Conflict and Consonance: Implementing an Evidence-Based Middle School Science Curriculum

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Abstract: This study is to investigate the middle school teachers' concerns and perspectives during the implementation of an evidence-based curriculum that supports the development of both content knowledge and scientific practices. Two themes emerge from data analysis: consonance and conflict.

Deficiencies in middle school science curriculum have implications for America's global economic positioning and advancement in science and technology. These inadequacies stunt the overall development of scientific literacy in students and deprive them of the necessary skills, attitudes, and values required to confront socioscientific and political issues. In order to improve middle school science instruction and learning and to attract more students into Science Technology Engineering and Mathematics (STEM) fields, teachers' science content knowledge and their support of reform-oriented pedagogy must be enhanced (Bell & Gilbert, 1996; Koch & Appleton, 2007). Furthermore, middle school teachers should possess a coherent understanding of both scientific practices and the instructional skills needed to foster students' critical thinking and problem solving skills (Loucks-Horsley, Hewson, Love, & Stiles, 1998). While attempts to develop, implement, and sustain coherent, reform-oriented science curriculum are undermined by teacher turnover and lack of preparedness to teach in assigned subject areas (Lankford, Loeb, & Wyckoff, 2002; National Center for Education Statistics [NCES], 1999), the need still exists for the enactment of curricula that support the development of both content knowledge and science practices. We define curriculum as practice in which the teacher involved in the curricular process (Grundy, 1989; Habermas, 1972) interprets the printed component as a practical action that engages learners in a process of making meaning. In our study, we investigated three middle school teachers' enactment of a science curriculum designed to facilitate the development of both content knowledge and scientific practices contextualized in real life situations. Defining scientific practices as "specifying ways in which students should be able to use knowledge meaningfully rather than what they should know" (Shwartz, Weizman, Fortus, Krajcik, & Reiser, 2008, p. 201), the curriculum is developed around the notion that learning scientific practices is essential if students are to understand science as a way of knowing and not just a body of facts. Specifically, our research seeks to understand the concerns and perspectives of the teachers during the implementation of such a curriculum.

Reform Curriculum and Scientific Literacy

While the roles of teachers are important in contemporary curricular processes, the development of new instructional materials to promote students' deep understanding of scientific concepts is key to reform efforts in science education. These educative materials must be designed to reflect standards-driven science-learning goals and innovative pedagogical approaches (Krajcik, McNeill, & Reiser, 2007) that will transform the way science is taught in schools. Several policy papers have proposed the development of reform curriculum that supports scientific literacy (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996) by encouraging students to confront scientific issues or problems, express their ideas, and make relevant contextual connections as a means of

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enriching their understanding of science concepts (Krajcik & Sutherland, 2010). Scientific literacy is defined by the National Science Education Standards (1986) as the understanding of science content and practices and the ability to use such knowledge to participate in decision-making that is personal or affects others in a global community. This definition suggests that students should be required to develop skills in critical thinking and inquiry, both of which emphasize the basic literacy skills of reading, writing, and oral discourse (Krajcik & Sutherland, 2010). An ideal reform curriculum, therefore, should be project-based (Sutherland, 2008) in its exploration of scientific phenomena that encourages further investigation and analysis; inquiry-based (Schneider, Krajcik & Blumenfeld, 2005), requiring students to solve real-world problems by asking and refining questions; and evidence-based (Krajcik & Sutherland, 2010) by focusing on students' ability to critically assess claims based on the quality of evidence presented.

Investigating and Questioning our World through Science and Technology (IQWST) is a middle school science curriculum project that features scientific practices aimed at developing students' literacy in science and reflects recommendations made by AAAS (1993) and NRC (1996). As such, the IQWST curriculum focuses on scientific practices that include the design of scientific investigations, the collection and analysis of data and the construction of evidence-based explanations of scientific phenomena (Krajcik, Reiser, Sutherland, & Fortus, n.d). One of the features of IQWST that promotes scientific literacy, and by extension, inquiry is the connection made between new ideas to prior knowledge and experiences. The elicitation of prior knowledge is particularly important when concepts are abstract and remote from the reality of students' daily experiences (Krajcik & Sutherland, 2010). Prior knowledge may be generated from real-world or classroom experiences and forms the building blocks for the construction of new knowledge through the collaborative expansion or modification of existing ideas. The embedded narrative text and real-world text from magazines and newspapers that complement the expository text in the lessons is one of the ways in which the (IQWST) curriculum connects students' experiences and scientific content. These reading materials promote active interaction with science concepts (Sutherland, 2008) and engage students in discussions about their diverse everyday activities while extending their understanding of activities carried out during the lesson (Krajcik et al., n.d). The opportunity for students to investigate scientific ideas with relevant context enhances meaningful and authentic learning and also aligns with recommendations for curriculum reform (Swartz et al., 2008).

A second important feature of the IQWST curriculum and its connection to scientific literacy is the exploration of scientific phenomena through inquiry and discourse. Inquiry-based curriculum not only introduces students to scientific practices that reflect the norms of real scientists as they investigate, analyze, evaluate, and rationalize scientific ideas (NRC, 1996) but also integrates literacy practices such as reading and writing (Krajcik & Sutherland, 2010). IQWST units are centered on a powerful, divergent question that connects the learning process with the natural interests and curiosities of the students. This question, also called the Driving Question (DQ), forms the foundation for the generation of various sub-questions that are collected, sorted, and posted on a Driving Question Board (DQB) typically placed on the classroom wall as a visual organizer of the ideas associated with the unit (Krajcik et al., nd; Krajcik et al., 2007; Shwartz et al., 2008). As questions are raised, they can be added to the board, which may serve the dual purpose of sustaining inquiry and mapping student learning throughout specific units (Krajcik et al., nd). In addition to driving the investigation of science content and engaging students in inquiry processes characteristic of real scientific practices, the questioning component of the IQWST curriculum also establishes goals for the reading and guides comprehension of the accompanying text (Krajcik & Sutherland, 2010).

The third feature of the IQWST curriculum that promotes scientific literacy is the use of models to facilitate students' explanation and prediction of scientific phenomena (Krajcik et al., nd). Students are able to create conceptual models or mental representations of a given process or concept, construct physical models to further explain or predict phenomena, and evaluate their models to ensure alignment with knowledge constructed during classroom discussions. By sharing their revised models, students clarify and advance their scientific knowledge through evidence-based argumentation, which is a fundamental component of scientific discourse. The ability to decipher models and other illustrative artifacts is an important aspect of scientific literacy that facilitates students' comprehension of abstract and complex ideas (Krajcik & Sutherland, 2010).

Embedded in the IQWST curriculum is another literacy practice that engages students in the construction of explanations and arguments (Krajcik & Sutherland, 2010). In order to engage in this practice, students have to articulate and defend their understanding of scientific phenomena to their teacher and peers using the language of science. The IQWST curriculum is, therefore, designed to support students' attempts to create and defend scientific explanations by dividing them into three components: claim, evidence, and reasoning (Krajcik et al., nd). Using strategies such as data gathering, scaffolding exercises, contextual activities, and written explanations, the curriculum seamlessly integrates instructional practices that support students as they learn how to use evidence for explanation and argumentation. Research indicates that students who routinely engage in argumentation enhance their understanding of the nature of science (Krajcik et al., n.d.; Sadler, 2006) and are more likely to read and write scientific ideas both as students and as citizens in a global society (Krajcik & Sutherland, 2010).

The IQWST curriculum supports the enactment of instructional practices through scaffolding to help teachers facilitate scientific inquiry and discourse, research-based comprehension strategies to promote literacy practices, and background information to support teacher understanding of science content. Despite the support available to teachers in IQWST, many teachers find the curriculum difficult to learn and enact (Schneider et al., 2005). Various studies carried out by the developers of the IQWST curriculum focus on documenting episodes of enactment with a view to improving the efficacy of educative materials. There is very little research that qualitatively describes the concerns, real or imagined, faced by teachers as they attempt to enact the IQWST curriculum. This study, therefore, investigates the following question: *What concerns do teachers express during the enactment of an evidence-based curriculum that focuses on the development of scientific practices?*

Methods and Context

Curriculum Overview

IQWST is a standards-based curriculum that promotes deep, coherent understanding of fundamental scientific concepts and practices by sequencing instruction across units both within individual grade levels and across the 6th-, 7th-, and 8th-grades. There are four units per grade—one each for biology, physics, chemistry, and earth system sciences—each of which focuses on selected learning goals and scientific practices. A meaningful, open-ended DQ that supports the students' connection with prior knowledge and experiences drives each IQWST unit, which is further divided into learning sets composed of lessons. Reading assignments provide opportunities for students to improve their literacy skills while helping them to make sense of science in their daily experiences and in their extended environment. Curricula also includes materials designed to engage students in scientific practices such as gathering, organizing, and analyzing data; modeling phenomena; constructing evidence-based explanations; and conducting investigations. For teachers, IQWST provides educative materials both to support their enactment of inquiry in the classroom and to guide formative assessment that would facilitate possible adjustment to instructional strategies. Lesson plans are comprehensive and coherent, offering pedagogical models that support deep understanding of scientific ideas and practices.

School Settings and Participants

The setting for this study was a developmental research school affiliated with a large university in southeastern United States. The school serves approximately 1,150 students in kindergarten through twelfth grade and, as a center of innovation for student learning, focuses on, among other things, the improvement of science instruction through state of the art educational technology. The three middle school teachers who participated in the study were Taylor, the 8th-grade teacher who has approximately four years of science teaching experience; Becky, the 7th-grade teacher who is in her first year of teaching; and Maggie, the 6th-grade teacher with four years of teaching experience (Pseudonyms are used). All teachers were certified to teach science by the state and had credentials ranging from masters to doctorate degrees in science-related areas.

Data Collection and Analysis

This qualitative research was shaped by constructivism. As an epistemology, constructivism purports that knowledge is formed through individuals' interaction with their environment (Crotty, 1998). Utilizing the constructivist paradigm in this research allows us to focus on the teachers' perspectives and their concerns during the process of curricular enactment. As such, our primary source of data was classroom observations of curriculum enactment over a period of five months. All three teachers' science lessons were observed at least twice per week during the period of data collection. Additional qualitative information was collected from semi-structured interviews, informal conferences before and after the observed lesson, curriculum support meetings, and other informal conversations related to classroom observations. The interviews were transcribed and, along with the notes from other data sources, were read repeatedly, coded, and compared. The resulting emergent themes are indicated in Table 1.

Findings and Discussion

Two distinct themes emerged from the data analysis: consonance, or consensus, among the teachers' perspectives of the efficacy of the IQWST curriculum in promoting scientific literacy; and conflicts that emerged during teachers' enactment of the curriculum.

Consonance

There was a general consensus that the IQWST curriculum allowed for implementation of new instructional approaches, provided narrative texts that enhanced opportunities for students' literacy development, supported the use of questioning as an instructional strategy, and facilitated the enculturation of teachers into the norms of scientific inquiry.

New instructional approaches. Participants agreed that the curriculum provided a rich source of instructional approaches for motivating and promoting deeper understanding among their students. For instance, the 6th-grade physics unit, "Seeing The Light: Can I Believe My Eyes," included activities that explored the laws of reflection; provided evidence that light is scattered when it bounces off paper but reflected when it bounces off shiny surfaces; and investigated how shadows are formed. Maggie indicated that she would not have conceptualized these strategies without the educative materials provided by the curriculum, neither would she have been able to effectively respond to students' common conceptions and misconceptions regarding this topic. She also admitted that students have shown increased motivation as they engage in the various activities that address the driving question for the unit. Additionally, the strategies included in IQWST allowed teachers to anticipate various problems or challenges that often emerge as students investigate scientific phenomena. This allowed them to plan ahead as well as to provide explanations for inconsistencies related to the data collection and organization. In the 7th-grade physics unit, "Why do some things stop and others keep going?," students explored pendulum movement focusing on the weight of the bob and the length of the string. During the discussion, however, Becky anticipated the students' insistence on perpetual motion as an explanation for the behavior of the pendulum activities. Data collected from previous activities provided evidence to challenge their notion of perpetual motion and provided the scaffolding needed to refine their models. Curricula offered suggestions that allowed her to use evidence-based strategies in order to address the misconception of bodies in perpetual motion.

Narrative text. The narrative that accompanies each lesson provides students with the opportunity to make connections with their daily experiences as well as to integrate literacy processes as they interact with science ideas. A story called "The Midnight Crime" was used to introduce a 6th-grade lesson that explored the scattering and reflection of light. The lesson connected to students' experiences by addressing common conceptions of how individuals see shadows and their shapes and positions during the night. This story became the basis for further exploration through scientific investigations that identified claims, evidence, and reasoning. Maggie also explained that students often connected "The Midnight Crime" story to ideas discussed in subsequent lessons after the reading was completed. Three weeks after this reading, one student in her class made reference to the story in his explanation of the size of shadows and the relationship between light source, objects, and the surface on which shadows appear.

Questioning. The IQWST curriculum is inquiry-based and as such requires the teacher to engage the students in asking and answering questions that allow them to see the relevance of specific scientific phenomena to their lives. The curriculum provides teachers with prompts that direct classroom discourse by encouraging students to reflect on ideas developed during the lesson. The general consensus among the teacher participants was that the DQB is an innovative idea, which encourages students to ask questions that arise from their own interests or misunderstandings even if they do not immediately relate to on-going class discussions. Additionally, they agree that this level of student questioning is not typical of traditional science curricula. In conversations with Becky, she constantly muses over the "ease at which the suggested questions and prompts lead to the development of the content." All the teachers confirmed this idea but they also recognized the benefits to students who generated their own questions in response to those being asked by the teacher. Our observations revealed several instances where students took the initiative to write their questions on sticky notes and post them to the DQB. Questioning as an important facet in the process of inquiry-based science along with the integration of literacy practices, therefore, became integral components of the daily science enactment in the middle school classrooms.

Enculturation. The scientific practices required for daily enactment of the IQWST curriculum allowed teachers to become enculturated into the norms of scientific inquiry. For instance, teachers using the educative materials associated with IQWST acquired an understanding of questioning strategies, scientific discourse, and integration of literacy practices in a typical science classroom. One of our teacher participants, Maggie, become very comfortable with this material, and was able to use a certain level of flexibility during enactment that allowed her to contextualize each lesson to make it relevant to state benchmarks and for her diverse classroom. The curriculum, therefore, may be used as a cognitive tool that contributes to lifelong learning as the teachers make adaptations of the various teaching materials.

Conflicts

Despite positive feedback provided by the teacher participants, they struggled with the following issues, some of which are typically associated with the enactment of new curriculum.

Resistance. In the enactment of curriculum, science teachers are responsible for interpreting the curricular text with the focus on students' learning. As the teachers in this study moved from using the traditional text as a curriculum to educative materials that provide a guide, they expressed a loss of control of the pace and development of their lessons and questioned the extent to which the state's benchmarks for science were being addressed. The IQWST curriculum, as discussed prior, incorporates a logical development and iterative progression of content that is not typical of many science textbooks. As a result, pacing became an issue for the teacher participants, who previously employed other strategies to reinforce concepts. Becky and Maggie both expressed levels of discomfort with the learning progression and felt constrained by the ostensibly slow process of allowing the consensus building required by the curriculum. Additionally, they agreed that their tendencies were to move on with the development of the lesson when they "sensed" that students had grasped the concept. "I feel the students get it and we can move on," Becky stated while, according to Maggie, "I sometimes feel that the curriculum holds back the students who are advanced." Taylor noted that because her students would have to face the state's assessment at the end of her year, her focus was to "cover" the benchmarks. She explained, "In the past, I get through the chapters in class and allow the students to continue learning as they read the text."

Teachers questioned the extent to which this curriculum was designed for *their students* who were accustomed to learning the science in traditional ways. The approach suggested in the curriculum requires dynamic interactions with the students' text and provides the opportunity for developing the science principles of the phenomenon under investigation focusing on claims, evidence, and valid reasoning. The interactive nature of the text requires students to document their observations, respond to pertinent questions and, at times, engage in argumentation. This organization, according to Becky, will lead to blank spaces in the students' texts and disenfranchisement of learners because of the reliance on consistency of student attendance. She lamented the lack of an accompanying traditional text to provide easy access to the information

Time management. The activities presented in the curriculum suggest possible time durations while encouraging adaptations in accordance with existing teaching periods. The teachers ignore the suggestions and constantly identify time and timing as areas of conflict. "Not enough time for the activities," "the number of different activities require too much time," and "the reading in class takes time away from instruction," were typical responses to the issue of time requirements. A school wide policy requires routine assignment of *warm-up* tasks to get students settled before the formal teaching. Our observations revealed that teachers spend an excessive amount of time engaging in *teacher talk* about absences, tardiness with assigned work, reviewing of homework assignments and other management issues. When asked about the time taken for these non-science teaching issues, their responses highlighted the importance of these tasks in the holistic functioning of schools. This challenge, according to Taylor is not easily seen unless one is immersed in the full culture of contemporary schooling and understands the managerial requirements of subject area teachers. Another area of time constraint was observed in the assignment of complementary narrative reading as an in-class activity. When challenged and encouraged to investigate whether more of the reading could be done as homework assignments, both Taylor and Becky agreed that it was important to have them read in class so they can be monitored as part of the school's reading initiative. Furthermore, according to Becky, "because this is their only formal resource, I have to ensure that they get it from the text."

Assessment. During the grading period, teachers were typically concerned about the nature and focus of their summative assessment instruments. These concerns were in response to the IQWST curriculum that require students to construct and refine models of their understanding through ongoing data collection and arriving at consensus over time rather than simply accumulating facts. The teachers, therefore, experienced a disconnect between assessment tasks that require recall of snippets of information versus that which measures students' ability to engage in scientific practices that focus on claims, evidence, and reasoning.

Efficacy. The effective enactment of the IQWST curriculum is hampered by teacher competence and knowledge of science content. Data revealed that the materials within the instructor's guide were not used in conjunction with other forms of cognitive support and, as a result, teachers were unable to accurately address various questions and alternative conceptions generated by students. For instance, in Maggie's class, the term *scattering* was sometimes used interchangeably with *reflecting* although both terms refer to two distinct reactions of light rays as they bounce off different objects. There was also a general tendency not to comment on the accuracy of students' conceptions, and teachers sometimes deferred students' questions to the DQB "in the interest of time." Furthermore, the lack of integrated subject matter knowledge limited teachers' ability to provide quality feedback to questions or comments that connected the content with their experiences outside of the classroom. In other words, they were unable to expand on ideas or questions related to the content arising from students' curiosity that also have relevance to the content under development. Teachers were also unable to effectively guide discussions when students tried to generate explanations for observed phenomena. As a result, teachers provided explanations for certain claims rather than having students *figure it out* for themselves. Also, classroom discussions were sometimes observed to involve the teacher and the extroverted students rather than engaging students in discussions among themselves.

Conclusion and Implications

One of the hallmarks of the IQWST curriculum is the inclusion of a coherent instructional sequence aimed at developing deeper levels of student understanding and engagement of scientific practices. Our investigation of the concerns and perspectives of the science teachers as they enacted the curriculum revealed consonance regarding their evaluation of the curriculum as a useful tool in the development of scientific literacy as well as conflicts that emerged during the implementation of the curriculum. These findings have implications for classroom research and practice. During the process of curriculum enactment, teachers should be engaged in intentional study of their own professional practice through practitioner research. Such efforts would allow them to advance their own practice and contribute to the existing knowledge base on curriculum. In addition, our findings also inform curriculum designers of the importance of teachers' involvement in the curriculum design process and how curriculum materials are presented to teachers during pre-implementation training sessions. Curriculum should not be a static document, but rather one that is continuously being shaped and reshaped by the input of the teachers who enact it. Cases of resistance from teachers who may feel a loss of autonomy or professional creativity with the use of a scripted curriculum complemented by substantive educative materials may likely be reduced when the teachers have positioned themselves as members of the curriculum process.

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Table 1

Summary of Issues Associated with Implementing an Evidence-based Middle School Science Curriculum

Themes	Codes	Descriptors
Consonance	New Instructional Approaches	Rich source of instructional approaches Anticipation of students' misconceptions
	Narrative Text	Students are able to make connections with daily experiences
	Questioning	Encourage students to ask questions relevant to their lives Provide teachers with prompts that direct classroom discourse
	Enculturation	Enculturate teachers into norms of scientific inquiry
Conflicts	Resistance	Loss of autonomy with respect to development of the lesson
	Time Management	Extended warm-up exercises Other housekeeping activities, such as organizing notebooks
	Assessment	Disconnect between summative assessments that require recall of scientific facts versus their level of engagement in scientific practices.
	Efficacy	Lack of science content knowledge affected the quality of the scientific discourse