Engaging Low-Income Latina/o Preschoolers in Science Inquiry through a Health-Based Curriculum

Walter Aminger
Nevada State University

Abstract

In recent years, there has been an effort to develop reform-oriented and inquiry-based early science instruction. Preliminary studies suggest that participation in inquiry-based learning activities promotes preschoolers' learning and interest in science. In addition, science education in early childhood is of great importance to many aspects of a child's development, and researchers suggest that science education should begin during the early years of schooling. The participants of this intervention were a total of 115 preschool students from six different public schools in a western, urban public-school district in California, USA. In this specific intervention analysis for one classroom only, a small sample of a total of 18 (4-5-year-old) Latino/multilingual preschool students (n =18; 9 boys and 9 girls) were exposed to an inquiry-based curriculum designed to teach them about health concepts in the context of science activities. The general goal of the study was to explore how different types of questions posed by an instructor related to children's biological conceptual understanding. The author hypothesized that children who responded to more teacher questions would exhibit higher levels of conceptual knowledge about health/biology concepts in a posttest interview. This intervention confirmed that students who engaged in question-asking and generated explanations during the lessons gained a deeper conceptual knowledge as evidenced by more sophisticated knowledge of cold/flu prevention concepts in the posttests. Thus, these preliminary findings demonstrated that this inquiry-based curriculum was effective at helping children understand the processes of contagion and illness. Finally, understanding how preschool students engage in science inquiry lessons could greatly benefit researchers, educators, and practitioners to maximize the students' conceptual knowledge about science.

Keywords: Multilingual learners, Science education, Reform-based instruction, Equity, Intervention

Introduction

In recent years, there has been an effort to develop reform-oriented and inquiry-based early science instruction. Examples of such programs include the Head Start on Science and Communication (Klein et al., 2000), and the ScienceStart! Program (French, 2004). Although research efforts to develop and deliver innovative preschool/kindergarten science curricula are in progress, several studies report science-specific learning outcomes from such projects. French (2004) has mentioned that while several reform-oriented science curricula promote teaching scientific inquiry in "developmentally appropriate" ways, the issue of what represents a developmentally appropriate curriculum is itself open to discussion (p. 144). She indicated that standard interpretations of developmental appropriateness may underestimate children's abilities for science learning. The intervention described in this study is part of the National Institutes of Health (NIH), a federally funded project to enhance science participation and engagement in public preschool classrooms. Throughout this intervention, science learning is seen as a process of domain-specific knowledge construction where children are considered active learners (Vygotsky, 1962).

Learning is a social activity, and inquiry skills contribute to meaning-making and the development of structured and coherent ideas (Chinn & Malhotra, 2002). The National Science Education Standards in the United States defined inquiry as asking students to generate questions and communicate their findings to others (National Research Council, 2001). Instructors implementing inquiry-based instruction are expected to engage children in meaningful back-and-forth exchanges that provide them with practice in question-asking and explanatory talk. Little is known about how this style of social interaction leads to different knowledge changes (Klein et al., 2000).

Preliminary studies have suggested that participation in inquiry-based learning activities promotes preschoolers' learning of and interest in science. They ask meaningful questions, make predictions about outcomes, observe and record evidence, display their knowledge, and communicate their findings (Samarapungavan et al., 2009). In addition, they enjoy science and feel confident engaging in scientific activities. Inquiry can be conceptualized as question-driven learning. It is a complex process which includes investigating a problem or phenomenon with initial questions, thinking of ways to answer them, looking for evidence, coming up with explanations, evaluating and communicating them, and going back to the original question, which could lead to several other questions. Carrying out scientific inquiry requires not only the recall of background knowledge but also the use of critical thinking skills, which are only in their early stages of development in students of the middle grades (Flick, 2000).

Increasing the motivation of students to learn science is a significant objective of the National Science Education Standards (National Research Council, 2007). These standards emphasize inquiry-based instruction as integral to promoting motivation as well as understanding. However, the overwhelming majority of inquiry-based science curricula have been developed for children in the upper elementary grades and beyond. Research about the effects of early science inquiry-based programs is sparse, and outcome measures have been limited to broad assessment data, such as tests of vocabulary and pre-/post-intervention improvements in science knowledge (Klein et al., 2000 p.144).

Early Childhood

Participation in early learning experiences has been identified as one factor that promotes academic success for vulnerable children (National Research Council, 2001). Many states' readiness standards now highlight preschool science as a key domain in the preparation of young children for the transition into formal schooling. The National Science Education Standards in the United States highlight an important aspect of inquiry-based instruction. Inquiry-based instruction emphasizes the active participation of students in generating their own questions, investigating these questions, and communicating their findings. This pedagogical approach encourages critical thinking and deepens understanding through engagement in meaningful social exchanges.

Young children need multiple and varied opportunities to engage in science exploration and discovery. They develop science understanding best when given multiple opportunities to engage in science exploration and experiences through inquiry-based approaches (Bosse et al., 2009). The range of experiences gives children the basis for seeing patterns, forming theories, considering alternate explanations, and building knowledge. This helps young children develop science skills and knowledge over time.

The National Science Teachers Association (NSTA) affirms that learning science and engineering practices in the early years can foster children's curiosity about and enjoyment of exploring the world around them. These experiences also lay the foundation for a progression of science learning in K–12 education and throughout their entire lives. Current research has indicated that young children have the capacity to construct conceptual learning and the ability to use the practices of reasoning and inquiry (National Research Council, 2007). Research has also suggested that children's attitudes toward science concepts and learning science are essentially shaped during the early years of their education. Attitudes toward science become hard to change as children approach adolescence (Archer et al., 2010). The US Department of Education (2011) and the President's 2011 agenda emphasized the fact that children from low-income and minority families perform at lower levels in language, science, technology, engineering, and math (STEM) subjects.

In addition, science education in early childhood is important in many aspects of a child's development, and researchers have suggested that science education should begin during the early years of schooling (Eshach & Fried, 2005; Watters et al., 2001). Engaging science experiences allow for the development of scientific thinking (Ravanis & Bagakis, 1998). Supporting children as they develop scientific thinking during their early childhood can lead children to easily transfer their thinking skills to other academic domains that may support their academic achievement and their sense of self-efficacy (Kuhn & Pearsall, 2000).

Children can begin learning inquiry process skills at a very early age. As they grow, they expand the variety of skills used to investigate. Preschoolers develop their inquiry skills by observing, doing (hands-on activities), and questioning. Previous research has demonstrated that students who are more motivated tend to engage in learning tasks more actively on behavioral, emotional, and cognitive levels and devote greater concentration to and become more enthusiastic about their learning (Fredricks et al., 2004; Jablon & Wilkinson, 2006). The idea is to start children on a journey from curiosity to inquiry by promoting their own curiosity. Steps of the scientific inquiry process for an early childhood classroom have been specified as follows:

1. Engage in topics and questions that are interesting and relevant to students' lives.
2. Investigate the concepts through different means of hands-on experiments and observations.
3. Discover patterns and relationships, and collect data to share findings.
4. Review the findings and transition to a new topic (Blake, 2009; Gelman & Brenneman, 2004).

Beginning inquiry-based science instruction in the early grades is sometimes suggested as a way to prevent the issue of children growing to view science as more difficult and less enjoyable to learn than other subjects. Early academic experiences promote the development of children's self-beliefs in various areas. In addition, it may be that for young children, extended and meaningful opportunities to engage in science in the classroom promote both the liking of science as well as the perception of competence in question (Wigfield & Karpathian, 1991).

Preschool Science

Children have the capacity to engage in scientific practices and develop understanding at a conceptual level. Current research in developmental psychology and cognitive science suggests that young children possess the capacity for conceptual learning and can engage in reasoning and inquiry as they explore and make sense of the world around them. (National Research Council, 2007). For example, when children play with blocks, water, and sand, they share some science-relevant characteristics. Young children can also learn to organize and communicate what they learn and know the difference between concrete and abstract ideas (Carey, 1985). Adults who engage children in science inquiry through the process of asking questions, investigating, and constructing explanations can provide appropriate environments that benefit from what children do as part of their everyday lives before starting formal schooling (National Research Council, 2007).

Howitt et al. (2011) investigated a case study in which a pre-service teacher implemented forensic science as a form of scientific inquiry in a preschool classroom. The pre-service teacher\provided opportunities to engage young children in knowledge building and inquiry-based learning through a series of integrated and engaging experiences. Samarapungavan et al. (2008) reported that children were able to successfully engage in science inquiry practices (questions, predictions, observations, sharing ideas, etc.) and conduct investigations to develop their biological knowledge. In addition, Peterson and French (2008) indicated that teachers using an inquiry science approach provided important sources of support for children's development of explanatory science discourse. Their study found that children could successfully engage in scientific explanation and inquiry as conversational partners to promote interest and engagement. Thus, they showed that learning to explain is important in developing children's discourse skills.

At a different level, however, significant evidence has suggested that children are able to track the nature of causal and relational patterns in the biological world. Considering the case of digestion, although young children do not understand the physiology of digestion in detail, they do seem to figure out early on that food is transformed in some way that gives organisms the ability to grow and to move (Inagaki & Hatano, 2006). They understand that an organism will physically die if it cannot ingest food, they know that the transformation of food is essential, and they know that only plants and animals transform food and need to digest it (Toyama, 2000). It therefore seems that preschoolers do have a sense of some of the characteristic processes that are essential to digestion.

Issues remain regarding the degree to which children are thinking about living things as a distinct and unique group. Additionally, children in other cultures may not be influenced by psychological similarity in the same way that North American children are when making decisions about biological properties (Atran, 2002). For example, if preschoolers carrying out a task are given a brief talk suggesting that they should focus on internal processes rather than social factors, they will make predictions that are based on biological as opposed to psychological evidence (Gutheil et al., 1998). Moreover, when children are asked to clearly reject or accept whether functional characteristics can be made about nonliving natural things, such as rocks, preschoolers tend to give a purposeful characteristic (Kelemen, 1999).

In terms of curriculum design and its implementation, several interventions were found in the literature addressing inquiry-based instruction. Samarapungavan et al. (2008) examined United States kindergarten (no age given) children's science learning of the butterfly life cycle using a guided inquiry approach where teachers selected an appropriate context and learning experiences to allow young children to create meaningful new knowledge. Howitt et al. (2011) investigated how to actively engage students in learning by encouraging curiosity and excitement of discovery and developing knowledge and understanding of scientific ideas. Peterson and French (2008) observed the development of preschool children's explanatory language through science inquiry in a five-week unit on color mixing. They also attempted to measure whether children increased their explanatory skills during the intervention. Kermani and Aldemir (2015) studied whether content-specific math and science curriculum activities (informally and via direct instruction) enhanced pre-K children's learning of math and science skills and concepts.

As mentioned previously, early childhood science learning is extremely important with the assistance of a more experienced and skilled adult support. Samarapungavan et al. (2008) suggested that teachers need to provide appropriate instructional support since children usually lack experiences with science as a discipline and have limited cognitive skills. Peterson and French (2008) showed that preschoolers could think and talk in complex and abstract ways when there is enough guidance and support from an experienced adult. Howitt et al. (2011) emphasized how capable and active young children are to learn from observation and participation with peers and teachers and to develop new skills and knowledge. Kermani and Aldemir (2015) reported their study that was designed to facilitate and support the learning of science and math in pre-kindergarten children from socio-economically disadvantaged backgrounds.

Teachers' Questions

Questioning is a significant part of teaching and science talk. As Tsui et al. (2004) have pointed out, questions posed at critical points of a lesson can focus students' attention on the important learning aspects and lead to further inquiry and learning. Meaningful learning and scientific inquiry cannot occur without questioning. The construction of a good question is a creative process and is what doing science is all about. Moreover, students' questions play an important role in the learning process as they are a potential resource for both teaching and learning science.

Teachers' questions in the inquiry-based classroom not only explore and make student thinking explicit in the class but also serve to guide and scaffold it. Several studies analyzing teachers' questions and their types have been reported; however, the need for a more detailed analysis has been addressed, especially in the inquiry-based setting (Chin, 2007). Young children develop science skills and learning by engaging in experiential learning. Mostly, they engage in science activities when an adult intentionally sets up the environment to allow children to fully engage with tools. The activities enable children to question, explore, investigate, make meaning, construct explanations, and organize knowledge by using materials.

Wells (1986), for example, has mentioned ways in which teachers may provide feedback by encouraging students to expose ideas and generate and test hypotheses. Thus, science discourse can be effective if teachers can scaffold students' knowledge through further supportive discourse (Bruner & Austin, 1986). By posing thought-provoking questions tailored to the students' current understanding, teachers guide them to explore concepts further, make connections, and develop new ideas. This approach aligns with strategies that promote active learning and critical thinking. Children's answers to their teacher's questions promote further questions and additional discussion. Scott et al. (2006) described an interactive/dialogic talk in which the teacher engages the children in a series of questions, but these questions also provide an opportunity for children to express their ideas. In addition, the teacher does not make a critical assessment of these ideas as right or wrong but rather allows the discourse to continue. When using this interactive/dialogic style, the teacher assesses their children's existing understanding of the topic of the lesson and can use this information to modify the topic of the lecture.

Another typical characteristic seen in the teacher-student interaction was that the teachers regularly repeated students' answers following their questions. This situation, called "revoicing" by Chapin et al. (2003, p. 1), helped make students' ideas accessible to all in the class (Edwards & Mercer, 1987). Moreover, it may also allow students, mostly those with weak language abilities and those who may have problems expressing their opinions, the chance to co-construct a response with their teacher and classmates. As a result, the teacher provides not only conceptual but also linguistic scaffolding, balancing both the cognitive and linguistic demands of students. Chin (2007) found that when the feedback was not just evaluative but also supportive, it promoted additional questioning that stimulated deeper thinking beyond simple memorization and engaged students in more cognitively demanding tasks.

Social Constructivist Theoretical Framework

The intervention described highlights the role of federally funded initiatives, such as those by the National Institutes of Health (NIH), in improving educational opportunities. This approach to science learning aligns with constructivist theories of education, where children are viewed as active participants in their own learning. (Vygotsky, 1962). One implication of this conceptual development view is that instruction should aim to support students' understanding of the core ideas and ways of thinking that are essential to a conceptual area (Smith et al., 2006).

In addition, this intervention views science learning as socially involved and based on specific cultural practices and domains (Driver et al., 1994; Rogoff, 1990). Moreover, in regard to science instruction, research indicates that scientific knowledge and practice are related to and influenced by specific sociohistorical contexts (Çalik & Ayas, 2005). According to recent studies (Thagard, 2004), inquiry-based science instruction should help students implement three associated areas of science learning: (a) cognitive, which includes the concepts of science and processes of scientific understanding, (b) epistemic, which includes frameworks for measuring scientific gain, and (c) social, which includes an understanding of sociocultural practices that show how scientific knowledge is established.

Children gain important ideas through active involvement with the environment. As they discover their surroundings, they build their own knowledge (Charlesworth & Lind, 1995). The main view of the constructivist approach is to consider individual children as intellectual explorers, discovering and building their own knowledge. Thus, teaching for conceptual change/understanding demands different approaches from those found in many traditional settings. In this context, instead of remembering science facts, children are motivated to use the inquiry method.

Although there are several forms of constructivism, all of the instructional approaches of constructivism consider children as important mediators in their personal new knowledge building (Gunstone, 2000). In addition, these instructional applications focus on promoting active learning and engaging on hands-on events with small groups and productive discussions. A common belief is that learners are expected to develop an understanding of science content in this kind of inquiry-based learning setting (Trundle et al., 2010). Children are likely to be active mediators in the learning tasks, which reinforces children's ideas of ownership in their work and increases their motivation. With this approach, children usually work in small groups, which promotes their teamwork skills and provides opportunities to scaffold their understandings. Important science activities, which are related to children's daily events, enable children to establish connections between prior knowledge and current learning.

Theoretical Framework

Questioning is an integral part of effective learning and scientific inquiry, as well as teaching and science talk. A "questioning-based discourse" framework was created for the analysis of classroom discourse in science, with a focus on questioning-based practices. This framework has been used to examine ways in which teachers use questions to shape and lead classroom discourse. The idea of teachers assisting student performance through the "zone of proximal development" also indicates that teachers can lead the discourse to support student learning, which may be considered a form of scaffolding (Bruner & Austin, 1986, p. 72).

Different than teacher questioning in traditional lectures, where the goal is to assess what students know, the purpose of questioning in constructivist-based or inquiry-based lessons is different. In these lessons, the teacher's objective is to promote what students think, to encourage them to develop their ideas, and to help students build their conceptual knowledge. Thus, questioning is used to recognize students' ideas and to scaffold their thinking (Chin, 2007).

As mentioned before, the constructivist-based approach focuses on the importance of the teacher's role in directing students toward conceptual understanding through "the zone of proximal development" and of using talk for shared knowledge. This current study and analysis are supported by a cultural perspective in which discourse has three central roles: as a cognitive tool, which children learn to use to build knowledge; as a social or cultural tool for sharing knowledge; and as a pedagogic tool to provide intellectual assistance (Mercer & Wegerif, 1999). In the context of how students develop new understandings in science classrooms, the Vygotskian viewpoint identifies the importance of teacher–student discourse in the classroom. Moreover, the teacher has an important role to perform in helping and transferring existing common knowledge to students.

Considering a social-cognitive viewpoint, question generation is a productive process and an important factor for student discourse in "talking science" (Lemke, 1990). Moreover, questions can promote discussion about different topics, encourage students to consider different views of a topic, and stimulate the process of argumentation and critical thinking in science. As a result, it is critical to help students with reasoning, hypothesis development, explanations, and evidence argumentation.

Methods

Participants

The participants of this intervention were a total of 115 preschool students from six different public schools in a western, urban public school district in California, United States. Treatment groups in different schools were chosen to implement the new germ curriculum, and control groups were selected for standard comparison (received regular science curriculum). All schools selected for the program served relatively high numbers of students living in poverty (low-income), generally performing below the state average on the state's academic achievement test and had a very high concentration of Latino/Multilingual Learners (ML). Also, a large percentage of all students who participated in our study received a free or reduced-cost lunch. In addition, in terms of gender composition, there were similar percentage rates for both boys and girls in the total student population.

In this specific intervention analysis for one classroom only, a small sample of a total of 18 (4-5-year-old) Latino/multilingual preschool students (*n* =18; 9 boys and 9 girls) were exposed to an inquiry-based curriculum designed to teach them about health concepts in the context of science activities. The science classroom provided an explanatory discourse community to examine how the development of inquiry skills was associated with their conceptual understanding of cold/flu prevention. A total of 115 students from 6 California state-funded preschool classrooms were exposed to an inquiry-based science curriculum intervention.

Procedures

This inquiry-based curriculum was implemented across 8 different lessons which were taught on a weekly basis at a different school each time. These Science Lessons were designed to provide children with an understanding of the inquiry-based germ biology curriculum, allowing students to organize health facts related to illness prevention as the general goal. The intervention consisted of the implementation of an overview of the "Think Biology" preschool curriculum designed to provide children with a conceptual understanding of germ contagion and contamination.

Every weekly lesson followed the same procedure: the students were first engaged in a large group activity/lesson for about 15 minutes, followed by a small group activity. This small group activity was designed to complement and reinforce the material introduced previously in the large group activity. Usually, the small group activity consisted of at least 3 different groups of students. During the small activity, the students were gathered in different groups based on their native language (English or Spanish) and their language proficiency. Therefore, during each lesson, there were a minimum of 3 groups: English native speakers (high proficiency), ML (multilingual Learners - low to medium English proficiency), and mixed group (consisted of English native speakers and ML with very high proficiency in English).

The eight lesson plans were carefully designed to promote active participation within students and among teachers and students. In addition, lesson plans were developed with the intention of increasing students' conceptual knowledge of germ biology and effective health habits. The first five lessons were created to cover the biological concepts of germ biology, including: characteristics of living organisms (be able to reproduce "make babies", food and water requirements, place to live, and be able to die), germ transfer, germ prevention, and general overview. The last 3 lessons in this inquiry-based curriculum were designed to cover topics related to food spoilage and included recent topics previously taught on germ biology. In order to support high levels of engagement and participation, as well as great interest from the students, all lessons were crafted to included tools and artifacts (visual aids, scientific tools, video clips, and songs, colorful books, etc.) to create a classroom environment suitable for active inquiry-based learning. The following section represents a brief summary of each of the eight lessons (also seen in Table 1), including the general lesson plans and tools/artifacts used:

Lesson 1: Living vs. Non-Living Things - Students were introduced to the concepts of living things (organism "germ") and non-living things. Students were able to compare and contrast these two ideas based on some important characteristics/behaviors that make something a living thing (organism) such as: the need of food and water, ability to reproduce "make babies", probability of dying, and a place to live requirement. *Materials*: Song, book, and pictures.

Lesson 2: Germ Environments - Students were able to define and understand what germs are in the natural environment. *Materials*: Pictures, Glo germ kit, microscopes, video clips, and laptops.

Lesson 3: Germ transfer (how germs spread) *Materials*: Song, book, spray bottle, pictures, tissue box, and glue.

Lesson 4: Preventive behaviors (hand washing, sneezing, coughing) *Materials*: Song, book, tissue box, crayons.

Lesson 5: Review of germ properties and topics in lessons 3 and 4. *Materials*: Song, book, crayon.

Lesson 6: Germ transfer and prevention - Students were able to understand that germs are everywhere, germs can get on your food, different ways that germs are transferred to food (e.g., dirty hands, exposure, etc.), or to prevent getting germs on food, and once something is contaminated, it should not be consumed.

Lesson 7: Food storage and food spoilage - Students were able to understand how germs can make babies on our food, germs do not make babies in very cold places, germs can make babies when left in warm places, and something that does not look dirty may still have germs.

Lesson 8: Safe and unsafe food - Students were able to understand that germs do not make babies in very cold places, and germs can make babies when left in warm places.

Table 1

Overview of the Eight Lessons Content Implemented During the Intervention

Lesson topic	Curriculum implemented

1. Living and non-living things	Attributes associated with living things, including movement, eating, making babies, and dying. Habitats are linked to these behaviors.
2. What are germs?	Germs are tiny, invisible living things. Microscopes, a UV-light activity, and a video depicting bacteria growth demonstrate this principle
3. Germ environments and germ transfer	Germs can be found everywhere, including bodily fluids. Germ transmission via cold symptoms such as sneezing and coughing are taught and illustrated with a spray bottle.
4. Preventative behaviors	Behaviors that reduce the risk of getting sick. The importance of hand washing is discussed with an emphasis on the causal mechanisms underlying germ transmission.
5. Germ review	An overview of the previous lessons, reviewing the key scientific knowledge components of the curriculum.
6. Germ transfer and prevention	Discuss various ways germs can get onto food. Once something is contaminated, it should not be consumed.
7. Food storage and spoilage	Germs in our food can reproduce. To slow the reproduction of germs in food, we store it in very cold places.
8. Safe and unsafe food	Determine which foods are safe and unsafe to consume based on how food was stored.

Each one of the eight lessons was videotaped for further analyses on students' classroom participation and engagement. Overall, lessons were videotaped to capture the various interaction behavior styles as children engaged in these lessons. The videotapes were used to study in which way classroom participation over a series of lessons was associated with individual children's ultimate conceptual understanding of the curriculum concepts. In order to assess and measure student's participation and engagement, the lessons were coded by measuring the number of questions individual children asked, the number of explanations offered by individual children (why, how, what), the number of spontaneous comments, factual responses, reasoning situations, outcomes (hypothesis and forecast), gesture instance, topic expansions, and the accuracy and relevance of their responses (Table 3). The type of question asked by the teacher was also coded for since it might have elicited a specific type of participatory behavior expressed by the students. As a result, coding of videotaped science lessons has allowed us the opportunity to capture various interaction styles as the children were engaged in the lessons.

After all the lessons were videotaped and the inquiry-based germ curriculum implemented for each class, the perspective preschoolers were interviewed before and after the program to assess gains in conceptual of various concepts regarding the germ biology curriculum. Therefore, students' ultimate conceptual knowledge of health and germs was measured by pre- and post-test interviews. Thus, by quantifying the children's classroom interaction skills and correlating these scores with their conceptual knowledge scores, we are in a position to obtain a better understanding of the effectiveness of inquiry-based instructional methods. Therefore, three key questions were randomly selected for this analysis of conceptual understanding. The following three questions were chosen: "Why did Daisy feel tired?", "How did Melissa/Fernando get sick?", and "What helped Daisy get better?"

Overall, the students' responses for each class were coded and assigned a rating according to the level of complexity, ranging from 0 being the lowest level to 3 being the most complex (0 = children stated that they did not know, 1 = children explained that the girl was tired because she was sick or sneezing, 2 = children invoked germs as a reason why Daisy felt tired, and 3 = children attributed feeling tired to germ biology). Finally, the children's classroom interaction skills were quantified and correlated with their conceptual knowledge scores to obtain a better understanding of the effectiveness of inquiry-based instructional methods (Table 6). Based on recent studies, the author hypothesized that children who were more skilled at asking questions and generating explanations in the classroom would develop deeper conceptual knowledge about the concepts.

The general goal of the study was to explore how different types of questions posed by an instructor related to children's biological conceptual understanding. The author hypothesized that children who responded to more teacher questions would exhibit higher levels of conceptual knowledge about health/biology concepts in a posttest interview. This study also explored whether the types of questions that children responded to also mattered. The author expected that the number of high- level cognitive questions such as explanatory questions would have a greater impact on student's conceptual understanding than lower-level cognitive questions such as factual recall. The following four sets of questions guided this research: (1) What types of questions and answers did the teacher use to encourage the growth of children's conceptual understanding? (2) What additional types of spontaneous comments/gestures did the children make? (3) What were the correlations among the question-answer responses and spontaneous comments/gestures? (4) How were characteristics of question-answer responses and spontaneous comments/gestures associated with children's conceptual understanding?

Findings

1st and 2nd Research Questions - *What types of questions did the teacher use to encourage the growth of children's conceptual understanding? (table 2) What types of spontaneous comments/gestures did the children make? (table 3)*

According to the previous procedure followed in this intervention, we measured the different types of interactive behaviors that the preschoolers displayed during the lessons. A summary of the results of these different types of engagement can be found in Tables 2 and 3.

Table 2

Types of Questions and Examples Used by the Teachers

Teacher questions	Definition	Question-response examples
Facts	Asking for factual information (e.g., attributes; definitions)	a. Do you remember what germs are? Little things. b. Where do germs like to live? Inside the mouth.
Explanation of why or how	Explanation of how or why a phenomenon occurs or will occur	a. What does Anna need to do to get better? She needs to stay in bed and get rest. b. How do germs die? When you wash your hands. c. Why can't we see the germs? They are invisible. d. Why do you think she's going to get sick? Because he coughed on her.
Explanation of what	Explanation of an event, process, or phenomenon that occurred	a. What did the germs do inside her body? They got her sick. b. What happened to the water? It got germs.
Hypotheses	Explanation of what would occur in each situation	a. What happens if you put our thumb in your mouth? You can get sick. b. If you wash your hands, would the germs go away? Yes.

Prediction	Predict or forecast an outcome	a. What's going to happen to the germs on her hands? They will go to the ball. b. Where will the germs go? On the fruit salad.
Reasoning	Asking for logical thinking; reasoning	a. Is it okay for Ana to eat the food? No, it has germs. b. Before they make their fruit salad what should they do? Wash their hands.

Table 2 describes the various types of questions used by the teachers to encourage the growth of children's conceptual understanding. Preschoolers were asked open-ended questions to explain their understanding of the concepts (which were usually presented in the form of scenarios accompanied by pictures). Each time a student responded to a question, the response was noted and was classified by question type. The number of times that the students responded to a given question type was summed.

Table 3

Types of Spontaneous Comments and Gestures Displayed by the Children in the Classroom

Spontaneous Comments/Gestures	Definition	Examples
Adding a new topic	Spontaneous comments introducing a new topic or idea	a. When you take a bath, the germs fall off your body
Building on a topic	Spontaneous comments that build on the topic being discussed	b. Sometimes they (germs) make babies in your dogs and cats Where do the germs go when I touch the sandwich? (Child 1) "On your hands." (Child 2) "The germs make babies when they are on your hands.")
Gestures	Hand movements (accompanying speech or without)	(e.g., spontaneous hand washing motions, baby rocking motions)

Table 3 summarizes the different types of spontaneous comments and gestures displayed by the children in the classroom. In order to assess and measure student's participation and engagement, the lessons were coded by measuring the number of questions individual children asked, the number of explanations offered by individual children (why, how, what), the number of spontaneous comments, factual responses, reasoning situations, outcomes (hypothesis and forecast), gesture instance, topic expansions, and the accuracy and relevance of their responses.

Table 4

Summary and Average of Different Types of Interactive Behavior

Type of interactive behavior	*M*	*SD*
Fact/Information	3.70	3.40
Explanation of-why-how	2.70	3.00
Expansion on topic	1.70	2.50
Addition of new topic	1.30	1.90
Hypothesis/Prediction	1.30	1.80
Reasoning	1.20	1.80
Explanation of what occurred	.70	1.10
Gesture	.40	.90

As shown in Table 4, the most common type of interactive behavior was Factual Response (*M* = 3.70; *SD* = 3.40), followed by Explanation of why/how (*M* = 2.70; *SD* = 3.00), Expansion (*M* = 1.70; *SD* = 2.50), Spontaneous Comment (*M* = 1.30; *SD* = 1.90), Prediction (*M* = 1.30; *SD* = 1.80), Reasoning (*M* = 1.20; *SD* = 1.80), Explanation of what (*M* = .70; *SD* = 1.10), and Gesture (*M* = .40; *SD* = .90). As a result, when controlling for age and gender, most of the participatory interactions were concise, short phrases given by the students during lessons. Moreover, we can conclude that Factual responses were significantly ($\alpha = .05$) more common than all other types of behaviors, followed by why and how explanations and spontaneous comments building on the topic. Finally, the average for the total number of interactive behaviors for this class was 16.31, which gives an average of approximately 1 interactive behavior per student.

3rd Research Question – *What were the correlations among the question-answer responses and spontaneous comments/gestures (table 5)?*

After quantifying and averaging the number of different interactive behaviors, we measured and analyzed how the interactive behaviors were associated with one another. A summary of the result of these different interactive associations can be found in Table 5.

As shown in Table 5, there was a significant strong correlation between Factual Response and Explanation of why/how (r =.77; p < .01) and Prediction (r = .73; p < .01). In addition, there was a significant moderate association between Factual Response and Reasoning (r = .48; p<.05). Since the correlation coefficients for these associations are positive, they indicated that children who displayed more concise phrases for interactive behaviors, also tended to use explanation reasoning more often as a way to engage in the inquiry-based germ curriculum during lessons. In summary, children who responded to more factual questions gave more why/how explanations, responded to more hypothetical/prediction question, and engaged in more reasoning.

Table 5 also presented other important findings. There was a significant moderate correlation between Explanation of why/how and Prediction (r= .57; p<.05), Reasoning (r= 54; p<.05), and Explanation of what occurred (r= .52; p<.05). Since the correlation coefficients for these associations are also positive, it indicated that preschoolers who gave more why and how explanations, also gave more explanations about something that occurred, responded to more hypothetical/prediction questions, and engaged in more reasoning situations as a way to engage in the inquiry-based germ curriculum during lessons. Other key findings can be found in Table 5. There was a significant strong correlation between Topic Expansion and Spontaneous Comment (r= .86; p<.01), and Expansion was also significantly moderately correlated to Explanation of what occurred (r= .49; p<.05). These positive correlation coefficients indicated that children who build/expand more on a topic, also gave more explanations about something that occurred and spontaneously introduced new topics. Lastly, Table 5 provided with other important results. There was a significant moderate correlation between Gesture and Explanation of why/how (r= .60; p<.01), and Gesture was also significantly correlated to Expansion (r= .56; p<.05). As a result, we can conclude that preschoolers who gestured more, also gave more explanations about why and how something occurred and expanded more on a topic as a way to participate in the inquiry-based germ curriculum during lessons. However, no significant differences were found among girls and boys, and 4 and 5-year-old.

Table 5

Association Among Different Types of Children's Interactive Behaviors

Types of behavior – teacher questions	Factual	Explain-why-how	Explain-what	Hypothesize	Reason	Add new topic	Build on topic
Factual							
Explain-why-how	.77**						
Explain-what-occurred	.26	.52*					
Hypothesize-Predict	.73**	.57*	.45				
Reason/form judgment	.48*	.54*	.12	.39			
Add new topic	.39	.30	.37	.21	.11		
Build on topic	.39	.36	.49*	.26	.20	.86**	
Gestures	.28	.60**	.42	-.09	.03	.40	.56*

* $p < .05$. ** $p < .01$. *** $p < .001$

4th Research Question – *How were characteristics of question-answer responses and spontaneous comments/gestures associated with children's conceptual understanding?*

Three key questions were randomly selected for the analysis of children's conceptual understanding: "Why did Daisy feel tired?", "How did Melissa/Fernando get sick?", and "What helped Daisy get better?"

1st posttest question - How did Melissa get sick?. For example, as seen in Table 6, the students' responses to "How did Melissa get sick?" for each class were coded and assigned a rating according to the level of complexity, ranging from 0 being the lowest level to 3 being the most complex ($M = 2.6$, $SD = 1.3$).

Table 6

Students' Explanations Coded from Simple to Complex (0–5) for Post-Test Question: How Did Melissa Get Sick?

Score	Response Definition	Examples
0	Child does not know	
1	Well-known transmission behavior	"Because the boy sneezed when she was walking with him."
2	Novel transmission behavior curriculum	"Because she put her finger in her mouth."
3	Both transmission behaviors	"Because the boy sneezed in her face and she put her finger in her mouth."
4	Transmission process	"Because she was holding his hand and he sneezed on her hands and she put her hand in her mouth"
5	Transmission behavior/process that mentions bodily fluids	"Because she put her finger in her mouth and it had germs from the saliva of the boy"

As shown in Table 7, children's classroom interaction skills were quantified and correlated with their conceptual knowledge scores to obtain a better understanding of the effectiveness of inquiry-based instructional methods. These results indicated that children who gave more complex explanations in the posttest interviews, also gave more why or how explanations, gave more explanations about something that occurred, responded to marginally more hypothesize/predictions, and engaged in more gesturing.

Table 7

Association Between Interaction Behaviors and Explanation Complexity

Types of questions	Explanation complexity
Factual	.02
Explain-why-how	.54*
Explain- what occurred	.54*
Hypothesize/Predict	.40
Reasoning/Form judgment	.08
Student-initiated	**Explanation complexity**
Add a topic	.10
Build on topic	.37
Gestures	.49*

* p <.05. ** p <.01. *** p <.001

2nd and 3rd posttest questions - Why did Daisy feel so tired? Why did Daisy feel better? Table 8 represents the effect sizes of the average complexity scores between biological and non-biological groups of children/students in regard to these two posttest questions: "Why did Daisy feel tired?" and "Why did Daisy feel better?". More specifically, 57% (n = 10) of the children reported that Daisy felt tired because the germs were making babies; Daisy felt better because the germs died; or both. These results also indicated that children who provided more "why," "how," and "what" explanations, as well as engaged in spontaneous gestures, demonstrated a deeper understanding of illness transmission and more biological knowledge about germs. Moreover, preschoolers who made spontaneous comments that built on the existing topic or introduce a new topic displayed more biological knowledge about germs.

Table 8

Effect Sizes of the Average Complexity Scores Between Biological and Non-Biological Groups of Children/Students

Types of questions	Biological (*n* =10)	Nonbiological or IDK (*n* = 8)	Effect size (Cohen's *d*)
Factual	3.60 (3.10)	3.90 (4.10)	.10
Explain-why-how	3.20 (3.40)	2.40 (2.60)	.80
Explain-what-occurred	1.00 (1.30)	.30 (.50)	.70
Hypothesize/Predict	1.60 (1.90)	1.10 (1.80)	.00
Reason/ form judgement	1.80 (2.40)	.60 (1.00)	.40
Add a topic	2.30 (2.20)	.30 (.50)	1.30
Build on topic	2.80 (3.10)	.80 (.90)	.90
Gestures	.70 (1.10)	.30 (.50)	.50

In terms of assessing gains of various concepts regarding the germ biology curriculum, the results of the post-test interviews (three questions analyzed) indicated an effect on students' ultimate conceptual knowledge of health and germs. Overall, in regard to the results of the post-test interview questions, children who displayed more engaging behaviors during the lessons overall exhibited a deeper conceptual understanding of the inquiry-based biology curriculum. In addition, students who engaged in question-asking and generated explanations during the lessons gained a deeper conceptual knowledge as evidenced by more sophisticated knowledge of cold/flu prevention concepts in the posttests.

Discussion

National policy documents including the National Science Education Standards (National Research Council, 2001) highlight the importance of inquiry-based activities to promote effective and interactive science learning. Many researchers have suggested the implementation of more authentic inquiry-based instruction to foster science learning (Singer et al., 2000). Positive attitudes toward science, feeling curious to learn science, and perceiving science as interesting are all factors that predict scientific engagement and achievement, especially at an early age where oral expression can be challenging (National Research Council, 2007).

This intervention confirmed that students who engaged in question-asking and generated explanations during the lessons gained a deeper conceptual knowledge as evidenced by more sophisticated knowledge of cold/flu prevention concepts in the posttests. In addition, by quantifying the children's classroom interaction skills and correlating these scores with their conceptual knowledge scores, researchers should be able to obtain a better understanding of the effectiveness of inquiry-based instructional methods. As a result, science instruction that engages children in inquiry skills has the potential to foster deeper levels of understanding of concepts.

Finally, understanding how preschool students engage in science inquiry lessons could greatly benefit researchers, educators, and practitioners to maximize the students' conceptual knowledge about science.

Limitations

In terms of limitations for this intervention program, one could argue for the lack of complexity and depth when assessing gains in conceptual knowledge regarding the germ biology curriculum. The random selection of just three post-test interview questions for analyses might not be sufficient to predict and accurately quantify the students' ultimate conceptual knowledge of health and germs. In addition, the analyzed low sample size (n=16 for one class) taken from a larger student population might have been a factor that could have contributed to the lack of significance of some of the results found, especially when considering the correlation coefficients.

Future Research and Implications

Another important area of research for future studies would be to analyze which lesson(s) was(were) more effective in terms of promoting active engagement/participation and eliciting a more complex and deeper conceptual understanding of the inquiry-based germ curriculum. This way, while implementing the intervention, researchers and educators will be able to make modifications to the lesson plans that were not very effective and redesign the curriculum. Thus, this potential analysis will have a great impact on pre-service teacher preparation in schools. More specifically, the implications on these programs will benefit educators and allow them to better support pre-service and current teachers to implement a more effective inquiry-based science curriculum in the classroom.

As discussed before as a possible source of limitation in this intervention, future analyses should consider using a greater number of post-test interview questions to address the students' conceptual knowledge gain after the curriculum implementation. A good and effective approach would be to choose more significant questions (pre-set number) or to select at least one exemplar question from each lesson. This way, one would cover the most important topics of the curriculum and an average/composite score for each student would be calculated accordingly.

Future research should focus on another important area of study regarding inquiry-based science curriculum and engaging participation. Ideally, there is a very strong reason to follow the developmental trajectory in individual children's classroom participatory behaviors across lessons to evaluate their ultimate understanding of the curriculum concepts. Therefore, a gradual growth in inquiry and explanatory skills over time across lessons should be expected. Moreover, one should investigate whether this potential increase in classroom interactive behaviors over time is associated with children's ultimate understanding of the curriculum concepts.

Conclusion

Overall, this study found some initial evidence supporting that different types of instructor-led questions were directly related to the depth of children's biological conceptual understanding. Precisely, questions that elicited children to explain curricular content were associated with children providing more complex biological-based responses during the intervention. This suggests that children's engagement in deeper lines of questioning during instruction were more equipped to provide more complex answers related to biological phenomenon. Thus, these preliminary findings demonstrated that this inquiry-based curriculum was effective at helping children understand the processes of contagion and illness. In summary, this inquiry-driven method of teaching may be a fruitful way to help children from low-income language minorities improve their scientific reasoning in early childhood settings.

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Author Biography

Dr. Walter Aminger is an assistant professor of Science Education at Nevada State University and has over 15 years of experience as a student and teacher of science/education and has taught K-12 sciences as well as undergraduate and graduate science education/pedagogy courses. Dr. Aminger enjoys working with pre-service k-12 teachers and supporting culturally and linguistically diverse learners. His interests include reform-based instruction in STEM education, especially in terms of equity, multilingual learners, and teacher preparation.