The Investigation of the Ways in Which Gender Stereotypes are Perpetuated Through Questioning and Assessment Strategies in Inquiry-Based Science Classrooms

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Abstract

The purpose of this study was to investigate the questioning strategies of preservice teachers whenteaching science as inquiry. The guiding questions for this research were: In what ways do the questioning strategies of preservice teachers differ for male and female elementary students when teaching science as inquiry and how is Bloom's Taxonomy evident within the questioning strategies of preservice teachers? Examination of the data indicated that participants asked a total of 4,158 questions to their elementary aged students. Of these questions, 974 (23%) were asked to boys, and 991 (24%) were asked to girls. The remaining questions (53%) were asked to the class as a whole, therefore no gender could be assigned to these questions. In relation to Bloom's Taxonomy, 74% of the questions were basic knowledge, 15% were secondary comprehension, 2% were application, 4% were analysis, 1% were synthesis, and 3% were evaluation.

Keywords: Gender, Inquiry, Science Education, Teacher Education

1. Introduction

Gender issues have long been a concern within science education (Sanders & Nelson, 2004). For example, "in 1992, a report on math and science education galvanized national attention. *How Schools Shortchange Girls* said girls took fewer advanced math and science classes than boys and received less attention from teachers in class, leading to poorer performance in those subjects" (Glazer, 2005, p. 448). Furthermore, "Altermatt, Jovano, & Perry (1998) found that teachers ask more questions of boys than of girls, 60.7% and 39.3%, respectively" (as cited in Jones & Dindia, 2004, p. 443)."Today, educators and researchers understand that most people learn best through personal experience and by connecting new information to what they already believe or know" (Hinrichsen, Jarrett, & Peixotto, 1999, p. 4). Hence, inquiry teaching and learning may be one way through which this gender issues may be addressed.

For an effective reform of elementary science education to take place in today's classrooms, teachers must "ask both girls and boys deeper follow-up [inquiry-based] questions" and that they are "calling on girls as often as on boys" (Sanders & Nelson, 2004, p. 77). As such, the purpose of this research was to investigate the ways in which gender stereotypes are perpetuated through the questioning and assessment strategies utilized by preservice teachers in inquiry-based science classrooms. Specifically, this research will analyze the questions that preservice teachers ask in relation to the classification levels of Blooms Taxonomy. The goal was to determine if male and female students are being provided with equal opportunities to use higher order thinking skills in science classrooms. As a result of this research, we will attempt to begin to expose the extent to which questioning plays a role in the science achievement abilities of male and female students. The guiding questions for this research included: In what ways do the questioning strategies of preservice teachers differ for males and females when teaching science as inquiry?In what ways do questioning strategies differ among grade levels?How is Bloom's Taxonomy evident within the questioning strategies of preservice teachers?

2. Theoretical Framework

2.1 Inquiry

Inquiry is not a new phenomenon in the area of science education. In fact, Schwab (1962) discussed inquiry as a way of teaching and learning science.

An inquiry-based approach to science "introduces students to the content of science, including the processes of investigation, in the context of the reasoning that gives science its dynamic character and provides" (Drayton and Falk, 2011, p. 25). As such, the learning that results is comprehensive and meaningful. An inquiry "approach emphasizes that science is the process of gaining knowledge (especially of the natural world), and that gaining knowledge is not the accumulation of facts but the development and enrichment of theories, explanations, and rigorous stories about how the world works" (Drayton and Falk, 2011, p. 26). Current reform efforts continue to stress the importance of inquiry based teaching and learning. The NRC, (2000) asserts that inquiry "builds on children' natural, human inquisitiveness" and "asks that we think about what we know, why we know, and how we have come to know" (p. 6).

Inquiry is a powerful way of learning that when implemented as a teaching tool, can take on many forms. For example, the amount of responsibility students assume may vary from self-directed to teacher directed. At the root of all of this however, "inquiry is intimately connected to scientific questions—students must inquire using what they already know and the inquiry process must add to their knowledge" (2000, p. 13). Regardless of the amount of guidance the teacher provides, inquiry is only present when all of the essential features of classroom inquiry are incorporated. These features as defined by the NRC include:

1. Learner engages in scientifically oriented questions
2. Learner give priority to evidence in responding to questions
3. Learner formulates explanations from evidence
4. Learner connects explanations to scientific knowledge
5. Learner communicates and justifies explanations (p. 29).

The National Science Education Standards (NSES) view scientific inquiry "as an integral component for restructuring science education" (Author, 2008). To clarify the importance of teaching and learning science through inquiry, the National Science Education Standards (NSES) and National Research Council (NRC) "stress that a distinguishing feature of reform science teaching is its focus on engaging students in active and extended scientific inquiry" (Shaw et al., 2009, p. 7). Proponents of reform in science education in America's elementary schools are assertive that there is substantial benefit of teachers varying the level of complexity of inquiry questions asked of students to challenge their cognitive thinking strategies. "Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (NRC, 1996, p. 23).

The standards define inquiry as:

> a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results (NRC, 1996, p. 23).

Experts have shown that the nature of human inquiry does not center on "learning environments that concentrate on conveying to students what scientists already know…" (NRC, 2000, p. 6). Rather, the goal is "to build student understanding of how we know what we know and what evidence supports what we know" (p.13). For elementary teachers teaching science through inquiry, it is critical not to "capitalize on experiences present in certain segments of the population" (Farenga & Joyce, 1997, p. 563). Instead, it is imperative that teachers effectively differentiate science instruction to ensure that the material being taught considers the experiences and educational strengths and weaknesses of both male and female students.

2.2 Gender

From birth, males and females are innately different in how they learn and what they learn (Spelke, 2005). For example, "male infants learn about objects and their mechanical relationships, whereas female infants learn about people, emotions, and personal relationships (as cited in Spelke, 2005, p. 950). Additionally, from a neurological standpoint, male students have a "more rapid rate of spatial thinking" while evidence supports that females have "finer motor skills" at the elementary school level (Anderson, 2009, p. 18). In response to these differences, teachers need to consider the different ways in which content at all levels of education should be presented for both genders and how learning for each gender may vary. "Even without blatant discrimination, girls may be treated differently than boys by science teachers (mostly males), who may interact differently with female students than they do with male students or who may not recognize that their teaching methods are not effectively reaching girls" (as cited in Mitchell & Hoff, 2006, p. 11 - 12).

In fact, Sadker & Sadker (1994) noted that boys receive more attention from teachers thereby dominating classroom discussion, which lead to higher achievement for boys. In addition, classroom climate is another important consideration. Teachers can create a negative classroom climate simply as a result of their "lack of knowledge or insensitivity to the different learning styles and needs of girls and boys" (as cited in Mitchell & Hoff, 2006, p. 11 - 12). Additionally, inadvertent behaviors can impact a classroom climate as well. For example, "not calling on girls when they raise their hands or praising males but not females" can lead the females to feel that their presence in the classroom and the contributions they can offer are not as welcome as their male counterparts (as cited in Mitchell & Hoff, 2006, p. 11 - 12). Teacher behavior, whether it is inadvertent or deliberate, can lead girls to believe that their scientific abilities and interests are less important than their male classmates. Some ways in which this can be perpetuated is through the: "grouping women in ways that indicate they have less ability or status; making seemingly helpful comments which imply girls are not as competent as boys; doubting girls work and accomplishments; expecting less of girls in the future; or calling males "men" and women "girls" (as cited in Mitchell & Hoff, 2006, p. 11 - 12).

Furthermore, the types of questions that are asked of girls are also often linked to gender differences in science. "For example, girls are often asked lower level factual questions which can be evaluated right or wrong and only permits specific instruction from the teacher. Whereas, boys are asked open-ended higher level questions which allows them to "display their talents," engage in critical thinking, and even guess at the answer (Sandler, et. al, 1996, p. 10). Because of the aforementioned biological, neurological and environmental factors, research has shown that "boys are more apt than girls to develop the knowledge and skills required by mathematics and science" (Spelke, 2005, p. 950). Hence, it is imperative that both males and females be provided with opportunities to take an interest in their science learning and demonstrate this interest and knowledge in rich, thoughtful ways that utilize each gender's strengths and require the use of higher-order thinking.

2.3 Blooms Taxonomy

One method for determining if male and female students are provided with equal opportunities in science is through measuring the effectiveness of questioning strategies in relation to Blooms Taxonomy. Bloom's Taxonomy has had widespread acceptance and is a classification of hierarchal learning categories that include six categories:

- Basic Knowledge—identification and recall of information
- Secondary Comprehension—organization and selection of facts and ideas
- Application—use of facts, rules, principles
- Analysis—separation of a whole into its component parts
- Synthesis—combination of ideas to form a new whole
- Evaluation—development of opinions, judgments, decisions (Edwards & Bowman, 1996, p. 9-10)

These categories are divided according to the cognitive skills students use in the classroom whereby "the first two categories, basic knowledge and secondary comprehension, do not require critical-thinking skills, but the last four – application, analysis, synthesis, and evaluation – all require the higher-order thinking that characterizes critical thought" (Bissell, 2006, p. 67).Although teachers indicate that they aspire to encourage critical thinking of their students through deliberate use of questioning strategies, most of the questions actually employed in the classroom consist primarily of basic knowledge and recall of information (Clegg, 1971). In fact, research indicates that "about 60% of teachers' questions require students to recall facts; about 20% require students to think; and the remaining 20% are procedural" (Gall, 1970, p. 713).

These statistics are disheartening because relying mostly on knowledge based and recall questions doesn't provide students with opportunities to engage in producing sophisticated responses to express understanding. When teachers "use questions requiring higher level thinking, they often find that their students will give responses at a higher level" (Edwards & Bowman, 2006, p. 5). Furthermore, abstract thought is most effective in promoting students to deeper levels of understandings (2006). Teachers tend to recognize and understand the importance of utilizing teaching strategies that elicit critical thought rather than the memorization of isolated facts and concepts. This leads one to believe that teachers understand the connection between the types of questions that teachers ask of their students and the cognitive skills that are elicited as a result (Edwards &Bowman, 2006). Although teachers report these understandings, there however seems to be a disconnect between what teachers believe and the practices they employ in the classroom (2006).

As a result, this study aimed at investigating the questioning strategies of preservice teachers to determine if gender gaps are being perpetuated in elementary science classrooms when science is taught using inquiry-based teaching methods. Specifically, the guiding questions for this research were: In what ways do the questioning strategies of preservice teachers differ for male and female elementary students when teaching science as inquiry and how is Bloom's Taxonomy evident within the questioning strategies of preservice teachers? The concern for making sure that preservice teachers at the elementary level are incorporating higher-order thinking skills within their inquiry-based teaching strategies becomes critical when considering ways that teachers can help to close the gender gap in elementary science education.

3. Methodology

The purpose of this research was to investigate the questioning strategies of preservice teachers to determine if gender gaps are being perpetuated in elementary science classrooms when science is taught using inquiry-based teaching methods. As such, data were collected from 8 preservice elementary teachers (7 female, 1 male) during their senior year student teaching experience at a university in central Pennsylvania. Of these student teachers, one taught at the kindergarten level, five taught at the second grade level, and two taught at the fifth grade level.

We began this research by viewing numerous videotapes of preservice teachers teaching science as inquiry within elementary science classrooms. These tapes were the basis of our research as we analyzed the types of questions each participant asked, to determine how often the questions were asked to male versus female students, what type of question each would classify as according to Bloom's Taxonomy and whether the questions differed in content and complexity. In total, forty-two lessons were analyzed. Furthermore, data was also analyzed in relation to grade level in an attempt to determine if differences in questioning strategies existed among grade levels.

In particular, we analyzed each question the preservice teachers askedrelative to the classification levels of Blooms Taxonomy to determine if male and female students were provided with equal opportunities to use higher order thinking skills in science classrooms. As a result, each question was classified in to the following six categories of Bloom's Taxonomy:

- Basic Knowledge—identification and recall of information
- Secondary Comprehension—organization and selection of facts and ideas
- Application—use of facts, rules, principles
- Analysis—separation of a whole into its component parts
- Synthesis—combination of ideas to form a new whole
- Evaluation—development of opinions, judgments, decisions (Edwards & Bowman, 1996, p. 9-10)

These categories operate in a hierarchical fashion in that they gradually increase according to the type and amount of cognitive skills required of students. For example, "basic knowledge and secondary comprehension, do not require critical-thinking skills, but the last four – application, analysis, synthesis, and evaluation – all require the higher-order thinking that characterizes critical thought" (Bissell, 2006, p. 67). In addition, we also investigated the frequency with which males and females were provided with opportunities to express their scientific understandings through higher-order thinking. The methods of choice for analyzing this data were instrumental case study and collective case study (Denzin & Lincoln, 2000). With an instrumental case study, the case itself "plays a supportive role, and it facilitates our understanding of something else" (2000, p. 437). A collective case study approach involves the use of "jointly studying a number of cases in order to investigate a phenomenon…" (p. 437). In an attempt to understand the extent to which questioning may play a role in the science achievement of male and female students, the researchers then linked these findings to substantive and formal theories (Denzin & Lincoln, 2000).

4. Data Analysis and Results

Examination of the data indicated that in combination, participants asked a total of 4,158 questions to their elementary aged students. Of these questions, 974 (23%) were asked to boys, and 991 (24%) were asked to girls. The remaining questions (53%) were asked to the class as a whole, therefore no gender could be assigned to these questions. In relation to Bloom's Taxonomy, 74% of the questions were basic knowledge, 15% were secondary comprehension, 2% were application, 4% were analysis, 1% were synthesis, and 3% were evaluation. Data analysis reveals that according to gender, boys were asked 22% of the basic knowledge questions as opposed to 21% for girls, and 57% for whole group. For the secondary comprehension level, 29% of the questions were asked to boys, whereas 30% were asked to girls, and 41% were asked to the whole group.

In relation to the application level of Bloom's Taxonomy, 16% of the questions were directed toward boys, 44% for girls, and 40% for the whole group. Questions categorized at the analysis level indicate that 20% were asked to the boys, 27% to the girls, and 53% to the whole group. For the synthesis level, 20% of the questions were asked to boys, whereas 35% were asked to girls, and 45% were asked to the whole group. Finally, the evaluation level revealed that 38% of the questions were asked to boys, 38% were asked to the girls, and 24% to the whole group. Detailed information regarding the classification of questions is summarized in Table 1. When analyzing data according to grade level, results indicate that at the *kindergarten level*, boys were asked 21% of the basic knowledge questions as opposed to 37% for girls, and 42% for whole group. For the secondary comprehension level, 33% of the questions were asked to boys, whereas 42% were asked to girls, and 17% were asked to the whole group. At the application level, no questions were asked. Questions categorized at the analysis level indicate that 33% were asked to the boys, 67% to the girls, and 0% to the whole group. Finally, no questions were asked at the synthesis and evaluation levels. Detailed information regarding the classification of questions is summarized in Table 2.

Results at the *second grade* level indicate that, boys were asked 22% of the basic knowledge questions as opposed to 21% for girls, and 57% for whole group. For the secondary comprehension level, 27% of the questions were asked to boys, whereas 31% were asked to girls, and 42% were asked to the whole group. In relation to the application level of Bloom's Taxonomy, 14% of the questions were directed toward boys, 46% for girls, and 39% for the whole group. Questions categorized at the analysis level indicate that 19% were asked to the boys, 27% to the girls, and 55% to the whole group. For the synthesis level, 16% of the questions were asked to boys, whereas 37% were asked to girls, and 47% were asked to the whole group. Finally, the evaluation level revealed that 40% of the questions were asked to boys, 39% were asked to the girls, and 21% to the whole group. Detailed information regarding the classification of questions is summarized in Table 3.

Data analysis from the *fifth grade* level, boys were asked 25% of the basic knowledge questions as opposed to 22% for girls, and 53% for whole group. For the secondary comprehension level, 45% of the questions were asked to boys, whereas 17% were asked to girls, and 38% were asked to the whole group. In relation to the application level of Bloom's Taxonomy, 33% of the questions were directed toward boys, 17% for girls, and 50% for the whole group. Questions categorized at the analysis level indicate that 33% were asked to the boys, 20% to the girls, and 47% to the whole group. For the synthesis level, 44% of the questions were asked to boys, whereas 22% were asked to girls, and 33% were asked to the whole group. Finally, the evaluation level revealed that 25% of the questions were asked to boys, 31% were asked to the girls, and 44% to the whole group. Detailed information regarding the classification of questions is summarized in Table 4. This data is significant in that it indicates similar findings to that of prior research in relation to the notion of basic knowledge questions being the most common type of questions asked of children in classrooms (Edwards & Bowman, 2006). Results were different however, with findings revealing that when compared to boys, girls had more opportunities to answer questions at all levels of Bloom's Taxonomy. In addition girls were also asked a greater number of higher order thinking questions (according to Bloom's Taxonomy) when compared to boys.

5. Discussion

This research allowed us to closely examine the questioning strategies of preservice teachers in inquiry-based elementary science classrooms. For effective reform of elementary science education to take place in today's classrooms, teachers must make sure that they "ask both girls and boys deeper follow-up [inquiry-based] questions" and that they are "calling on girls as often as on boys" (Sanders & Nelson, 2004, p. 77). Data analysis from this study revealed patterns in the overall data,as well as according to grade level. Conducting these two separate analyses made it possible to investigatethe overall findings, as well as the impact grade level may have had on the types of questions the participants asked according to the classifications of Bloom's Taxonomy. Althoughprevious research supports the notion of lower cognition questions being more advantageous than questions of higher cognition for elementary aged students (Cotton, 1988), results revealed that grade level was not an influential factor within this study.Specifically, findings reveal that the frequency of the types of questions asked (according to the Bloom's Taxonomy) was consistent throughout the grade levels represented in the study. This finding is intriguing since one might assume that more lower-level questions would typically be asked at the lower grades and a greater number of higher-level questions would typically be asked at the higher grades. Furthermore, this finding may suggest that inquiry-based science instruction which efficiently combines a balance of high and low cognition questions may have a positive influence on both male and female achievement at all grade levels.

When analyzing the overall results, data revealed that participants asked basic knowledge questions most often and synthesis questions least often. By calculating the totals for each level of Bloom's Taxonomy, we were able to rank the levels according to frequency, from most to least as follows: basic knowledge, secondary comprehension, analysis, evaluation, application, synthesis. This data parallelsprevious research, which indicates that the majority of questions being asked to elementary aged students are classified at the lowest two levels of Bloom's Taxonomy, which require the least critical-thinking skills(Gall, 1970; Clegg, 1971). This information can be disheartening to researchers and educators who advocate for the use of higher order thinking skills in elementary classrooms. Hence, it is imperative for educators and research to work towards improving the priority that problem solving and critical thinking is currently being provided within elementary classrooms. As such, we must consider the ways in which inquiry-based teaching approaches may be improved through the use of deeper and more thoughtful questioning techniqueswith both male and female students. Data also revealed that a greater number of questions were asked to girls in the early grades and a greater number of questions were asked to boys in the later grade. Although the grade levels present within this study are not exhaustive, it would be interesting to further investigate why fewer opportunities were provided to girls in the higher grades, and if this pattern exists among all grade levels. Further exploring the differences that may exist in questioning strategies among grade levels may provide useful information in regard to the gender gap in science education.

Data analysis also indicated that at all levels of Bloom's Taxonomy, the overall majority of questions were asked to the 'whole group'. However, when comparing only boys to girls, the girls had more opportunities to answer questions at all levels of Bloom's Taxonomy. The results from this study are encouraging because they offer evidence that suggest that as a whole, preservice teachers are effectively balancing their projection of questions to both genders of elementary aged students. This provides reason to believe that by giving girls the opportunity to answer more questions at all levels of Bloom's Taxonomy, they can begin to close the existing gender achievement gap in elementary science education.An interesting finding from this study indicated thatthe male preservice teacher asked questions that were more balanced across Bloom's Taxonomy in comparison to the results from the other seven female participants. This finding leads us to suggest that further research on the extent to which the gender of the teacher affects the type and quantity of questions asked to male versus female elementary aged students would be advantageous and may provide insightful suggestions for ways in which preservice and inservice teachers may more effectively teach science as inquiry, while balancing the opportunities for both male and female students. Furthermore, exploring other experimental factors that might affect gender and academic achievementsuch as the classroom environment, type of teacher feedback (positive, negative or neutral), frequency of feedback given,as well as student behaviors in the classroom would all be insightful topics to further explore.

Additionally, the deliberate and thoughtful selection of science topics to be studied is another way in which gender issues may be addressed. A more careful selection of topics for exploration in elementary science classrooms will also play a key role in helping to close the gender gaps in science achievement. Choosing science topics and assessments that enhance higher-order thinking and require both males and females to engage in inquiry-based science explorations that are abstract and hands-on in nature will help male and female students integrate their strengths, which will lead to successful learning. Overall, the findings of this research reveal approaches to teaching science that were implemented by the participants. This research may assist researchers, teacher educators, administrators, in-service teachers, and preservice teachers in better comprehending effective approaches teachers can and should be using to help close the gender achievement gap in science education.This data, paired with research on gender disparities in science education will provide insight as to the progress preservice science teachers are making towards a more reform-based approach of teaching science as inquiry,which simultaneously addresses the strengths of both male and female students as well as their prior experiences with science.

Table 1: Classification of Questions According to Gender: Overall

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Boys	(22%)	(29%)	(16%)	(20%)	(20%)	(38%)
Girls	(21%)	(30%)	(44%)	(27%)	(35%)	(38%)
Whole Group	(57%)	(41%)	(40%)	(53%)	(45%)	(24%)
Totals	3063	648	75	186	60	126
N = 8						

Table 2: Classification of Questions According to Gender: Kindergarten

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Boys	(21%)	(36%)	(0%)	(33%)	(0%)	(0%)
Girls	(37%)	(45%)	(0%)	(67%)	(0%)	(0%)
Whole Group	(42%)	(18%)	(0%)	(0%)	(0%)	(0%)
Totals	19	12	0	3	0	0
N = 1						

Table 3: Classification of Questions According to Gender: Grade 2

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Boys	(22%)	(27%)	(14%)	(19%)	(16%)	(40%)
Girls	(21%)	(31%)	(47%)	(27%)	(37%)	(39%)
Whole Group	(57%)	(42%)	(39%)	(55%)	(47%)	(21%)
Totals	2809	577	69	168	51	110
N = 5						

Table 4: Classification of Questions According to Gender: Grade 5

	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Boys	(25%)	(45%)	(33%)	(33%)	(44%)	(25%)
Girls	(22%)	(17%)	(17%)	(20%)	(22%)	(31%)
Whole Group	(53%)	(38%)	(50%)	(47%)	(33%)	(44%)
Totals	235	60	6	15	9	16
N = 2						

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