CO;2-2

Crawford, G. B. (2004). *Managing the adolescent classroom: Lessons from outstanding teachers*. Thousand Oaks, CA: Corwin.

Davidovitch, L., Parush, A., & Shtub, A. (2006). Simulation-based Learning in Engineering Education: Performance and Transfer in Learning Project Management. *Journal of Engineering Education*, *95*(4), 289-299.

Dede, C. (2010). Comparing frameworks for 21st century skills. *21st Century Skills: Rethinking How Students Learn*, *20*, 51-76.

Dickinson, G., & Jackson, J. K. (2008). Planning for success: How to design and implement project-based science activities. *The Science Teacher, 75*(8), 29-32.

Discks, R. S. (2013). How can technical communicators manage projects? In J. Johnson-Eilola & S. A. Selber (Eds.), *Solving problems in technical communication* (pp.310-332). Chicago, IL: University of Chicago Press.

Doolittle, P. E. (1997). Vygotsky's zone of proximal development as a theoretical foundation for cooperative learning. *Journal on Excellence in College Teaching*, *8*(1), 83-103.

Driver, R., Asoko, H., Leach, J., Scott, P., & Mortimer, E. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12. doi:10.3102/0013189X023007005

Duit, R., & Treagust, D. F. (1998). Learning in science: From behaviourism towards social constructivism and beyond. *International Handbook of Science Education*, *1*(Part 1), 3-25.

English, M. C., & Kitsantas, A. (2013). Supporting student self-regulated learning in problem-and project-based learning. *Interdisciplinary Journal of Problem-Based Learning*, *7*(2), 6. doi:10.7771/1541-5015.1339

Framework for 21st Century Learning. (2016). Retrieved from http://www.p21.org/about-us/p21-framework

Glaser, B. G. (1978). *Theoretical sensitivity: Advances in the methodology of grounded theory*. San Francisco, CA: Sociology Press.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Piscataway, NJ: Transaction publishers.

Gokhale, A. A. (1995). Collaborative learning enhances critical thinking. *Journal of Technology Education, 7*(1), 22-30.

Goncalves, M., Heda, R., & Goncalves, M. (2010). *Fundamentals of agile project management: An overview*. New York: American Society of Mechanical Engineers.

Harris, C., & Rooks, D. (2010). Managing inquiry-based science: Challenges in enacting complex science instruction in elementary and middle school classrooms. *Journal of Science Teacher Education, 21*(2), 227-240. doi:10.1007/s10972-009-9172-5

Harris, C. J., Penuel, W. R., Angelo, C. M., Debarger, A. H., Gallagher, L. P., Kennedy, C. A., . . . Krajcik, J. S. (2015). Impact of project-based curriculum materials on student learning in science: Results of a randomized controlled trial. *Journal of Research in Science Teaching, 52*(10), 1362-1385. doi:10.1002/tea.21263

Highsmith, J. A. (2010). *Agile project management: Creating innovative products* (2nd ed.). Upper Saddle River, NJ: Addison-Wesley.

Houser, N. O. (2005). Inquiry island: Social responsibility and ecological sustainability in the twenty-first century. *The Social Studies*, *96*(3), 127-132.

Huber, R. A., & Moore, C. J. (2001). A model for extending hands-on science to be inquiry based. *School Science and Mathematics, 101*(1), 32-42.

Ingersoll, R. M., & Smith, T. M. (2003). The wrong solution to the teacher shortage. *Educational Leadership, 60*(8), 30-33.

It's About Time. (2017). Retrieved from http://www.iat.com

Johnson, R. T., & Johnson, D. W. (1994). An overview of cooperative learning. In J. S. Thousand, R. A. Villa, & A. I. Nevin (Eds.), *Creativity and collaborative learning: A practical guide to empowering students and teachers* (pp. 31-44). Baltimore, MD: Brookes Press.

Krajcik, J. (2015). Project-based science: Engaging students in three-dimensional learning. *The Science Teacher*, 82(1), 25.

Kounin, J. S. (1970). Observing and delineating technique of managing behavior in classrooms. *Journal of Research and Development in Education, 4*(1), 62-72.

Larmer, J., Mergendoller, J., & Boss, S. (2015). *Setting the standard for project based learning*. Alexandria, VA: ASCD.

Lawson, A. E. (1995). *Science teaching and the development of thinking*. Belmont, CA: Wadsworth.

Lawson, A. E. (2000). Managing the inquiry classroom: Problems & solutions. *The American Biology Teacher*, *62*(9), 641-648.

Lee, D., Huh, Y., & Reigeluth, C. M. (2015). Collaboration, intragroup conflict, and social skills in project-based learning. *Instructional Science, 43*(5), 561-590.

Lee, O., Miller, E. C., & Januszyk, R. (2014). Next generation science standards: All standards, all students. *Journal of Science Teacher Education, 25*(2), 223-233. doi:10.1007/s10972-014-9379-y

Lingard, R., & Barkataki, S. (2011). *Teaching teamwork in engineering and computer science.* Paper presented at the 41st ASEE/IEEE Frontiers in Education Conference, Rapid City, SD.

Malmgren, K. W., Trezek, B. J., & Paul, P. V. (2005). Models of classroom management as applied to the secondary classroom. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 79*(1), 36-39. doi:10.3200/TCHS.79.1.36-39

Marek, E. A., & Cavallo, A. M. L. (1997). *The learning cycle: Elementary school science and beyond* (Rev. ed.). Portsmouth, NH: Heinemann.

Marek, E. A. (2008). Why the learning cycle?. *Journal of Elementary Science Education*, *20*(3), 63-69.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Blunk, M., Crawford, B., Kelly, B., & Meyer, K. M. (1994). Enacting project-based science: Experiences of four middle grade teachers. *The Elementary School Journal, 94*(5), 517-538. doi:10.1086/461781

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., & Soloway, E. (1997). Enacting project-based science. *The Elementary School Journal, 97*(4), 341-358. doi:10.1086/461870

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Fishman, B., Soloway, E., Geier, R., & Tal, R. T. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of research in Science Teaching*, *41*(10), 1063-1080.

Melnik, G., & Maurer, F. (2003). Introducing Agile methods in learning environments: Lessons learned. In *Extreme Programming and Agile methods-XP/Agile universe 2003* (pp. 172-184). Berlin, Germany: Springer.

Mergendoller, J. R., Markham, T., Ravitz, J., & Larmer, J. (Eds.). (2006). *Pervasive management of project based learning: Teachers as guides and facilitators.* Mahway, NJ: Erlbaum.

Mergendoller, J. R., & Thomas, J. W. (2001). Managing project based learning: Principles from the field. Buck Institute for Education. Available: http://www. bie. org.

Merriam, S. B. (1998). *Qualitative research and case study applications in education: Revised and expanded from case study research in education.* San Francisco, CA: Jossey-Bass.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474-496.

Minstrell, J., & van Zee, E. H. (Eds.). (2000). *Inquiring into inquiry learning and teaching in science.* Washington, DC: American Association for the Advancement of Science.

National Research Council. (1996). *National science education standards*. Washington, DC: The National Academies Press. doi:https://doi.org/10.17226/4962.

National Research Council. (2012). *A framework for k-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press. doi:https://doi.org/10.17226/13165.

National Science Teachers Association. (2014a). About the next generation science standards. Retrieved from http://ngss.nsta.org/about.aspx

National Science Teachers. (2014b). Why k-12 science standards matter - And why the time is right to develop next generation science standards. Retrieved from http://ngss.nsta.org/why-standards-matter.aspx

Next Generation Science Storylines. (2016). Retrieved from http://www.nextgenstorylines.org

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

Oklahoma State Department of Education. (2011). *Priority academic students skills for science (PASS).* Oklahoma City, OK: author.

Oklahoma State Department of Education. (2013). *Oklahoma academic standards for science (OASS)*. Oklahoma City, OK: author.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., & Dubash, N. K. (2014). *Climate change 2014: synthesis report. Contribution of*

Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change (p. 151). IPCC.

Perera, G. I. U. S. (2009). Impact of using agile practice for student software projects in computer science education. *International Journal of Education and Development using Information and Communication Technology*, 5, 85-100.

Piwowar, V., Thiel, F., & Ophardt, D. (2013). Training inservice teachers competencies in classroom management. A quasi-experimental study with teachers of secondary schools. *Teaching and Teacher Education, 30*, 1-12. doi:10.1016/j.tate.2012.09.007

Plucker, J., Kennedy, C., Dilley, A. (2015). *What we know about collaboration* [PDF]. Retrieved from htt://www.p21.org/our-work/4cs-research-series

Pope-Ruark, R. (2012). We scrum every day: Using scrum project management framework for group projects. *College Teaching, 60*(4), 164-169.

Pope-Ruark, R. (2015). Introducing agile project management strategies in technical and professional communication courses. *Journal of Business and Technical Communication, 29*(1), 112-133. doi:10.1177/1050651914548456

Pope-Ruark, R., Eichel, M., Talbott, S., & Thornton, K. (2016). Let's Scrum: How Scrum methodology encourages students to view themselves as collaborators. *Teaching and Learning Together in Higher Education*, *1*(3), 5.

Pruitt, S. (2014). The next generation science standards: The features and challenges. *Journal of Science Teacher Education, 25*(2), 145-156. doi:10.1007/s10972-014-9385-0

Penuel, W. R., & Means, B. (2000). *Designing a performance assessment to measure students' communication skills in multi-media-supported, project-based learning.* Paper presented at the meeting of American Educational Research Association, New Orleans, LA.

Renner, J. W. (1982). The power of purpose. *Science Education*, *66*(5), 709-716.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, *55*(1), 68.

Schwaber, K. (1997). Scrum development process. In *Business Object Design and Implementation* (pp. 117-134). London: Springer.

Schwaber, K., & Sutherland, J. (2012). *Software in 30 days: How agile managers beat the odds, delight their customers, and leave competitors in the dust*. Hoboken, NJ: John Wiley & Sons.

Sherif, M. (1961). *The Robbers Cave experiment: Intergroup conflict and cooperation*. Wesleyan University Press.

Starr, L. J. (2010). The use of autoethnography in educational research: Locating who we are in what we do. *Canadian Journal for New Scholars in Education/RCJCÉ*, *3*(1).

U. S. Global Change Research Program (2009). *Climate literacy: The essential principles of climate science.* Retrieved from http://www.globalchange.gov/browse/reports/climate-literacy-essential-principles-climate-science-high-resolution-booklet

U. S. Global Change Research Program (2014) *National climate assessment*. Retrieved from http://nca2014.globalchange.gov/

Von Secker, C. (2002). Effects of inquiry-based teacher practices on science excellence and equity. *The Journal of Educational Research, 95*(3), 151-160.

Watson, S. (2006). Novice science teachers: Expectations and experiences. *Journal of Science Teacher Education, 17*(3), 279-290. doi:10.1007/s10972-006-9010-y

What is project based learning (PBL)? (2017). Retrieved from http://bie.org/about/what_pbl

Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science Education, 87*(1), 112-143. doi:10.1002/sce.10044

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education, 92*(5), 941-967. doi:10.1002/sce.20259

Wong, H. K., Wong, R. T., & Seroyer, C. (2009). *The first days of school: How to be an effective teacher*. Mountain View, CA: Harry K. Wong.

Appendix: IRB

The UNIVERSITY of OKLAHOMA

Institutional Review Board for the Protection of Human Subjects

Approval of Initial Submission – Exempt from IRB Review – AP01

Date: March 31, 2017 **IRB#:** 7905

Principal Investigator: Amelia Ann Cook **Approval Date:** 03/30/2017

Exempt Category: 1

Study Title: Adaptive Classroom Project Management: Facilitating Sustained Science Inquiry with SCRUM

On behalf of the Institutional Review Board (IRB), I have reviewed the above-referenced research study and determined that it meets the criteria for exemption from IRB review. To view the documents approved for this submission, open this study from the *My Studies* option, go to *Submission History*, go to *Completed Submissions* tab and then click the *Details* icon.

As principal investigator of this research study, you are responsible to:

- Conduct the research study in a manner consistent with the requirements of the IRB and federal regulations 45 CFR 46.
- Request approval from the IRB prior to implementing any/all modifications as changes could affect the exempt status determination.
- Maintain accurate and complete study records for evaluation by the HRPP Quality Improvement Program and, if applicable, inspection by regulatory agencies and/or the study sponsor.
- Notify the IRB at the completion of the project.

If you have questions about this notification or using iRIS, contact the IRB @ 405-325-8110 or irb@ou.edu.

Cordially,

Aimee Franklin

Aimee Franklin, Ph.D.
Chair, Institutional Review Board