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Investigation of Inquiry-Based Science Pedagogy among Middle Level Science Teachers: A Qualitative Study

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Abstract

This study implemented a qualitative approach to examine the phenomenon of "inquiry-based science pedagogy or inquiry instruction" as it has been experienced by individuals. Data was collected through online open-ended surveys, focus groups, and teacher reported self-reflections to answer the research questions: 1) How do middle level science teachers conceptualize "inquiry-based instruction?" 2) What are preferred instructional strategies for implementation in middle level science classrooms? And 3) How do middle level science teachers perceive the connection between science instruction and student learning? Findings support the need for strong, job-embedded professional development, the cultivation of learning communities dedicated to the investigation and implementation of inquiry-based science, the focusing of curricular programming to allow for in depth investigation of scientific concepts, and the commitment of time and resources to support effective science instruction. It is recommended that additional support be provided to teachers of science to engage in job shadowing, field experiences and internships to allow for the uncovering of applications of science beyond the classroom. These research findings could inform the work of the educational reformers, professional developers, teacher preparation programmers, and researchers as they aspire to improve the quality of student learning and science instruction.

Keywords: Inquiry, Pedagogy, Teacher Preparation, Professional Development, Science Reform

1. Introduction

Science for All Americans (SFAA) (1989) established urgency to reform science instruction with an emphasis on scientific literacy for all. SFAA (1989) emphasized the importance of providing all learners with opportunities to experience science as a way of thinking and doing, providing learners with opportunities to construct knowledge through experience with the types of thinking and activities in which scientists would engage. More than fifteen years later, the National Research Council (NRC) published *National Science Education Standards (NSES)* outlining a "vision of science education that will make scientific literacy for all a reality in the twenty first century" (1996, p. ix). This publication emphasizes the need for all citizens to engage in critical thought regarding scientific and technological advancements and critical discourse and debate regarding scientific issues that face our society (NRC, 1996). In order to strengthen the vision for science education, the *NSES* provide guidance for educational practitioners, outlining the knowledge, understandings and dispositions that students must possess to be considered "scientifically literate" at each grade level (NRC, 1996, p. 2).

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The *NSES* maintain that students in grades 5 through 8 should develop “abilities necessary to do scientific inquiry and understandings about scientific literacy” (National Research Council, 1996, p. 143). The NRC (1996) also maintains that with appropriate curriculum and instruction, middle-school students can develop skills of investigation and an understanding of scientific inquiry as it is guided by “knowledge, observations, ideas, and questions” (p. 143).

In order for these competencies to be cultivated within middle level science classrooms, the National Science Teacher’s Association (NSTA) states that teachers of science must “be fully qualified to teach science” and “have a strong knowledge of science content” (NSTA, 2003, p. 1). To be deemed fully qualified, or “highly qualified” as stated in *No Child Left Behind*, teachers must have: “1) a bachelor's degree, 2) full state certification or licensure, and 3) prove that they know each subject they teach” (*No Child Left Behind*, 2004, p. 2). NSTA (2003) also emphasizes the importance of inquiry-based science instruction in the middle school years, recognizing that adolescents experience dramatic amounts of physical, emotional and cognitive change and making it of paramount importance to capture students’ excitement, motivation and enthusiasm for science. Within a 2003 position statement, NSTA emphasized the importance of middle school science education, emphasizing the importance of presenting science concepts “in an age-appropriate, engaging way so that students can build on their prior knowledge and attain the necessary background to participate successfully and responsibly in our highly scientific and technological society (para 1).”

In addition, NSTA stresses the importance of engaging middle level students in science recognizing that the middle school years are “a pivotal time in their understanding of and enthusiasm for science” (para 2). “Research has shown that if educators don’t capture students’ interest and enthusiasm in science by grade 7, students may never find their way back to science NSTA, 2003, para 2).”

Additionally, the NSES (2003) promotes the planning and implementation of inquiry-based science programs for students, maintaining that teachers should act as facilitators of learning, actively participating in the planning and development of the schools science program, designing and managing the learning environment in order to provide students with the time, space, and resources needed for learning science. Teachers of science should continually act as reflective practitioners as they engage in ongoing assessment of pedagogy and student learning, strive to establish communities of learning that value the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning (NSES, 2003).

The purpose of this phenomenological study was to examine the perceptions and experience of inquiry-based instruction among middle level science teachers. The intent was to uncover the perception of inquiry-based science instruction and practices that are implemented within middle level science classrooms in northeast Pennsylvania.

1.1 Research Questions

Research Questions	**Topical Sub-questions**
1) How do middle level science teachers conceptualize “inquiry-based instruction?” 2) What are preferred instructional strategies for implementation in middle level science classrooms? 3) How do middle level science teachers perceive the relationship between science instruction and student learning?	1) How do middle-level science teachers characterize effective instruction? 2) How do middle-level science teachers structure instruction? 3) How do middle level science teachers view their role in relation to student learning?

Theoretical Perspective

Lev Vygotsky's (1978) theory on social constructivism suggests that all learning is mediated through social interactions with more knowledgeable others. One assumption of Vygotsky's theory is that individuals are active learners, interacting with the environment and capable of constructing understanding through these interactions. Constructivist assumptions related to learning suggest that learners should engage in structured situations in which they interact with primary sources, manipulatives and interactions with others (Schunk, 2008).

In *The reflective practitioner*, Schön (1983) suggests that individuals must reflect in action throughout their life to facilitate learning and understanding. Teachers of science must be encouraged to engage in reflective practice. This may contribute to the construction of multiple schemata related to inquiry-based science instruction while strengthening relationships within the classroom and school system. Through engagement in reflection, individuals may actively select to cultivate obligations and responsibilities for others. This reflection will encourage teachers of science to understand the values present within the system. Schauber (1996) suggests that through the process of self-reflection, one will identify that which they value and that which they believe in and will engage in actions and behaviors that encourage the continuation of commitment to these beliefs.

In light of these theories, it is believed that science educators will report goals related to making a significant difference in the lives of their students and would report aspirations of preparing students to be scientifically literate. To this end, it is believed that teachers are acting as reflective practitioners and are planning instruction to enhance student engagement and development of conceptual understanding.

1.2 Methodology

1.2.1. Research Design

This study implemented qualitative approach to examine the phenomenon of "inquiry-based science pedagogy or inquiry instruction" as it has been experienced by individuals.

Data was collected through online open-ended surveys, focus groups, and teacher reported self-reflections to answer the research questions:

1) How do middle level science teachers conceptualize "inquiry-based instruction?" 2) What are preferred instructional strategies for implementation in middle level science classrooms? And 3) How do middle level science teachers perceive the connection between science instruction and student learning?

The objective of this phenomenological study was to examine teachers' understanding and implementation of inquiry-based instruction among middle level science teachers. The intent was to uncover the teachers' understanding and perceptions of inquiry-based science instruction and practices that are implemented within middle level science classrooms in northeast Pennsylvania.

1.2.2 Sample

In order to gather data regarding the phenomenon of inquiry-based science instruction, the researcher sought a sample of 10 teachers of middle level science, defined as 5th through 9th grade. The research sample was limited to middle level science teachers currently practicing within one of six school districts located within the northeast region of Pennsylvania. There are approximately 30 teachers of science at the middle level, grades 5 through 9, within these six school districts. This purposeful sampling procedure has allowed for follow-up questioning to gain clarification and participant feedback, both of which contributed to the validity of observations and interpretations. The purposeful sample was selected to "best help the researcher to understand the problem and research questions" (Cresswell, 2003, p. 185).

1.2.3 Instrumentation

Upon receipt of approval from district superintendents and Marywood's Institutional Review Board (IRB) an informational email was sent to principals of school buildings in which students enrolled in grades 5 to 9 are participating in science instruction. This email outlined the purpose of the research, the instrumentation used, and the potential time commitments that could be expected by participating teachers. Building principals were asked to disseminate invitation and informed consent to teachers of science in grades 5 to 9 within their building.

1.2.4 Online Survey

Upon the receipt of the informed consent letters, the researcher sent an e-mail that contained instructions for completing an open-ended survey to participants. Open-ended survey questions were implemented using Zoomerang, an online survey software tool. Zoomerang does not provide the IP Address or email addresses of survey respondents. Data from Zoomerang surveys are stored at a secure hosting facility with both physical and software-based security systems. In order to retrieve survey data, researcher must login to Zoomerang using login information.

Section one of the online survey served to compile assigned identification number and demographic information. Section two of open-ended online survey served to collect teacher responses related to instruction in order to establish baseline information related to inquiry-based instruction (see Appendix F).

1.2.5 Focus Groups

Following implementation of survey, participants were sent a letter inviting participation in focus groups. Focus groups were conducted within educational settings at the convenience of participants. Participants were asked to respond to open-ended questions regarding inquiry-based science instruction and student learning (see Appendix H). It is important to note that these questions were formulated to encourage reflection and honest dialogue from the participants and to avoid "leading" participants towards biased responses. While this list served as a guiding framework for the communication, additional questions were constructed throughout the focus groups to obtain thick descriptions and detailed elaboration. The researcher created a table demonstrating the alignment between research questions, topical subquestions, open ended survey items and focus group items (see Appendix I).

Focus groups were conducted by the researcher between the months of May and June 2011. Each focus group contained no more than 5 participants. The researcher digitally recorded all focus group responses to facilitate accurate transcription and maintained notes detailing observations regarding the participants' demeanor, attitude, facial expressions, hesitations, and any additional observations that could reveal significance in the data analysis phase. Each focus group lasted no longer than two hours and refreshments were offered participants. The researcher transcribed all focus group correspondence.

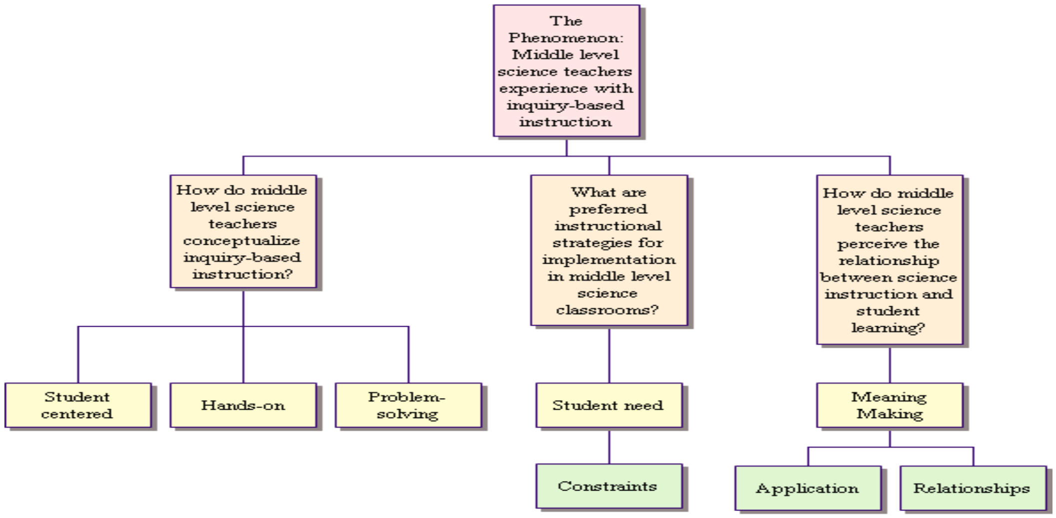
Following participation in focus groups, participants were invited to share in a confidential self-reflective analysis of classroom practice, implementing observation protocol developed by the *National Institute for School Leadership* and aligned with the NSES Science Triangle (see Appendix J). This self-reflection contains 14 items intended to identify teachers' perception of their pedagogy. This self-reflection contains a 7-point Likert scale with descriptors related to evidence of implementation. Teachers were asked to rate themselves and provide reflective feedback related to their rating.

1.2.6 Findings

Following data collection, information from focus groups and self reflections was transcribed, and online survey data was compiled. Research questions were organized to facilitate analysis related to the three research questions: (1) How do middle level science teachers conceptualize inquiry-based instruction?; (2) What are the preferred instructional strategies for implementation in middle level science classrooms?; (3) How do middle level science teachers perceive the relationship between science instruction and student learning?

Figure 3 outlines identification of themes and subthemes related to each research question associated with the phenomenon of middle level science teachers experience with inquiry-based instruction.

Figure 3: Identification of Themes



The participants within this research study represent 33 percent of teachers in grades 5 through 9 within six school districts in northeastern Pennsylvania. Of the 12 consent forms originally obtained, 10 teachers completed all three phases of the data collection, including the online survey, participation in focus groups, and teacher self-reflection. 60 percent of the participants taught only science, and 40 percent taught all content areas. Of the ten participants, 50 percent were certified teachers of science and 50 percent were certified as teachers of elementary education. 70 percent of the research participants reported having obtained a master's degree, with 60 percent of these degrees being received in areas of education, and 10 percent in the area of science. The research participants have a total of 85 collective years of experience as professional educators, with the average years of experience being 8.5 years.

1.2.6.1 Teachers Experience with Inquiry-Based Instruction

Data collected from participants in relation to their experiences with inquiry-based science instruction revealed that participants characterized "inquiry-based" instruction as that which contained elements of *student centered instruction*, *hands-on* learning opportunities and *problem solving* processes. These activities within the science classroom are characterized by the participants' descriptions of learners' engagement with scientific materials throughout laboratory exercises and investigations and students' collaboration to solve problems when inquiry is taking place in the science classroom.

This research finding is consistent the National Research Council's (1996) characterization of inquiry-based instruction as that in which students are actively engaged in hands-on and minds-on experiences. In addition, these findings are reflective of recommendations from the *National Science Education Standards* (1996) and National Institute for School Leadership's (NISL) *Science Inquiry Triangle* (2008), which places students "engagement with phenomenon" or hands-on experience as one of the three components of essential science instruction. In addition, the research findings reflect the report of the National Research Council's (2011) publication of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Idea*, in which one of the eight essential practices for K-12 science curriculum includes engaging learners in problem solving and hands-on experiences through students "planning and carrying out investigations" (Chapter 3, p. 5).

In addition, this report emphasizes the importance of students engaging in hands-on investigations that "range from those structured by the teacher…to those that emerge from students' own questions (NRC, 2011, Chapter 3, p. 11).

1.2.6.2 Preferred Instructional Strategies

The findings related to middle level science teachers' preferred instructional strategies and how they structure instruction revealed that *student need* emerged as the most important consideration for informing the structure of instruction and the instructional planning processes. In relation to Schön's (1983) ideas related to reflective practice, this finding would suggest that student need and identifying these needs to support student success are extremely valued by participants.

1.2.6.3 Science Instruction and Student Learning

The findings related to participants perceptions of the relationship between teaching and learning uncovered the theme of *meaning making,* which was subdivided into the two subthemes of *application* and *relationships.* The researcher was not surprised that the importance of application of science content to the real world was revealed as an important part of the teaching and learning experience. This finding is consistent with the Committee on How People Learn (2005) report indicating that students must have opportunities to "organize knowledge in ways that facilitate retrieval and application" (p.1). The importance of application, and the meaning associated with fostering these connections for students was consistently reported.

1.2.7 Implications

This research reinforces a clear need for significant reform to teacher preparation programs, professional development programming, standards and curricular planning within educational systems serving students in grades 5 through 9. The findings support the need for high-quality, professional development experiences that will allow teachers of science to experience inquiry-based instruction, reflect on the experience, analyze the relationship between teaching and learning and plan for transfer into their classrooms. In addition, it is imperative that these professional learning opportunities provide time for collaboration related to planning and implementation of instruction.

An additional implication is the need for middle level teachers of science to have opportunities to observe and analyze teachers modeling inquiry-based science instruction. It is apparent that a clear picture of inquiry-based learning is desired, and through engaging science teachers in the observation of science lessons and analysis of instructional practices a deeper understanding of inquiry-based instruction and how students learn would emerge.

Finally, consistent with the recommendations of Schmoker (2011) in *Focus: Elevating the Essentials to Improve Student Achievement,* it is recommended that educational systems support revisions to the current demands of curriculum. This recommendation was reinforced in *A Framework for K-12 Science Education* (2011), which strived to provide "greater coherence in K-12 science education" rather than the promotion of standards that contain "long lists of detailed and disconnected facts" (Chapter 1, p.3). *A Framework for K-12 Science Education* was developed with a focus on "learning as a developmental progression, a limited number of core ideas and science" and an emphasis on "the integration of knowledge of scientific explanation and the practices needed to engage in scientific inquiry" (Chapter 1, p. 3). Engaging teachers in collaborative inquiry of *A Framework for K-12 Science Education* would serve to establish collective understanding related to the vision for science education. Furthermore, with this knowledge, teachers would be empowered to reduce the breadth of topics covered within the science curriculum which would in turn allow students to engage in the deep investigations of scientific concepts and the development of conceptual understanding.

It is clear that the implications of this research are consistent with the recommendations contained within *Framework for K-12 Science Education* (2011), which maintains that significant improvements need to be made in teacher preparation programs and professional development programming for teachers of science.

Additionally, the *Next Generation Science Standards* (NGSS), published in April 2013, are based on the *Framework for K–12 Science Education*. "The NGSS are standards, or goals, that reflect what a student should know and be able to do - they do not dictate the manner or methods by which the standards are taught" (NGSS Executive Summary, 2013, p. 2). In order to support teachers to uncover how to best engage learners in experiences aligned with these standards, we must make a commitment to prioritize time for collaboration in order to make improvements to science curriculum, instruction and assessment so that all students are prepared to be scientifically literate.

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Appendix F

Open-ended Online Teacher Survey

The following survey was designed to uncover how teachers have experienced the phenomenon of inquiry-based science instruction in middle level classrooms. Completion of this survey will be helpful and needed in gathering data as part of research on inquiry-based science instruction. The information you are sharing will remain confidential. Individuals and schools will not be identified; only aggregated responses will be reported. The survey should take no more than fifteen minutes to complete and submit.

In the case that you wish to withdraw from the research, you will need to provide the unique identification number provided to you by the researcher. This will allow for your responses to be removed from the database of responses.

Thank you in advance for sharing your experiences as your expertise is an integral part of this research!

Section One:

Assigned Identification Number:
Grade Level Taught: 5 6 7 8 9
Subject(s) Taught:
Gender: Male Female
Degrees obtained College/University, and Year(s) of Completion:
Areas of Pennsylvania Certification:
Years in Education:
Years at current school:
Years of teaching science:

Section Two:

Please respond to the following questions from your individual experience and perspective.

1) Why did you become a teacher of science?

2) What influences your decision making related to implementation of different instructional strategies within your classroom?
3) What does it mean to teach science through inquiry?
4) What does inquiry-based instruction mean to you?
5) What instructional practices do you implement in your science classes?
6) Have you studied "inquiry" in your undergraduate or graduate course work? If so, please describe the course.
7) Have you had any professional development related to "inquiry-based" instruction? If so, please describe the training.
8) What do you think is most difficult about the implementation of inquiry-based instruction?
9) Do you feel that there is a strong consensus among the science educational community related to inquiry-based instruction? Please elaborate.
10) What suggestions would you share related to preparing teachers to implement inquiry within science classrooms?
11) What do you find fulfilling about your position as a teacher of science?
12) What do you find challenging about your position as a teacher of science?
13) What suggestions do you have for administration related to the teaching of science?

Appendix H

Focus Group Questions

Welcome, this focus group will be facilitated with colleagues teaching science in grades 5 to 9 within the northeast region on PA. The purpose of this focus group gathering is to uncover how you have experienced the phenomenon of inquiry-based science instruction in your middle level classrooms. I thank you for providing me with the opportunity to collaborate with you on this research. Participation in this focus group will be helpful and is needed in gathering data as part of research on inquiry-based science instruction. The focus groups will be recorded and will be later transcribed by the researcher. Information you are sharing will remain confidential. Individuals and schools will not be identified; only aggregated responses will be reported. The focus group should take no more than two hours.

Please be reminded that discussion and commentary during the focus group session should be kept confidential. Please do not repeat comments outside the group. All are encouraged to be open and honest! Thank you in sharing your experiences as your expertise is an integral part of this research!

1. What professional development was useful and relevant to classroom instructional practices?
2. What qualities do you identify as most important in your role as a teacher of science?
3. What does inquiry-based instruction mean to you? When inquiry is taking place, what is the teacher doing? When inquiry is taking place, what are the students doing?
4. What qualities should an effective teacher of science possess?
5. What does it mean to be an inquiry-based teacher?
6. What do you consider meaningful related to student learning?
7. On a continuum between dissemination and facilitation, where do you place yourself?
8. How do your professional aspirations align with the reality of education?
9. What does it look like when students are engaged in learning?
10. Where do you find the most meaning within your work?
11. What suggestions would you make to administration related to supporting effective science instruction?

Appendix I

Research questions, Topical Subquestions, Survey items and Focus group items

Research Questions	Topical Sub-questions	Survey Questions	Focus Group Questions
1) How do middle level science teachers conceptualize "inquiry-based instruction?"	1) How do middle-level science teachers characterize effective instruction?	What influences your decision making related to implementation of different instructional strategies within your classroom? What does it mean to teach science through inquiry? What does inquiry-based instruction mean to you? Have you studied "inquiry" in your undergraduate or graduate course work? If so, please describe the course. Have you had any professional development related to "inquiry-based" instruction? If so, please describe the training. What do you think is most difficult about the implementation of inquiry-based instruction? Do you feel that there is a strong consensus among the science educational community related to inquiry-based instruction? Please elaborate. What suggestions would you share related to preparing teachers to implement inquiry within science classrooms? What suggestions do you have for administration related to the teaching of science?	What does inquiry-based instruction mean to you? When inquiry is taking place, what is the teacher doing? When inquiry is taking place, what are the students doing? What does it mean to be an inquiry-based teacher? What does it look like when students are engaged in learning? What suggestions would you make to administration related to supporting effective science instruction?
2) What are preferred instructional strategies for implementation in middle level science classrooms?	2) How do middle-level science teachers structure instruction?	What influences your decision making related to implementation of different instructional strategies within your classroom? What instructional practices do you implement in your	What professional development was useful and relevant to classroom instructional practices? On a continuum between dissemination and facilitation, where do you place yourself?

		science classes?	
3) How do middle level science teachers perceive the relationship between science instruction and student learning?	3) How do middle level science teacher view their role in relation to student learning?	Why did you become a teacher of science? What influences your decision making related to implementation of different instructional strategies within your classroom? What does inquiry-based instruction mean to you? What do you think is most difficult about the implementation of inquiry-based instruction? What suggestions would you share related to preparing teachers to implement inquiry within science classrooms? What do you find fulfilling about your position as a teacher of science?	What qualities do you identify as most important in your role as a teacher of science? What qualities should an effective teacher of science possess? What do you consider meaningful related to student learning? How do your professional aspirations align with the reality of education? What does it look like when students are engaged in learning? Where do you find the most meaning within your work? What suggestions would you make to administration related to supporting effective science instruction?

Appendix J

Leadership for Excellence in Science: Self-reflection on Classroom Science Practice

Self-Reflection on Classroom Science Practice

Assigned Identification Number: _______________

Please complete the chart below based on your self-reflection and analysis of your classroom science practice. Please consider evidence of implementation of each element within your classroom. Please provide information related to each item as it applies to your instructional practice	Grow = no evidence of this practice; Glow =extensive evidence of this practice For each item, please place an X on continuum where you consider yourself. Please provide your thoughts related to this determination. Grow (-) Glow (+) ← 1 2 3 4 5 6 7 →
Conceptual Understanding	
1. The instructional strategies and activities respect students' prior knowledge and the preconceptions inherent therein. [teacher indicates knowledge of typical misconceptions and addresses them and teacher surfaces misconceptions of current students with formative assessment (+); teacher organizes instruction without consideration of misconceptions (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**
2. My lessons involve fundamental concepts of the subject.	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 →

[teacher regularly connects and asks students to connect activities to "big ideas" or fundamental ideas in the discipline (+); teacher treats activities as self-contained learning experiences (-)]	**Comments and self-reflection:**
3. My lessons promote strongly coherent conceptual understanding. [teacher stresses connections between concepts (+); teacher does not address conceptual connections (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**
4. I have a solid grasp of the subject matter content inherent in the lessons. [teacher approaches content in multiple ways and is able to respond to students' ideas with clear explanations (+); teacher is linear in approach t o content and does not consider students' questions(-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**
5. I act as a resource person, working to support and enhance student investigations. [teacher provides ideas and resources to students to allow them to pursue their own ideas (+); teacher focuses students on a correct line of investigation (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**

Evidence-Based Explanations	
1. My lessons are designed to engage students as members of a learning community. [teacher engages with students and has students engage with each other around science content (+); little to no interaction between students or students and teacher (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**
2. My lessons encourage students to seek and value alternative modes of investigation or of problem solving. [teacher actively encourages or introduces different approaches or solutions (+); teacher encourages one solution or approach (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**

1. I value intellectual rigor, constructive criticism, and the challenging of ideas. [students are engaged with the ideas of other students in constructive ways including debate and discussion (+); student ideas are evaluated by the teacher with little or no probing for evidence or support or interaction with other students (-).]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**
2. There is a high proportion of student talk within my classroom and a significant amount of it occurs between and among	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 →

students. [much of the classroom talk is by students and a majority is student to student (+); most of the classroom talk is by the teacher (-)]	**Comments and self-reflection:**
3. Students are asked to support explanations they made with evidence of some kind (empirical or conceptual). [students are asked to support their ideas with evidence and conceptual explanations (+); students' ideas are evaluated as correct or incorrect (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**
4. Students are encouraged to generate conjectures, alternative solution strategies, and/or different ways of interpreting evidence. [multiple student ideas are generated and evaluated during classroom discussions (+); students are not asked to generate ideas about the content of the lesson (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**
Engagement with Phenomenon	
5. Students are directly engaged with scientific phenomenon. [students engage in hands-on investigations of key science phenomenon (+); students are shown demonstrations or are given descriptions of phenomenon (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**
6. Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulatives, etc.) to represent phenomena. [students are asked to make multiple representations of ideas and describe or explain connections between representations (+); students work with one type of representation at a time with little to no emphasis on different representations of phenomenon (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**
7. Student questions and comments often determine the focus and direction of classroom discourse. [the focus of science lesson, in particular the conversations, is students' ideas (+); the focus of the science lesson is correct scientific ideas (-)]	Grow (-) Glow (+) ← 1 2 3 4 5 6 7 → **Comments and self-reflection:**

Adapted from National Institute for School Leadership. (2008). *Leadership for excellence in science: Instructors Guide.* Washington, DC: National Center for Education and the Economy.