Exploring Elementary Student-Driven Inquiry Science: A Mixed Methods Case Study of the S.W.I.M.A.S. Model

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The purpose of this study is to explore student-teacher interactions, student-student interactions, student perceptions of the learning environment, and student performance within a fifth grade elementary science classroom implementing a model for student-driven inquiry-based learning. The model for inquiry is called Students With Inquiring Minds Are Scientists (S.W.I.M.A.S). Data sources include a student survey, teacher interviews, and classroom observations. Both quantitative and qualitative data sources are used to describe this instructional model from various perspectives.

INTRODUCTION

The benefits of elementary inquiry-based science are well documented within scholarly literature, as are the challenges to successful implementation. Within inquiry-driven science classrooms, learners interact, collaborate, collect data, determine evidence in support of ideas, and negotiate meaning. Conceptual understanding develops through experiential learning, collaborative discourse, and the formation of frameworks or mental models for understanding. Researchers in science education, both historical and current, recommend an inquiry-based approach to science teaching at the elementary level (AAAS, 1993; NRC, 1996; NSTA, 2002; NRC, 2012; Minner, Levy & Century, 2009). Some of the barriers that inhibit successful implementation of inquiry-based elementary science teaching include educators' inexperience with learning through inquiry, a lack of self-efficacy for teaching through inquiry, and insufficient curriculum resources and instructional time to support this approach (Sanger, 2006; and Forbes, 2011). In order to successfully implement student-driven inquiry science, teachers first need to believe that this is a meaningful way to learn science and that they are capable of teaching in this way (Ireland, Waters, Brownlee & Lupton, 2012; Harwood, Hansen & Lotter, 2006).

A possible solution to the challenge of successful implementation of elementary student-driven inquiry science is the development of a model for the inquiry process that can be replicated by other educators. One such model incorporates pre- and post-assessments, student-generated questions, flexible learning pathways, individual student conferences, and standards-aligned explorations. The Students With Inquiring Minds Are Scientists (S.W.I.M.A.S.) model was developed by a fifth grade educator over a six-year period. During the second year of the journey a mixed methods study was conducted in order to gather qualitative and quantitative data to assess the effectiveness of the S.W.I.M.A.S. approach from the perspectives of the students as well as the teacher. One goal of the study was to inform the educator as he continued to refine his practice. A second goal was to inform other educators of the potential benefits of the S.W.I.M.A.S. model so they might consider incorporating this approach into their own classrooms.

INQUIRY-BASED SCIENCE TEACHING

The *National Science Education Standards* emphasize the inquiry approach as an instructional methodology in K-12 science classrooms. "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (NRC, 1996, p. 31). Throughout the *National Science Education Standards* (NRC, 1996) document, classroom examples of student-driven inquiry are provided as models. *A Framework for K-12 Science Education* (NRC, 2012) further promotes the use of inquiry science practices in order to help students understand the work of scientists. Although *A Framework for K-12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013) provide some structure for inquiry by clearly articulating the science practices involved, full implementation of an inquiry science approach is not consistently observed within elementary science classrooms (Ireland, Watters, Brownlee & Lupton, 2011; Harwood, Hansen & Lotter, 2006). Some teachers find the management of inquiry learning a challenge (Howes, Lim & Campos, 2008). Others report uncertainty that students will master the required standards when allowed to pursue their own inquiry investigations (Aldridge, Fraser, & Huang, 1999). Some elementary schedules do not provide sufficient time for an inquiry-based approach to science. This problem is compounded by the emphasis on math and reading assessments for state and national accountability measures.

Historical and Theoretical Background for Inquiry Teaching

Several efforts have taken place to promote inquiry-based science. Project 2061 (AAAS, 2015), which was developed in 1985 and prompted by the passing of Halley's comet, set a goal to increase literacy in science, mathematics, and technology among the next generation so that science education in the US will have dramatically improved by the time that Halley's comet returns in 2061. A key focus area of Project 2061 was the emphasis on teaching science through inquiry. *Science for All Americans* (AAAS, 1990) describes scientific inquiry as the reliance on evidence, blend of logic and imagination, and use of hypotheses and theories to drive explanations and predictions. Scientific inquiry is further described as a complex social activity that occurs in all nations of the world. The *Benchmarks for Science Literacy* (AAAS, 1993) promotes the "doing" of science, especially within elementary classrooms. Students should be encouraged to "ask questions about nature and seek answers, collect things, make qualitative observations, organize collections and observations, discuss findings, etc." The *Atlas for Science Literacy* (AAAS, 2001) describes inquiry at grades K-2 as "raising questions about the world and seeking answers" which extends in grades 3-5 to the gathering of evidence to support claims. Continued research indicates that young children are capable of conducting inquiry investigations that resemble the processes of scientists (Metz, 1998). "...Even children in kindergarten have surprisingly sophisticated ways of thinking about the natural world based on direct experiences with the physical environment…" (Michaels, Shouse & Schweingruber, 2008, p. 6).

The Practice of Inquiry Teaching

While inquiry-based science has been lauded for its importance in developing young scientists, it has also been recognized as a challenging model to implement within the classroom. Inquiry-based science places many demands on educators as they develop authentic problems, model the actions and thinking of scientists, facilitate the collection and analysis of data, and support the development of conceptual understanding (Crawford, 2000). The complexity of implementation is further hindered by the lack of sufficient planning time. Research studies focused on specific aspects of the inquiry-based science classroom, such as student-teacher interactions, may help to minimize the complexity of implementation.

Student and Teacher Questioning Techniques

Questions are a central feature of inquiry-based science classroom interactions. In a collaborative study involving elementary, high school, and college level educators, Van Zee, Iwasyk, Kurose, Simpson, and Wild (2000) documented teacher and student questions during guided discussions, student-generated inquiry, and peer collaborations. Findings of the study included the assertions that student questions occurred when the teachers set up discourse structures that elicited them, when students were engaged in conversations about familiar contexts in which they had made observations over a long time period, when the discourse environments felt safe for sharing ideas, and when small collaborative groups were included. A focus on teacher questioning strategies revealed that student thinking was elicited through questions about conceptual understanding, an environment that valued various points of view, and a deliberate effort for students to monitor their own thinking. These findings can inform inquiry practices and the intentional development of structures, practices and environments that provoke student-generated questions and conceptual thinking.

Student Questions and Use of Original Data

Some classroom efforts to implement inquiry-based science lead to misconceptions about the nature of scientific thinking. In a study of the cognitive demands of authentic vs. textbook-driven science inquiry tasks, Chinn and Malhotra (2002) determined that most science classroom tasks employ an epistemology that differs from the epistemology of authentic science. Simple inquiry tasks contribute to the misconception that scientific thinking and reasoning follow algorithmic or linear thinking. Within authentic science inquiry, students pursue questions they have generated, control for multiple variables, incorporate multiple measures of dependent and independent variables, guard carefully against observer bias, constantly question whether their results are accurate or flawed, judge whether or not their findings are generalizable, develop theories that explain a diverse body of evidence, and study the research of other scientists. Classroom science inquiry practices that simplify these processes promote misconceptions about the nature of science and scientific reasoning.

New Roles for the Teacher

Traditional roles of teachers as disseminators of knowledge and students as passive recipients do not apply to inquiry-based science classrooms. Barbara Crawford (2000) conducted an in-depth study of an inquiry-driven secondary science educator and described the characteristics of the course design as well as the roles of the teacher that contributed to successful implementation. The educator situated instruction within authentic problems, promoted the importance of grappling with data, fostered collaboration of students and teacher, connected students with the community, modeled the behaviors of a scientist, and fostered student ownership of the learning. The role of the teacher changed with the changing tasks. Observed teacher roles included motivator, diagnostician, guide, innovator, experimenter, researcher, modeler, mentor, collaborator, and learner. The complexity of implementation of inquiry science teaching moves far beyond the descriptor of teacher as facilitator. Support is needed for teachers as they embrace the essence of inquiry.

Inquiry and a Constructivist Learning Environment

The learning of science involves a conceptual change as learners examine new evidence in relation to prior understandings (Abd-El-Khalick & Akerson, 2003). Collaborative discussion facilitates this conceptual change. Collaboration is a pillar of the social constructivist learning environment and it enables students and teachers to make meaning through valuable social interactions (Vygotsky, 1978). Within student-inquiry-driven learning environments, collaboration is essential to fostering the development of the skills and processes used in real world scientific problem solving. Classrooms that promote interaction and collaboration in learning may be forging the minds of students to behave as scientists or as Duschl and Hamilton (1998) suggest, “Carefully constructed learning environments can facilitate students’ appropriation of scientific habits of mind”. Often, constructivist environments lead to positive perceptions of the learning environment, which, in turn, increase achievement and produce more favorable attitudes toward learning (Fraser, 2007; Wubels and Levy, 1993). Further, fostering positive attitudes about learning among students contributes to academic achievement and success (Akey, 2006). Students develop positive attitudes when they have autonomy and can make critical choices regarding the curriculum within science-like learning environments with ill-defined problems and high levels of uncertainty and ambiguity (Roth, 1995). A student-inquiry-driven learning environment allows for student choice and autonomy in the pursuit of complex problems.

The WIHIC Questionnaire

The What is Happening in this Class (WIHIC) questionnaire was developed by Fraser, McRobbie, and Fisher (1996) to capture students' perceptions of features within a constructivist learning environment. The WIHIC questionnaire combines scales from past constructivist learning environment instruments with contemporary classroom practices. The WIHIC questionnaire, which has been used in various learning environments around the world, includes the following scales: student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation, and equity (Aldridge, J., Fraser, B., and Huang, T., 1999). The student cohesiveness scale measures the extent to which students know, help, and are supportive of one another. The teacher support scale measures the extent to which the teacher helps and is interested in students. The involvement scale measures the extent to which students participate in discussions, have attentive interest, and enjoy the class. The investigation scale measures the emphasis on the skills and processes of inquiry and their use in problem solving and investigation. The task orientation scale measures the extent to which completion of planned activities and staying focused on the subject matter are important. The cooperation scale measures the extent to which students cooperate rather than compete with one another on learning tasks. The equity scale measures the equal treatment of all students by the teacher (Pickett & Fraser, 2010). Past uses of the WIHIC questionnaire have provided insight into student perceptions of the various dimensions within a constructivist learning environment.

Implementation of Inquiry Teaching in the Elementary Science Classroom

It has been suggested that institutional school cultures tend to support the status quo rather than the reform-minded practices such as inquiry teaching (Grandy and Duschl, 2007). However, there are strong arguments for supporting such reform practices as inquiry-based science. Harlan (1998) proposes three reasons to support inquiry-based science at the elementary level. First, children are naturally curious and are constantly developing their own ideas of how the world works. Second, the interdependence of science content and processes suggests that teaching inquiry science can help develop better learners. Third, inquiry science fosters in students the idea that science is enjoyable and comprehensible. Rote learning about science content at an early age might discourage students from pursuing further science studies. With the need for and benefits of inquiry-based science clearly defined within scholarly literature (AAAS, 1993; NRC, 1996; NSTA, 2002; NRC, 2012; Minner, Levy & Century, 2009), addressing the real or perceived barriers to successful implementation is critical.

Rationale for Current Study

Findings from research within the field of inquiry-based science indicate that a major concern is inconsistent implementation of inquiry-based science teaching within elementary classrooms. By delving deeper into the processes, practices, environment, strategies, roles, assessments, and planning involved in successful implementation of inquiry science teaching at the elementary level, a model for successful implementation by others may be developed. Findings from both quantitative and qualitative data provide insight not only into the teacher's perspective, the observed classroom interactions, and the student assessment performance, but also into the students' perceptions of various aspects of the learning environment and the support for learning.

RESEARCH METHODS

Research Design

Through a mixed methods case study approach with an embedded quantitative measure, the researcher focused on a particular teacher and his use of a learner-centered inquiry science model called Students with Inquiring Minds Are Scientists (S.W.I.M.A.S.). The study explored the interactions, through questioning, between students as well as between the teacher and students within a student-driven inquiry-based learning environment. The study also explored the classroom and learning environment features as perceived by the researcher, the teacher and the students. The researcher conducted a semi-structured interview with the teacher and two classroom observations, collected pre- and post- student constructed response assessments (additional qualitative data), and administered a student survey (quantitative data) to examine learner growth and determine how students perceived the various components within the classroom learning environment.

Sampling Within the Current Study

The primary subject of the S.W.I.M.A.S. case study was the fifth grade classroom teacher. The educator was selected purposefully due to his prior experience as a part of a district cadre of teachers focused on refining their inquiry science teaching practices for the past year and a half. The researcher conducted classroom observations as well as a semi-structured interview focused on the inquiry model employed by this teacher.

Secondary subjects within the study included the class of fifth grade students. A sample of pre- and post- assessments and a sample journal were collected as artifacts with no student names or other identifiers that would link them back to the individual students. The fifth grade students for whom the researcher received informed consent, following principal assent, completed the 56-item survey. No student names or identifiers were written on the survey.

Within this classroom, the teacher does not refer to students by name. Instead he and the students refer to other students by nicknames. Although this is a standard practice of the teacher, this added an additional layer of anonymity for the student subjects within this study. The researcher never heard the students referred to by their given names.

Qualitative Data Collection and Analysis

In order to answer the qualitative question: What processes, practices, strategies, interactions, and artifacts are evident within the S.W.I.M.A.S. classroom, qualitative data were gathered through classroom observations, a semi-structured teacher interview, and a comparison between pre- and post- constructed response student assessments for a sample of students. During the interview and the classroom observations, handwritten field notes were recorded in a journal and audio recordings were collected. The field notes and audio recordings were transcribed for use during the data analysis phase of the project. The pre- and post-assessments were collected as artifacts.

Quantitative Data Collection and Analysis

The quantitative question within this study is: What are fifth grade student perceptions of the learning environment within the S.W.I.M.A.S. classroom? A quantitative student survey added to the collected data the students' perceptions of specific aspects of a constructivist learning environment. The What Is Happening In This Class (WIHIC) survey (Fraser, McRobbie & Fisher, 1996) consists of 56 questions divided among the following scales: student cohesiveness, teacher support, involvement, investigation, task orientation, cooperation and equity. Responses range from almost never to almost always across a Likert scale. Following an explanation of the voluntary nature of the survey and the opportunity to sign a consent form, student participants completed the 56-item survey. The researcher collected the surveys and entered the data for each student survey into an Excel spreadsheet. The mean and standard deviation were determined for each item as well as for each of the 7 scales.

Mixed Methods Analysis

The mixed methods question within this study is: What results emerge from comparing the exploratory qualitative data about a student-driven inquiry methodology with the outcome quantitative data measured on a learning environment instrument? Both qualitative and quantitative data were considered when addressing the mixed methods research question and considering emergent themes. Through an embedded mixed methods case study design, the quantitative data were used to support findings and increase understanding of the themes that emerged through the analysis of the qualitative data (Creswell, 2014).

DISCUSSION: A LOOK INSIDE THE S.W.I.M.A.S. CLASSROOM

Qualitative Findings

In analyzing the qualitative interview, observations, and artifacts to address the qualitative research question (What processes, practices, strategies, interactions, and artifacts are evident within the S.W.I.M.A.S. classroom?) the following categories emerged: processes, practices, and strategies; interactions; and artifacts of learning. Additional categories based on the teacher interview included: foundations and moving forward. As the data were analyzed, two themes emerged: S.W.I.M.A.S. involves active engagement of the teacher and the students, and student-centered inquiry benefits teachers and students.

Processes, Practices, and Strategies Within the S.W.I.M.A.S. Model

The S.W.I.M.A.S. model consists of the following processes, practices, and strategies: preparation, exploration, assessment, student-generated questions, investigations, and classroom management. The teacher begins preparing for a S.W.I.M.A.S. unit a few weeks in advance. The preparation includes deconstructing the standards and bundling them into a unit that makes sense, developing constructed response pre-assessment items, and designing exploration experiences aligned with the bundled standards. The deconstruction of the standards includes considering how students might develop an understanding of the concepts through investigations and research, as well as a review of where the standard fits within the vertical alignment of the science standards and within the bigger picture of the development of scientifically literate citizens.

The pre-assessments vary in length and in design by unit. In some cases the teacher develops 2-3 open-ended questions addressing the same standard. Sometimes the pre-assessments include an application component. Other times the pre-assessment may consist of one very broad question. The purpose of the pre-assessment is "for me to get a picture of what they already know."

The explorations are hands-on experiences that are designed to build background knowledge and foster inquiry into the concepts to be studied. During the first classroom observation, students were working within a science lab wearing goggles and lab coats as they explored and classified a variety of items that were placed on trays at each table. The items included two containers of two different white granular substances, and one of each of the following: rock, shell, fossil, spatula, cup of a red colored liquid, cup of a green colored liquid, marble, whiffle ball, cup of cooking oil, metal 1000-g mass, tennis ball, foam ball, and craft stick. Students were asked to classify the items in as many different ways as possible and, in the process, to generate questions for further investigation.

The exploration phase of S.W.I.M.A.S. is the students' first experience with the content of the unit. This occurs without any prior instruction and generally prior to the pre-assessment. During the exploration phase, students write any questions they can think of on Sticky Notes and post them on the chalkboard. Through questioning, thinking is extended as students are challenged to develop questions to investigate or research during the next few weeks. Following the few days of exploration and question-generation, students as a class look at the questions posted on the chalkboard and classify them into researchable and investigable questions. Where possible, they are challenged to transform researchable questions into investigable ones.

Students then complete their pre-assessment. From there, the class moves from a "we're all investigating this together to an individualized plan." They sit down with their pre-assessment and come up with a plan based on what they know, what they didn't know, and what they need to know. They build a menu for themselves that contains a mix of investigable and researchable questions that specifically target the pre-assessment needs. For approximately the next two weeks students work individually, or in small groups when their questions align, to complete their S.W.I.M.A.S. menu. As they begin investigating questions on the menu, students carefully record their questions, predictions, observations, data, claims, and evidence within their S.W.I.M.A.S. journals. During these two weeks of independent study, the teacher conferences with each student to compare the planned menu with the pre-assessment and to re-direct or extend the menu and the thinking, as needed.

After the investigation and data collection and analysis phase of S.W.I.M.A.S., students complete their post-assessments. Sometimes students are given back their pre-assessments and asked to add their scientific thinking and reasoning and address any possible prior misconceptions using a different color of ink. Other times the post-assessment consists of questions asked in a different format from the pre-assessment. This varies with each unit.

During the S.W.I.M.A.S. process, classroom management procedures are evident. The prior establishment of lab safety practices is clear as students "suit up" for S.W.I.M.A.S. by wearing lab coats, goggles, gloves, and hot mitts where needed. When something spills or is at risk of boiling over, the students' first reaction is to tell the teacher. Proper disposal of chemicals is modeled and reinforced. The teacher uses strategies for keeping the class on task, such as time limits or warnings.

"I want everyone sitting down in the next 30 seconds and let's get ready to rock and roll." "Hands up 5, 4, 3, 2, 1. Make sure everything is on your trays, then take your goggles off your eyes. Hands down, go!"

The teacher also supports positive interactions among peers and acceptance of all. The teacher reminds students of the tasks to be accomplished at the beginning of and within the class period. He has assigned question leaders at each table whose role is to "push their team in a new direction all of the time: to think differently, see differently, ask questions differently." Another component of classroom management within the S.W.I.M.A.S. approach includes providing materials needed for independent student investigations. This may be done using existing resources within the science lab, having students provide materials from home, or having the teacher bring in purchased or donated items.

Interactions Within the SWIMAS Model

During the flow of the S.W.I.M.A.S. process, much interaction occurs among small groups of students, between the teacher and individual students, between the teacher and small groups, and between the teacher and the whole class. There are few whole class interactions and they are mainly focused on instructions or classroom management. The interactions and strategies can be classified into the areas of questioning, negotiating meaning, cooperation, and conferencing.

As would be expected within an inquiry-driven classroom, many interactions center around questioning. The teacher uses questioning to challenge and extend student thinking. Examples observed include "What do we gain as scientists by classifying matter?" and "If I want to communicate this data…what would be an effective and efficient way to communicate information?" Students also interact through questioning, such as "Would you consider milk to be a liquid or a solid" and "Can a liquid be classified by smoothness or roughness?"

Many of the student-to-student as well as teacher-to-student interactions are centered around negotiating meaning as students try to make sense of what they are observing and measuring. For example, a conversation between students included the following:

S1: Can a liquid be rough?
S2: That is technically "smooth". Because it is a liquid it has to be smooth.
S1: You could add stuff to it.
S2: But the water would go up or down.
S1: (posts on a Sticky Note) – Can liquid be classified by smoothness or roughness?

During the second observation, a student explained how his thinking changed as he negotiated the meaning through observations and data collection.

> I was thinking that substances with higher density had a higher boiling point, but I found that this was not correct when I measured the boiling point of a different substance. Now I am going to re-measure the boiling points of maple syrup and Karo syrup to make certain that I have accurate data.

Whether working collaboratively in small groups or independently at a table with others working on different investigations, students interact as they share and make sense of what they are observing.

Some of the interactions that occur within the SWIMAS classroom exemplify cooperation. During the introductory exploration phase, groups decide collaboratively how to classify their objects. They work together to determine how to explore the shared materials at their tables. During the two-week investigation stage of SWIMAS, the students with common investigable questions cooperate to share materials, when needed. During the second observation, a group of approximately six students was working together to reconstruct a density column by placing the liquids in the container in reverse order from how they were added during a previous investigation. Students working independently also cooperate with others as they share materials and observations. One student noted another student's results and replied, "you should take a video to show the silver layer between the clear lamp oil and the red vinegar."

Throughout the investigation stage, the teacher conducts individual student conferences to ensure that the planned menus align with the learning needs based on the student pre-assessment data. The conferencing interactions include comments such as "These questions are based on where you need to grow. Where in your menu of questions have you looked at density, mass, and weight?" Through conferencing, the teacher interacts with each student, making certain the learning pathway for each is appropriately challenging and aligned with the learning goals.

Artifacts of Learning

After the initial explorations, students complete a pre-assessment that consists mainly of open-ended constructed response-type items, many of which include pictures, diagrams, graphs, or data tables as stimuli. With this S.W.I.M.A.S. unit, students wrote their responses on the pre-assessment with one color of ink, then were handed back their pre-assessment at the end of the unit and asked to change or extend their original responses using a different color of ink. Question 5 on the assessment asked students to propose a method for separating a mixture of salt and pepper. Student 1's response on the pre-assessment was "I think you can use color to separate." On the post-assessment, the student extended the answer by adding that you could "stir the mixture in water then filter the pepper out because salt dissolves in water".

Question 3 on the assessment included a data table listing the densities of 9 different substances, including copper (8.9 g/cm^3) and lead (11.3 g/cm^3). The question associated with the data table was "a student observes that lead floats in a certain liquid and copper sinks. What should the student conclude from the data?" Both student 1 and student 2 left this item blank or stated that they did not know on the pre-assessment. On the post-assessment, however, both students indicated that it was not possible for lead to sink in a liquid and copper to float, given the information in the data table. Student 2 went on to state that this was impossible unless the density of the liquid changed in between trials or if there was an "anomaly".

Question eleven on the assessment included a data table listing temperatures of water in 4 different types of containers over a 4-minute time period. The question associated with the data table stated that boiling water was placed in four different types of containers, all of the same size and shape, but made from different materials. Students were to state which container was the best insulator, then make claims about the materials making up each of the 4 different containers and justifying their claims with evidence. Both students 1 and 2 correctly identified the container that was the best insulator on the pre-assessment, but left blank the second part of the question. On the post-assessment, student 2 added that container 1 was made of plastic, container 2 of glass, container 3 of metal thermos and container 4 of wood. The student did not give a justification for choosing the materials, however, the teacher shared that he will be responding with additional questions on the post-assessments and giving students a third opportunity to extend or expand their answers.

The S.W.I.M.A.S. journals document students' learning as they record the questions they are pursuing, the predictions or hypotheses they generate, the data they collect, the claims they make and the justification or reasoning why the claim is supported by the evidence. The S.W.I.M.A.S. journals document the initial thinking during the exploration phase, the menu once students have taken the pre-assessment and conferenced with the teacher, and the scientific process throughout the investigation phase as students seek to answer researchable and investigable questions. One student's journal included the questions:

- What would happen to the density column if you put in the lowest density liquids first?
- What is the boiling point of dish soap? Does it differ for different brands?
- How does magnetism work?
- If you combine different liquids together, will the mixture have a higher boiling point?
- How does freezing temperature make a liquid into a solid?

Each question was written at the top of a page within the S.W.I.M.A.S. journal, followed by a full page or more of predictions, collected data, research findings, evidence, and claims based on evidence. Diagrams and data tables were included as well. The S.W.I.M.A.S. journals provide a clear picture of students' questions and how they went about finding the answers to those questions.

Benefits of Student-driven Inquiry

The teacher shared that prior to designing and implementing the S.W.I.M.A.S. model, his science classes were centered around students answering questions from the state-adopted textbook. They tried to apply scientific thinking, "but it never worked". As the teacher has implemented student-driven inquiry-based science teaching through the S.W.I.M.A.S. model, he has observed benefits not only for his students, but also for himself. Students have developed greater autonomy. Through the S.W.I.M.A.S. model, students develop a deeper conceptual understanding because they are the ones who are actively engaged in observing, collecting data, and the using evidence to support claims. Students also develop a greater sense of achievement in science, from their perspective. One of the greatest benefits is an improved attitude toward science. Students say, "we get to do S.W.I.M.A.S." instead of saying "we have to do science". As an observer, I noticed many smiles and much enthusiasm among the students within the S.W.I.M.A.S. classroom.

When reflecting on his own growth as a result of implementing the S.W.I.M.A.S. model, the teacher responded that he understands scientific processes better because he had to learn to implement them with children. He also shared that his science knowledge has grown deeper because he has learned along with his students as they pursue answers to questions they have generated. The teacher noted that his improved pedagogy as a result of the design and implementation of the S.W.I.M.A.S. model has transformed his thinking about teaching and learning and set forth a new ideal.

Discussion of Qualitative Findings

The classroom observations and teacher interview provided insight into the processes, practices, strategies, and interactions within the S.W.I.M.A.S. classroom (the qualitative research question within this study). Through the qualitative data analysis process, one theme that emerged was: S.W.I.M.A.S. involves active ongoing engagement of the teacher and the students. This was evident as the teacher explained the preparation work when planning an upcoming S.W.I.M.A.S. unit, as well as during the student exploration phase (Observation 1), and during the customized investigation phase (Observation 2). At no time did I observe off-task or disinterested student behaviors. Students participated actively throughout each class. The teacher circulated around the room conducting conferences or asking questions to extend student thinking. Established classroom management techniques were evident as students responded to cues quickly and demonstrated clear understanding of the work to be accomplished. Students modeled appropriately how to find and wear the appropriate safety garments, and return them at the end of class, with little or no prompting. One strategy that specifically increased student engagement was the assignment of question leaders at each table to keep the groups challenged and directed toward inquiry regardless of whether or not the teacher was in close proximity.

A second theme that emerged through the teacher interview was: Student-driven inquiry benefits teachers and students. The teacher clearly articulated ways in which he and his students have grown as a result of student-driven inquiry through the S.W.I.M.A.S. model. Not only did the teacher's content knowledge base increase, he also developed a deeper understanding of the processes and practices of science as he led children through these processes. His pedagogical knowledge increased as he developed a greater appreciation for the learning process and began designing the experiences needed to facilitate learning. The students increased in autonomy and self-efficacy by taking ownership of their learning pathways (menus) based upon their own needs to know. Their critical thinking skills seemed to improve as they were manipulating materials and negotiating meaning for themselves rather than passively taking in information from someone else.

Quantitative Findings

The quantitative data were analyzed in light of the research question: What are fifth grade student perceptions of the learning environment within the S.W.I.M.A.S. classroom? Based upon a 5 point Likert scale, ranging from 1 = almost never to 5= almost always, the overall mean score for the 21 participants in the WIHIC survey was 4.36 with a standard deviation of 0.87.

Taking a closer look at the individual items within each scale, within the student cohesiveness scale, items 1-5 all had mean scores of 4.6 or greater with standard deviations less than 0.6. This indicates very similar positive responses among the class members to the questions: I make friendships easily among students in this class, I know other students in this class, I am friendly to members of this class, members of the class are my friends, and I work well with others in this class. Question 8 within this scale; In this class, I get help from other students; showed greater variance than other items with a mean of 3.95 and a standard deviation of 0.86**.**

Within the teacher support scale, items 10, 12, 13 and 16 scored a mean greater than 4.5 and a standard deviation of 0.81 or less. The questions include: the teacher goes out of his way to help me, the teacher helps me when I have trouble with the work, the teacher talks with me, and the teacher's questions help me to understand. Within this scale, item 15, the teacher moves about the class to talk with me, showed greater variance among the classmates' responses, with a mean of 3.52 and a standard variation of 1.08.

The involvement scale had the overall lowest mean score with the greatest standard deviation. Item 19 within this scale, the teacher asks me questions, had the highest mean score of 4.71 with a standard deviation of 0.56. All other items within this scale had mean scores of less than 4.4 with standard deviations ranging from 0.73 – 1.33. These questions included: I discuss ideas in class, I give my opinions during class discussions, my ideas and suggestions are used during classroom discussions, I ask the teacher questions, I explain my ideas to other students, students discuss with me how to go about solving problems, I am asked to explain how I solve problems.

Within the investigation scale, items 26 and 31 had mean scores greater than 4.57 with standard deviations of 0.73 or less. These questions were: I am asked to think about the evidence for statements and I find out answers to questions by doing labs in class. Two items within this scale had mean scores of less than 3.7 with standard deviations greater than 1. These questions were: I carry out labs in class to answer questions coming from discussions and I explain the meaning of statements, diagrams, and graphs.

Within the task orientation scale, items 33, 36, 37, 38, and 40 had mean scores of greater than 4.6 with standard deviations less than 0.6. These questions included: getting a certain amount of work done is important to me, I am ready to start this class on time, I know what I am trying to accomplish in this class, I pay attention during this class, and I know how much work I have to do. Item 39, I try to understand the work in this class, had a mean score of 5.0 with a standard deviation of 0.

Within the scale of cooperation, items 43, 44, 45, 46, and 47 showed mean scores greater than 4.5 with standard deviations less than 0.75. These questions included: when I work in groups in this class, there is teamwork; I work with other students on projects in this class; I learn from other students in this class; I work with other students in this class; and I cooperate with other students in this class.

Within the equity scale, items 53 and 56, I receive the same amount of encouragement from the teacher as other students do, and I get the same opportunity to answer questions as other students, had mean scores greater than 4.5 and standard deviations less than 0.75.

Discussion of Quantitative Data

Overall the quantitative results indicate a strong, positive response to the WIHIC questionnaire. With a class mean of 4.36 on a 5-point survey, the results indicate a positive alignment between the S.W.I.M.A.S. classroom experience and the WIHIC scales. A standard deviation of 0.87 indicates a general alignment among students' perceptions of the S.W.I.M.A.S. learning environment. The larger standard deviations for the involvement and investigation scales indicate greater variance among student responses. This may be due to questions that are not always interpreted in the same way by all students, differences in students' perceptions of what is occurring within the classroom, or lack of alignment between the S.W.I.M.A.S. model and the questions asked within the survey.

Within the investigation scale, the question: I carry out labs in class to answer questions coming from discussions might have been interpreted differently among students within the S.W.I.M.A.S. classroom. One of the returned student surveys had a circle around the word "lab" with a question mark indicating lack of understanding of this term. Perhaps the use of the word lab in this way is unfamiliar to students. The teacher uses the words investigation, exploration, or experiment as the activities and the word lab as the place where these activities are conducted. In addition, the statement specifies that students carry out labs to answer questions coming from discussions. Within the S.W.I.M.A.S. classroom, the labs (or investigations) are carried out to answer questions generated by students during their explorations or in response to the pre-assessment. Because the classroom focus is on student-driven inquiry, the S.W.I.M.A.S. model does not begin with a classroom discussion, but instead with student explorations from which questions are generated. The statement: I explain the meaning of statements, diagrams, and graphs; from the WIHIC scale, does not align with daily practices within the S.W.I.M.A.S. classroom. Students explain the meanings of statements, diagrams, and graphs during the pre- and post- assessment phases of the S.W.I.M.A.S. model, but not during the exploration, questioning, or investigation processes.

Within the involvement scale, the lower mean and higher standard deviations among the questions: I discuss ideas in class, I give my opinions during class discussions, my ideas and suggestions are used during classroom discussions, may be attributable to the use of small group and individual explorations, investigations, and negotiation of meaning within the SWIMAS classroom rather than a whole class model of instruction. Students do discuss their ideas, but among small groups rather than as a whole class. Similarly, the questions: I ask the teacher questions, I explain my ideas to other students, students discuss with me how to go about solving problems, and I am asked to explain how I solve problems, might have resulted in low scores because these occur within small groups or through conferences with the teacher rather than as a whole class. Another interpretation of the results, however, is that not all students perceive that they have equal voice or involvement within their small groups.

The high mean scores for the scales student cohesiveness (4.55), task orientation (4.71) and cooperation (4.5) indicate that students have similar favorable perceptions of the questions asked within these scales. The small group and student-centered structures within SWIMAS provide many opportunities for students to work together to accomplish tasks. Within the task orientation scale, the question: I try to understand the work in this class, with a mean score of 5.0 with a standard deviation of 0, indicates that all students within the class put forth effort to understand.

Discussion of Merged Data

The qualitative and quantitative data were merged for the purpose of addressing the question: What results emerge from comparing the exploratory qualitative data about a student-driven inquiry model with the outcome quantitative data measured on a learning environment instrument? One method for comparing qualitative and quantitative data is through a joint display arraying qualitative categories and quantitative scales. Creswell & Plano Clark (2011) recommend a display that compares the processes individuals have experienced with outcome data for an embedded mixed methods design.

In comparing the qualitative and quantitative data, there is a consistency among the data collected through observations, interviews, the gathering of artifacts and the students' perceptions of their environment, as recorded within the quantitative survey instruments. The student responses in the areas of task orientation, student cohesiveness, cooperation, and teacher support are consistent with the classroom observation and interview notes. Task orientation ranked high among the scales on the WIHIC survey. This is consistent with the observation data. No students were seen to be off task or disengaged. All were actively working to accomplish the learning goals. Student cohesiveness was apparent as students worked together to make certain all had the materials and equipment needed to conduct their investigations and as students shared their observations and investigations with one another. Cooperation was observed as students worked in groups during the exploration phase to determine how to classify their materials and during the explorations and investigations as they collaboratively negotiated meaning. Ongoing teacher support was clearly evident as the teacher carefully designed exploratory learning experiences, developed thoughtful pre-assessment items, conducted individual student conferences, and circulated around the room, interacting through questioning.

SIGNIFICANCE OF THE STUDY

Successful implementation of student-driven inquiry science at the elementary level is not well documented in the research. With a state and national emphasis, through standardized testing, on literacy and mathematics at the elementary level, resources and professional learning in these areas are readily available. Elementary teachers need support for, training in, and successful implementation models of inquiry-based science. Utilizing an emergent design mixed method case study approach brings clarity and understanding to what is actually happening within a student-driven inquiry science classroom. Through reading this study, other educators might gain insight and be willing to move further toward inquiry-driven science.

IMPLICATIONS OF CONCLUSIONS

The fifth grade class that was the focus of this study exhibited evidence of successful implementation of inquiry through the S.W.I.M.A.S. model. The classroom educator, through an interview, explained the process and the structures used to plan for and implement this approach. The student surveys provided insight into student perceptions of the learning environment within an inquiry science classroom. The artifacts supported that there were learning gains as a result of this approach.

Limitations

The educator in this study has been a practicing elementary educator for 21 years. He received the district level Elementary Teacher of the Year award a few years prior to implementing the S.W.I.M.A.S. methodology. It is possible that a less effective or less seasoned educator might experience less success in implementing a similar approach. The educator teaches fifth grade science in a self-contained classroom. This means that he sees one class of students all day and that he teaches all subject areas. Implementing the same approach with a student load larger than one class (N=21) might be less effective. It is possible that the success of this class is in part due to the close trusting relationships between the educator and the learners within a self-contained classroom.

DIRECTIONS FOR FUTURE RESEARCH

Future research might expand the study to the implementation of the S.W.I.M.A.S. model by other elementary science teachers, by secondary science teachers, or by teachers of non-science disciplines. In debriefing with the educator and sharing all transcripts, data tables, and analysis, he shared an interest in conducting a more focused study on the authentic use of student journals during discourse and argumentation within the S.W.I.M.A.S. model.

SUMMARY

The study provided insight into the processes, practices, strategies, interactions, and artifacts observed within an elementary science student-driven inquiry classroom. The embedded quantitative survey data provided insight into student perceptions of different factors within the classroom learning environment and provided support for the emergent qualitative themes and categories. One emergent theme was the S.W.I.M.A.S. approach involves active ongoing engagement of the teacher and the students. Evidence of this engagement included field notes from classroom observations and artifacts of student work. The structures, processes, and practices employed within the SWIMAS model ensured engagement of all students. A second emergent theme was that student-driven inquiry benefits the teacher and the students. Student responses to survey questions and transcripts from the teacher interviews provided evidence that all became better scientific thinkers through the S.W.I.M.A.S. process.

YEARS 3-6 OF S.W.I.M.A.S. IMPLEMENTATION

Following the study conducted during the second year of development of the S.W.I.M.A.S. model, the teacher and science director continued to collect both quantitative and qualitative data to inform future iterations. Quantitative data, which included both teacher-developed formative assessments and the state level summative assessment, indicated that students in their first year as English Language Learners were not showing the gains achieved by native English speakers within the class. To address this concern, intentional use of vocabulary strategies was added to the S.W.I.M.A.S. model. One such strategy consists of the use of an interactive word wall where students not only post academic vocabulary, definitions, illustrations, and examples, but they also use yarn to connect vocabulary terms across the board. Along the yarn line, students post descriptors of how the connected terms are related. The intentional use of vocabulary strategies within the model resulted in improved performance among all students, including English Language Learners.

Another change that was made to the S.W.I.M.A.S. model was the development of a rubric to provide specific feedback to students about their application of science practices and where they might improve in the areas of questioning, observing, and making claims based on evidence. Classroom observations and teacher feedback indicate that the rubric has helped students continue to challenge themselves to become better scientists as they work to intentionally improve their use of the science practices.

The model was developed in Texas, a state that has not adopted the *NGSS* (NGSS Lead States, 2013) or the *Framework for K-12 Science* (NRC, 2012). As the teacher and science director have continued to learn about what is happening across the country within states that have adopted or adapted the *NGSS* (NGSS Lead States, 2013) and/or *Framework for K-12 Science* (NRC, 2012), they have discovered many parallels between the S.W.I.M.A.S. model and 3-Dimensional Learning. Some next steps include the use of the Matrix for Cross-Cutting Concepts (NGSS Lead States, 2013) as well as the EQuIP rubric for unit design (Achieve, 2018) to further align the SWIMAS model with the expectations of 3-Dimensional Learning.

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