Inquiry-based Instruction in Secondary Science Classrooms: A Survey of Teacher Practice

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Abstract

The purpose of this paper is to present findings from survey research that examined the extent to which secondary science teachers, who were certified through Connecticut's BEST portfolio assessment process between 1997 and 2004 and had taught secondary science during the past academic year, reported practicing the indicators of inquiry-based instruction in the classroom and the factors that they perceived facilitated, obstructed, or informed that practice. Indicators of inquiry-based instruction were derived from Bybee's (1997) 5E model. The method for data collection was a researcher-developed, self-report, questionnaire that was disseminated using a slightly modified Dillman (2000) approach. Nearly all of the respondents reported practicing 5Es of inquiry-based instruction in their secondary science classrooms. Further, a majority of respondents indicated that they had access to the factors that they considered extremely important to the practice of inquiry-based instruction.

Background and Rationale

At the beginning of the twentieth century, the science content taught in secondary classrooms was viewed as information to be memorized and mentally compartmentalized (Lawson, 1995). Later, teaching methods shifted to students making meaning of knowledge and developing reasoning skills. Today, science pedagogy supports the view that science is a process as well as a body of knowledge (National Research Council [NRC], 1996). The use of inquiry-based teaching and learning as a method of presenting and acquiring scientific knowledge gained acceptance in the 1960s (NRC, 2000, p. 15). Current learning theory supports the use of inquiry-based teaching and learning in science classrooms (Bransford, Brown, & Cocking, 2000; Bruner, 1977, 1996; DeBoer, 1991; Jensen, 1998; NRC, 1996, 2000, 2003). Moreover, inquiry-based teaching and learning provided the basis for the philosophy of the National Science Education Standards (hereafter referred to as "the Standards") published by the NRC in 1996. While the Standards recognized inquiry-based instruction as one of several instructional strategy to meet the needs of all students, they also emphasized inquiry-based instruction as a means for balancing the more traditional approaches to science instruction that persist in many classrooms (NRC, 1996, 2003).

Teaching Secondary Science in Connecticut

In Connecticut, the Standards (NRC, 1996) have served as the foundation for current teacher certification in science and the expectations of teacher practice secondary science classrooms for ten years. Furthermore and related to this investigation, beginning science teachers must demonstrate the ability to teach in an inquiry-based manner as part of the science portfolio (CSDE, 2004b). This ability is assessed through the science teaching portfolio that is part of the Beginning Educator Support and Training (BEST) program for all beginning science teachers; it requires candidates to demonstrate the ability to plan a two-week unit, teach the unit, and assess student learning (CSDE, 2004a).

In 1993, the Connecticut State Department of Education (CSDE), in collaboration with practicing science educators, developed the Science Education Support and Assessment Program (SESAP; Lomask & Baron, 1995). The goals of this program included recognizing the various stages of development that beginning teachers go through and providing resources to assist them during the process. The expectation was that this process would positively affect a teacher's professional growth and ultimately, student learning. The CSDE recognized that an individual's evolution into a practicing educator takes time: "Only after committing themselves to classroom teaching, do teachers begin the long process of learning how to transform their own knowledge of science into a coordinated set of learning activities that are relevant, accessible and meaningful to their students" (p. 2).

As the Standards were released in 1996, the CSDE Bureau of Certification was piloting a science performance assessment. The original science portfolio assessment included dimensions of knowledge for teacher assessment and professional science teaching standards (Lomask & Baron, 1995, pp. 12 - 14). Shortly thereafter, in 1999, the CSDE released the most recent version of the teaching standards, the Common Core of Teaching (CCT), which outlined three phases in the teaching career. During the first phase, called the pre-service phase, prospective teachers are expected to demonstrate knowledge about the Connecticut standards of teaching (i.e., CCT) and learning (i.e., Common Core of Learning [CCL]). They are also expected to demonstrate knowledge about the instruments that are used annually to assess student learning, the Connecticut Mastery Test (CMT) and the Connecticut Academic Performance Test (CAPT).

During the second phase, called the induction phase, teachers complete the BEST portfolio, demonstrating competence in foundational skills and competencies and discipline-based professional standards. The third phase, denoted continuous professional growth, outlines the standards for teacher evaluation and guidelines for professional development (CSDE, 1999, p.1).

It is during the induction phase that prospective secondary science teachers, the subject of this study, must produce a science, teaching portfolio. The dimensions of knowledge for teacher assessment that were the basis for the original science portfolio assessment were: (a) knowledge of students as learners of science, (b) knowledge of science as a discipline, (c) knowledge of science teaching, and (d) professionalism and leadership (Lomask & Baron, 1995, p. 12). Likewise, the professional science teaching standards included were: (a) planning for students' learning, (b) facilitating students' learning, (c) reflecting on students' learning and (d) supporting students' learning (Lomask & Baron, 1995, pp. 13 - 14).

Similarly, the 1999 version of the CCT outlined the requisite foundational skills and teaching competencies for prospective teachers. Of note are the following three foundational skills and competencies that teachers must demonstrate: (a) teachers have knowledge of students, content, and pedagogy; (b) teachers apply this knowledge by planning, instructing, and assessing and adjusting; and (c) teachers demonstrate professional responsibility through professional and ethical practice, reflecting and continuous learning, and leadership and collaboration (CSDE, 1999, p. 3).

In the BEST portfolio, beginning teachers demonstrate their instructional competency and their ability to implement the professional teaching standards set forth in the CCT (CSDE, 1999). Beginning science teachers must also demonstrate content knowledge and pedagogy as outlined in the discipline-based professional teaching standards for teachers of science (CSDE, 1999). Specifically, science teachers must demonstrate competence related to: (a) science nature and content, (b) science logic and construction of knowledge, (c) science context and applications, (d) students' diversity, (e) learning environment, and (f) instructional resources (CSDE, 1999, p. 23). Furthermore, a recent handbook for the development of the science, teaching portfolio states that

> the CCT standards should be foremost in guiding the work of all science teachers. . . . The National Science Education Standards, as well as the Connecticut Science Framework, define science literacy as the understanding of the content of science (life, physical and earth science concepts and theories), the nature of science (inquiry), and the context of science (historical, societal and technological aspects). (CSDE, 2005a, p. 14)

The 5E Model of Inquiry

The Connecticut State Department of Education's framework of inquiry-based instruction for the science classroom as presented in the BEST portfolio assessment program (CSDE, 2001a) served as a conceptual framework for this study. Specifically, the focus was on the indicators of inquiry-based instruction as identified in the CSDE BEST training manual for science portfolio scorers (CSDE, 2001a), which were based upon the "5E" model of inquiry (CSDE, 2001a) and were adopted from the Biological Sciences Curriculum Study (BSCS) 5E model (Bybee, 1997).

The instructional model put forth by Bybee (1997) was founded in a constructivist approach to teaching and learning: "Constructivism is a dynamic and interactive model of how humans learn" (p. 176). Bybee's assumption is that teachers should ordinarily use strategies that enable students to take an active role in their learning and the construction of knowledge. Bybee's instructional model consists of a five phase learning cycle known as the 5Es: Engage, Explore, Explain, Elaborate, and Evaluate. Furthermore, as an instructional model, Bybee's 5Es provide the active learning experiences described in the Standards (NRC, 1996).

Engage

Engagement encompasses specific teacher practices related to the ways in which a teacher involves students in learning the content and concepts of a unit of study through, among other strategies, the use of scientifically oriented questions (CSDE, 2001a; Trowbridge & Bybee, 1990). If the teacher asks students what they know or observe about a phenomenon or event related to the unit at the start of the study, students connect the event or topic observed with " . . . . what they already know, (which) creates dissonance with their own ideas, and/or motivates them to learn more" (NRC, 2000, p. 35). The research has shown that teachers in these classrooms engage students with activities such as using a KWL chart (What do I know? What do I want to know? What did I learn?) at the beginning of a unit, probing questions, or brainstorming sessions on the topic under study, drawing out responses that uncover what students know or think about the topic (Trowbridge & Bybee, 1990).

Explore

Indicators of a classroom characterized by exploration include a setting where the teacher encourages students to collaborate without providing direct instruction, in effect acting as a consultant rather than as an authority on the subject (CSDE, 2001a; Trowbridge & Bybee, 1990). The teacher in such settings also observes and listens to student interactions, asking probing questions to re-direct investigations if necessary and providing time for students to work through problems (Trowbridge & Bybee, 1990). In these classrooms, teachers use activities that provide students with opportunities to investigate a unit-related problem through hands-on experiences that culminate in the formulation and testing of a hypothesis, problem-solving and the creation of explanations for what students observed (NRC, 2000, p. 35).

Explain

Explain covers the stage where students analyze and interpret the data to synthesize ideas, build models, and clarify concepts (Bybee, 1997; CSDE, 2001a). The evidence that students collect is used to justify the explanations they develop (NRC, 2000, p. 35). Indicators of a classroom characterized by explanation include when the teacher asks students to give explanations in their own words, including clarifications and justifications for their thinking. At this point, the teacher might also present more formal definitions, directions, and labels or explanations for students (Trowbridge & Bybee, 1990).

Elaborate

Instructional strategies that promote elaboration include those used during the explanation stage and ones where the teacher serves to guide or re-direct student thinking (CSDE, 2001a; Trowbridge & Bybee, 1990). The goal is to have students "extend their new understanding and abilities and apply what they have learned to new situations" (NRC, 2000, p. 35). Teachers expect students to use formal labels and definitions learned in class during the explanation stage. They ordinarily remind students of alternative explanations and encourage them to apply and extend new concepts and skills in new situations. (Bybee, 1997).

Evaluate

The final dimension of the conceptual framework is evaluate and evaluation should be embedded in every step of the instructional model (CSDE, 2001a; Trowbridge & Bybee, 1990). In a classroom characterized by evaluation, students and their teachers review and assess that which they have learned in light of other explanations and how it was learned it (NRC, 2000, p.

35). As teachers evaluate students learning they observe students applying new concepts and skills, assess their knowledge and skills and look for evidence that students have changed their behavior or thinking as a result of their new learning. Additional indicators of this phase of inquiry-based instruction include teachers providing formative feedback to students to enhance student thinking and skills and, students evaluating their own performance, learning and group-process skills (Trowbridge & Bybee, 1990).

Facilitators and Obstacles to Inquiry-based Instruction

While inquiry-based instruction continues to be a highly recommended practice for teaching science, research has shown that there are facilitators and obstacles to this practice (Beyard, 2003; Goossen, 2002; Louden, 1997; Luft, 2001; Marlow & Stevens, 1999; NRC, 2000, 2003). Among the factors reported as affecting teacher's practice of inquiry-based instruction are: time, resources, professional development, science topic or content, and mandatory assessments.

The factor time refers to the length of a class period (i.e., block versus non-block schedule), semester or school year such that the teacher makes a decision to practice inquiry-based instruction if the teacher feels that there is sufficient time to do so (Louden, 1997). The resource factor refers to the equipment or materials, supplemental to a course text, that affect inquiry-based instruction. Resources may include laboratory equipment, online access, etc. The professional development factor refers to the training that teachers receive to inform their practice of inquiry-based instruction and increase their pedagogical knowledge and confidence in this practice (Luft, 2001; NRC, 2003). The research has shown that certain science content or topic(s) may lend themselves to a more inquiry-based approach and therefore be a factor in a teacher's conscious pedagogical approach (Marlow & Stevens, 1999). Finally, it has been shown that the need to administer high-stakes mandatory assessments may force a teacher to make choices between using an approach that encourages more student inquiry and covering material for an exam (NRC, 2000, 2003).

Research Focus

Despite Connecticut's history of assessing beginning secondary science teachers through BEST, we knew little about whether teachers who had been certified through the state's portfolio assessment process as capable of teaching in an inquiry-based fashion continued to practice this model of instruction once they have been deemed qualified to do so. Therefore, the purpose of this investigation was to describe the extent to which secondary science teachers in Connecticut, who were certified under the Connecticut BEST portfolio assessment, between 1997 and 2004, and who had taught secondary science during the past academic year: (a) reported practicing the indicators of inquiry-based instruction in the classroom and (b) the factors that they perceived facilitated, obstructed, or informed that practice. These indicators are based upon the "5E" model of inquiry (CSDE, 2001a) described by Lawson (1995) and adopted from BSCS (1992) 5E model (Trowbridge & Bybee, 1990).

As such, the following research questions guided the investigation.

1. To what extent do teachers report practicing the indicators of inquiry-based instruction, as delineated in the 5E model (CSDE, 2001a)?
2. What factors do teachers report facilitate or obstruct implementation of inquiry-based instruction?

3. What factors do teachers report best informed their practice of inquiry-based instruction?

Methodology

Given the purpose of this study, describing secondary science teachers' reports of the extent to which they continued to practiced inquiry-based instruction in the classroom and the factors that they perceived facilitated or obstructed that practice, a cross-sectional, survey design was selected to answer the research questions. According to Creswell (2000), this type of design is appropriate when the aim of an investigation is to collect data about opinions or beliefs at one point in time, as was the case in this investigation. A single instrument, a researcher-developed, self-report, questionnaire, was used to collect data. Further, the design and construction of the questionnaire and the study procedures followed the recommendations in Dillman's (2000) *Mail and Internet Surveys: The Tailored Design Method.*

Instrument

The Inquiry-based Instruction in Secondary Science Classrooms: A Survey (IISSC) is a three part questionnaire that was designed to assess teachers reports of the extent to which they continued to practiced inquiry-based instruction in the classroom and the factors that they perceived facilitated or obstructed that practice (Appendix A). Part I contains 35 items that are aligned with the indicators of inquiry-based instruction identified in the BEST training manual for science portfolio scorers and based on the "5E" model of inquiry (CSDE, 2001a) adopted from the BSCS (1992) 5E model (Trowbridge & Bybee, 1990). With their entire teaching assignment in mind, respondents are asked to indicate, on a Likert-scale, the extent to which they practice the indicators of inquiry-based instruction in their classrooms. The final item in Part I, asks teachers to rank order the top three experiences or resources that most informed their understanding of how to teach in an inquiry based fashion.

Part II of the IISSC contains a series of nine items designed to collect information about the factors that teachers perceived as facilitators and obstacles to the implementation of inquiry-based instruction in the secondary science classroom. The final item in Part II asks respondents to rank order a list of six possible obstacles to the implementation of inquiry-based instruction the classroom. Part III of the IISSC contains six demographic questions.

Validity (both content and construct) of the IISSC was addressed during the development of the instrument. Following Creswell's (2002) advice, three steps were taken. First, the purpose of the questionnaire was defined, as noted above. Second, the content was based on a review of the related literature and items were directly connected to the conceptual framework. Third, the questionnaire was pilot tested. The pilot participants included a university physics professor who provides professional development and instructs science teachers; a science administrator at a public high school; and six science teachers, one retired high school teacher, three high school teachers, and two middle school teachers. This study was the first time IISSC was used; there are no data available on its reliability.

Procedures

The sample for this study was the 820 secondary science teachers certified in Connecticut under the BEST portfolio assessment between 1997 and 2004 and teaching during the 2005-2006 school year; a list of names and addresses was obtained from the Bureau of Educator Preparation, Certification, Support and Assessment of the Connecticut State Department of

Education. The data collection procedures followed a slightly modified version of Dillman's (2000) method. One week before the mailing of the questionnaire, a postcard was sent to each of the 820 teachers, informing them that the survey would be arriving shortly and requesting their response. The questionnaire, with detailed cover letter, a copy of the informed consent, and a self-addressed envelope with first class postage, was then mailed. Approximately two weeks after the questionnaire had been mailed out, a thank-you postcard was sent expressing appreciation for participation. This postcard included a reminder to return the survey if recipients have not yet done so and an email address for the request of another copy of the questionnaire. Six weeks later, a final mailing of postcards was sent in an effort to secure responses from those recipients who had yet to respond.

Of the 820 teachers surveyed, 304 teachers returned surveys, a response rate of 37.1%. Table 1 contains data about study participants' reports of the years in which they submitted their BEST portfolio. Of the sub-sample of teachers responding to this item (n = 304), 3.9% (n = 12) of the study participants reported that they submitted a portfolio in 1997; this number increased each successive year, with the exception of 2003, to 21.4% (n = 65) of the sub-sample of respondents indicating that they submitted a portfolio in 2004.

Table 1

Sample Distribution by Year of Portfolio Submission (N = 304)

Year	*n*	%
1997	12	3.9
1998	25	8.2
1999	27	8.9
2000	30	9.9
2001	48	15.8
2002	55	18.1
2003	42	13.8
2004	65	21.4

A majority (59.9%) of the survey respondents indicated that they taught in a high school as opposed to a middle/junior (38.5%) high school setting. All of the science disciplines, with the exception of general science, were represented in this sample. Table 2 displays the subject taught by those who responded to this survey item. Among the subjects reported under the category other, were forensic science, environmental science and advanced placement courses.

Table 2

Science Subject Taught (N = 304)

Science Subject	*n*	%
Biology/life science	134	44.1
Chemistry	68	22.4
Physics	61	20.1
Earth science	56	18.4
Other	60	19.7

Data Analysis

Data from the IISSC were entered into SPSS 11.5 for Windows and a statistical analysis was conducted. Frequency distributions and percentages were calculated for each item. The data were represented and summarized using tables. Additionally, the 35 items that related directly to indicators of each of the five essential elements of inquiry-based instruction were included in a factor analysis. A ten-factor solution accounting for 70% of the interitem variance was obtained. All of these items had a factor loading of greater than .486 and each item loads on one factor.

Results

Teachers' Reports of Practicing Indicators of Inquiry-based Instruction

Part I of the IISSC contained 35 items designed to measure teachers' reports of the extent to which they practiced the 5Es (engage, explore, explain, elaborate, evaluate) of inquiry-based instruction in their secondary classrooms. The data revealed that the secondary science teachers in this study indicated practicing 27 (77.7%) of the 35 indicators of inquiry-based instruction either always or sometimes during a one-month period before completing the survey. Table 3 depicts survey respondents' reports of their practice.

More specifically, the IISSC included three items that measured survey respondents' reports of practicing the indicator engagement in their classrooms. The data indicate that 87.8% of the teachers in this study began lessons with a probing question either always or sometimes and 72.4% used brainstorming either always or sometimes.

Four items measured respondents' reports of practicing the indicator exploration. In this case, 99% of respondents reported observing student interactions either always or sometimes and

99.4% indicated that they redirected students' thinking with a probing question either always or sometimes.

The IISSC contained 8 items that were designed to measure teachers' reports of practicing the indicator explanation in their classrooms. The data indicate that 98.7% of the teachers in this investigation asked students to explain concepts in their own words either always or sometimes. Additionally, 98% of respondents reported they provided directions for students either always or sometimes.

There were nine items in the IISSC that measured teachers' reports of practicing the indicator elaboration in their classrooms. The data indicate that 98.4% of the survey respondents reported encouraging students to apply concepts in new situations either always or sometimes, 97.7% encouraged students to extend concepts in new situations either always or sometimes, and 97.7% encouraged students to apply skills in new situations either always or sometimes.

Finally, the IISSC included 11 items that were designed to measure respondents' reports of practicing the indicator evaluation in their classrooms. The data indicate that 98.7% of the teachers in this study indicated they observed students as they applied new skills either always or sometimes. Similarly, 98.3% of the teachers in this study reported they observed students as they applied new concepts either always or sometimes.

Table 3

Respondents' Reports of Practicing the 5Es of Inquiry-based Instruction (N = 304)

5Es and Indicators	*n*	Always		Sometimes		Rarely		Never	
		n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Engagement									
Begin Lesson with Probing Questions	296	72	23.7	195	64.1	31	10.2	2	0.7
Begin Lesson with Brainstorming	298	23	7.6	197	64.8	69	22.7	12	3.9
Ask Students for Information	298	16	5.3	107	35.2	100	32.9	78	25.7
Exploration									
Observe Student Interactions	302	263	86.5	38	12.5	1	.3		
Ask Probing Questions to Redirect Students	304	231	76.0	71	23.4	2	.7		
Act as Consultant for Students	302	211	69.4	88	28.9	3	1.0		
Create Opportunities for Students to Work Together	304	111	36.5	178	58.6	13	4.3	2	.7
Explanation									
Ask Students to Explain Concepts	304	215	70.7	85	28.0	4	1.3		
Ask Students to Justify Their Thinking	303	206	67.8	90	29.6	6	2.0	1	.3
Draw on Students' Previous Experiences	297	201	66.1	94	30.9	2	.7		
Ask Students to Clarify Their Thinking	302	190	62.5	105	34.5	6	2.0	1	.3
Ask Students to Explain Definitions	304	187	61.5	107	35.2	7	2.3	3	1.0
Provide Directions for Students	304	153	50.3	145	47.7	6	2.0		
Provide Explanation for Students	303	126	41.4	161	53.0	15	4.9	1	.3
Provide New Labels for Diagrams	274	54	17.8	160	52.6	48	15.8	12	3.9

Table 3 (continued).

5Es and Indicators	n	Always		Sometimes		Rarely		Never	
		n	%	*n*	%	*n*	%	*n*	%
Elaboration									
Encourage Students to Apply Concepts	304	224	73.7	75	24.7	5	1.6		
Encourage Students to Apply Skills	302	218	71.7	79	26.0	5	1.6		
Encourage Students to Extend Concepts	304	205	67.4	92	30.3	7	2.3		
Encourage Students to Extend Skills	304	197	64.8	99	32.6	8	2.6		
Refer Students to Existing Evidence	301	159	52.3	134	44.1	7	2.3	1	.3
Remind Students of Alternative Explanations	304	129	42.4	162	53.3	12	3.9	1	.3
Expect Students to Use Explanations	297	120	39.5	158	52.0	17	5.6	2	.7
Expect Students to Use Definitions	301	112	36.8	160	52.6	26	8.6	3	1.0
Expect Students to Use Labels	284	105	34.5	136	44.7	30	9.9	13	4.3
Evaluation									
Assess Students' Knowledge	303	267	87.8	36	11.8				
Observe Students Applying New Concepts	304	236	77.6	63	20.7	5	1.6		
Observe Students Applying New Skills	304	235	77.3	65	21.4	4	1.3		
Assess Students' Skills	304	234	77.0	66	21.7	4	1.3		
Provide Students with Feedback to Enhance Thinking	301	182	59.9	114	37.5	5	1.6		
Provide Students with Feedback to Enhance Skills	301	182	59.9	114	37.5	5	1.6		
Ask Open-ended Questions	300	162	53.3	131	43.1	6	2.0	1	.3
Look for Evidence of Changed Behavior	301	155	51.0	118	38.8	26	8.6	2	.7
Look for Evidence of Changed Thinking	301	151	49.7	130	42.8	17	5.6	3	1.0
Allow Students to Assess Their Own Learning	302	72	23.7	176	57.9	49	16.1	5	1.6
Allow Students to Assess Their Group Skills	302	53	17.4	165	54.3	70	23.0	14	4.6

Teachers' Reports of the Experiences and Resources that Informed Their Understanding of How to Teach in an Inquiry-based Manner

Part I of the IISSC contained one item that measured survey respondents' reports of the experiences or resources that most informed their understanding of how to teach in an inquiry-based manner. Teachers were asked to select and rank order three items from the list, from greatest (1) to least (3). Classroom experience was identified by 77% of respondents as the number 1, 2, or 3 factor informing their understanding of how to teach in an inquiry-based manner. Further, 56% of the study participants reported that a science discipline teaching colleague was the number 2 or 3 factor that informed their understanding of how to teach in an inquiry-based manner. Table 4 depicts respondents' reports.

Table 4

Factor(s) that Informed Teachers' Understanding of Inquiry-based Instruction (N = 304)

Factor	First Choice		Second Choice		Third Choice	
	n	%	*n*	%	*n*	%
Classroom experience	120	39.7	63	20.9	43	14.2
Science teacher colleague	42	13.9	83	27.5	38	12.6
College coursework	34	11.3	13	4.3	32	10.6
Professional development	26	8.6	44	14.6	40	13.2
Other	21	7.0	10	3.3	13	4.3
Student teaching	14	4.6	23	7.6	22	7.3
BEST portfolio completion	11	3.6	14	4.6	22	7.3
BEST induction seminar(s)	7	2.3	8	2.6	11	3.6
BEST mentor	5	1.7	6	2.0	5	1.7
Book	3	1.0	5	1.7	12	4.0
Teacher colleague	1	.3	3	1.0	14	4.6
NSES	1	.3	4	1.3	6	2.0
CCT	-	-	2	.7	5	1.7
Website	-	-	3	1.0	14	4.6

Teachers' Reports of Factors that Facilitate Inquiry-based Instruction

Part II of the IISSC contained five items designed to measure teachers' reports of the importance of factors that are known to facilitate decisions to practice inquiry-based instruction and five items that measured the degree teachers felt they had access to those factors. Results indicate that 77.6% of the study participants reported that time was extremely or reasonably important in their decisions to practice inquiry-based instruction in their science classrooms. Additionally, 77.2% of the teachers indicated that resources were extremely or reasonably important in their decisions to practice inquiry-based instruction in their science classrooms. Table 5 depicts the survey respondents' reports of the importance of the factors that are known to facilitate the practice of inquiry-based instruction.

Table 5

Importance of Factors Known to Facilitate the Practice of Inquiry-based Instruction (N = 304)

Factor	*n*	Extremely Important		Reasonably Important		Somewhat Important		Not at all Important	
		n	%	*n*	%	*n*	%	*n*	%
Time	304	132	43.4	104	34.2	41	13.5	27	8.9
Resources	303	101	33.3	133	43.9	45	14.9	24	7.9
Professional Development	303	58	19.1	96	31.6	105	34.5	44	14.5
Science Topic	302	97	32.1	122	40.4	61	20.2	22	73
Mandated Testing	303	112	37.0	103	34.0	60	19.8	28	9.2

Respondents were also asked to report the degree to which they felt they had access to each of the facilitators of inquiry-based instruction (time, resources, professional development) and the degree to which the science topic affected their ability to practice inquiry-based instruction. Table 6 depicts study participants' reports of their access to these factors. The data indicate 69.4% of teachers in this investigation reported they strongly agreed or agreed that they had to time to practice inquiry-based instruction. Likewise, 69.4% reported that they strongly agreed or agreed that they had access to needed resources. Finally, 68.7% of the survey respondents indicated that they strongly agreed or agreed that the science topic affected their ability to practice inquiry-based instruction.

Table 6

Access to Factors that Facilitate Inquiry-based Instruction (N = 304)

Factor	*n*	Strongly Agree		Agree		Disagree		Strongly Disagree	
		n	%	*n*	%	*n*	%	*n*	%
Time	304	42	13.8	169	55.6	76	25.0	17	5.6
Resources	304	52	17.1	159	52.3	80	26.3	13	4.3
Professional Development	302	26	8.6	143	47.4	99	32.8	34	11.3

Teachers' Reports of Factors that Obstruct Inquiry-based Instruction

Part II of the IISSC contained one item that measured teachers' reports of the factors that obstructed their practice of inquiry-based instruction. Teachers were asked to rank order these factors from greatest (1) to least (5) as obstacles to their practice. The data collected from this survey show that the most common rank ordering of factors as obstacles was time, science topic, the need to cover material for mandated testing, professional development on inquiry-based instruction, and resources. The data indicate 64.5% of the survey respondents ranked time as the number 1 or number 2 obstacle to practicing inquiry-based instruction. Additionally, 55.4% of the survey respondents ranked the need to cover material for mandated testing as the number 1 or number 2 obstacle to practicing inquiry-based instruction.

Discussion

The aim of this investigation was to describe the extent to which secondary science teachers in Connecticut, who were certified under the Connecticut BEST portfolio assessment between 1997 and 2004, and who had taught secondary science during the past academic year: (a) reported practicing the indicators of inquiry-based instruction in the classroom and (b) the factors that they perceived facilitated, obstructed, or informed that practice. Almost all of the study participants reported practicing the 5Es (engage, explore, explain, elaborate, and evaluate) of inquiry-based instruction (CSDE, 2004b) in their secondary science classrooms. Moreover, a majority of respondents in this investigation indicated that they had access to the factors that they considered extremely important to the practice of inquiry-based instruction.

The differences between the practice and teaching environment of Connecticut teachers and teachers in other states may be related to at least three conditions. First, a secondary science teacher in Connecticut is required to demonstrate an understanding of, and the ability to implement, inquiry-based instruction. This requirement demands that the teacher be familiar with the approach. Second, the Connecticut statewide assessment of student learning (CAPT) includes a component that evaluates competency in some inquiry skills, although the assessment contains more items that focus on content. Finally, the teachers who participated in this survey ranked classroom experience as the primary factor in informing their understanding of inquiry-based instruction. Their second factor was a science-teaching colleague. Connecticut’s SDE recognizes the professional growth that occurs as teachers practice their craft. The state has a teacher-in-residence for each content area whose responsibilities include providing a practitioner’s perspective in the development of policy and procedures at the state level, serving as an information resource to school districts trying to interpret policies and procedures, and acting as a liaison between the SDE and school district personnel.

Implications for Practice

States and local boards of education should allocate sufficient resources to support the practice of inquiry-based instruction. In a classroom that promotes inquiry-based instruction, learning resources must be available to support student inquiry. Learning resources can include, but not be limited to laboratory equipment, printed and electronic documents, educational technology, mentors, and speakers. Each school district should have a five-year plan that identifies goals and needed resources for science program implementation in grades Pre-K – 12.

The Horizon study (NRC, 2003) confirmed the NSES (NRC, 1996) position that implementation of the Standards to the degree that they will have impact on science teaching and learning will not happen unless substantial funding is available. In 2003, the administration implemented a new initiative aimed at improving the quality of math and science instruction throughout the United States. Originally, $100 million was allocated to this purpose and the funding for 2004 and 2005 was increased from $149 million to $180 million respectively. After the funding has Congressional approval, each state receives and manages its funds through several sources including the Title II, Part A grant and the Mathematics and Science Partnership (MSP) grants. Although districts receive entitlement grants based upon demographic formulas, the MSP grants are competitive.

School districts depend upon federal, state, and local funding to support professional development. District-wide professional development is difficult to plan when the amount of funding is uncertain from year to year. Educational Cost Sharing funds, Special Education costs, and utility costs are a few of the variables that are unknown until late in the school year. Due to the uncertainty of local fund sources, it is imperative that the federal government increase funding for enhanced teacher training, particularly in the areas of math and science.

In order for this funding to have an impact on teacher practice, professional development that is sustained (at least 80 hours of focused training) and conducted by experts in pedagogy must be a priority. MSP grants currently require that a school district collaborate with an institution of higher education to serve as content area experts. Although college faculty may serve as content area experts, their experience in teaching students in grades 7–12 may be limited or non-existent, therefore, the dimensions of inquiry-based instruction across grade levels and knowledge of developmental learning should not be overlooked in designing professional development on content pedagogy.

Likewise, school districts should consider implementing block scheduling in secondary science classrooms to provide adequate amounts of time for teachers to practice inquiry-based instruction. The findings from this study reflect those from national research (NRC, 2003) that show time to be an important factor in the implementation of inquiry-based instruction. Given the demands placed upon teachers and the diversity of student needs in the classroom, the popular perception is that teachers often lack the time to complete daily objectives. Inquiry as a teaching and learning process does require more time for students to construct knowledge in an individual manner (NRC, 1996).

The traditional high school class period is approximately 45 minutes. In some high school settings, those students taking a science course that includes a laboratory section may have a double period of the science course every fifth or sixth day. This allows a double period for science lab activities. Those high schools that employ a block schedule have longer class periods.

In a configuration known as the AB block schedule, classes meet for 80 minutes or more every other day for the entire semester. In the 4-by-4 block, the student takes four 80 minute classes for one semester and another four 80 minute classes for the next semester. There is debate over the value of block scheduling; whether the advantages (e.g., longer class periods for in-depth discussion and more concentrated study) outweigh the disadvantages (e.g., students missing one class period miss a larger amount of content and discussion). Nevertheless, extended class time would allow for deeper investigations and learning, in addition to opportunities for students to demonstrate their learning in various, authentic ways.

Finally, the teachers who participated in this study reported that the two most important experiences or resources that informed their understanding of inquiry-based instruction were classroom experience and a colleague who taught in the science area. Creating a dialogue between practitioners of varying levels of expertise and understanding would create a powerful resource that science teachers would have access to within their own school. The findings from this study suggest that the creation of professional learning communities (Hord, 2004) focused on the practice of inquiry-based instruction has the potential to deeply affect teacher practice and ultimately student achievement.

Even more specialized communities of practice involve people ". . . bound together by shared expertise and passion for joint enterprise" (Wenger & Snyder, 1999, p. 139). Originally a business phenomenon, communities of practice are, not surprisingly, breaking into the educational domain because their appeal is strongest for those who crave knowledge (Hodkinson & Hodkinson, 2003). Communities of practice assist practitioners in solving problems, developing new strategies, creating innovations, and keeping abreast of new ideas and personal development, to name just a few benefits. This study of secondary science teachers has shown that the respondents highly value their colleagues' feedback on inquiry-based instruction. Teachers should have the opportunity to develop the collegial network within their school, district, professional organization or discipline to enhance their practice.

Schools and districts should facilitate and provide resources for the development of communities of practice focused on inquiry-based instruction in science classrooms. Opportunities for teachers to reflect upon their practice and support each other in the professional setting are keys to professional growth (Hord, 2004). District and building administration should support the growth of communities of practice by scheduling common planning time and providing resources for release time for teachers. This time is necessary for teachers with common expertise (inquiry-based instruction) to meet and identify the key areas of interest and study (domain), develop a relationship, and refine their practice.

Implications for Future Research

To expand our understanding of inquiry-based practices in secondary science classrooms, research should be conducted using a valid, reliable instrument for observing teachers' inquiry-based practices. This descriptive study relied on the use of a single method, a survey, through which secondary science teachers self-reported their classroom practices. A future study should incorporate observations of this cohort of teachers so that we can more fully understand their reports of their classroom practices. Additionally, this study could be repeated in other states in an effort to gauge teachers' use of inquiry-based instruction. This type of investigation could incorporate data paired with an analysis of student performance on standardized tests to determine what, if any, relationship exists between science teacher's reports of their classroom practices and student achievement.

Limitations

The limitations of the present study are derived from its design and implementation. First, the IISSC was developed by the researchers and this is the first time it has been used. Second, a single method was used to collect data. Study participants volunteered the information requested but they were not observed or interviewed personally, although there were several opportunities for respondents to add comments to the survey. Third, the intent was to use the entire population of teachers certified during the expressed time; nevertheless, those teachers who had not taught within one year of receiving the survey or who were not teaching in public schools were not included in the sample.

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Appendix

"Inquiry-based Instruction in Secondary Science Classrooms: A Survey"

**Inquiry-based Instruction in Secondary Science Classrooms:
A Survey**

This questionnaire is part of a study designed to explore the degree to which secondary science teachers in Connecticut report using inquiry-based practices when they teach science. The survey is being sent only to secondary science teachers who have submitted a teaching portfolio in the years 1998 through 2004 to the Connecticut State Department of Education as part of the teaching certification process known as the Beginning Educator Support and Training (BEST) program. While inquiry-based instruction may look different from one classroom to the next, the essential features of classroom inquiry are:

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically-oriented questions.
- Learners communicate and justify their proposed explanations.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.

(Adapted from CSDE, 2001)

Your participation is **voluntary** and by returning this survey you are giving me permission to use this information in this study. Your opinion is extremely valuable and there are no right or wrong answers.

There are three parts to this questionnaire. There are a total of 49 questions in Parts I and II, and six questions intended to collect demographic information in Part III. Please **DO NOT place your name on this questionnaire** (or the name of your school). Your answers will not be associated with your name and will be grouped with the answers of other respondents.

If you have questions about this questionnaire, please contact Linda Gejda at 203-729-7808 or lag@snet.net, Dr. Diana J. LaRocco at 860-768-5807 or dlarocco@hartford.edu, or Dr. Peter Kennedy 860-768-4823 or pkennedy@hartford.edu.

Return your form in the enclosed addressed stamped envelope by December 1, 2005 to:
Linda Gejda
75 Buckingham Drive
Beacon Falls, CT 06403

Instructions:

Please follow these instructions exactly.

1. Please DO NOT place your name or the name of your school on this questionnaire.
2. Read each item.
3. Follow the directions for each part of the survey.
4. Do not skip any items.
5. Return your form in the addressed stamped envelope by December 1, 2005.

**Inquiry-based Instruction in Secondary Science Classrooms:
A Survey**

PART I: **Indicators of Inquiry-based Science Instruction**

Directions: The table on the following page contains a list of statements describing the indicators of inquiry-based instruction. Reflect on all of the **science** classes that you teach **during the period of one month**. With your entire **science** teaching assignment in mind, place an "X" in the column after each statement indicating whether or not you have used the practice in your teaching of **science**. Do not skip any items.

Indicator	Statement	Always	Sometimes	Rarely	Never
Engage	1.1a. I begin my lesson with a probing question focused on the lesson concept.				
	1.1b. I begin my lesson with a brainstorming session focused on the lesson concept.				
	1.1c. I ask students for information to use in an organizational chart, such as a KWL chart (What do I **k**now? What do I **w**ant to know? What did I **l**earn?).				
Explore	1.2a. I create opportunities for students to work together without direct instruction from me.				
	1.2b. I act as a consultant for students as they work.				
	1.2c. I observe students' interactions as they work.				
	1.2d. I ask probing questions to redirect students' investigations, when necessary.				
Explain	1.3a. I ask students to explain concepts in their own words.				
	1.3b. I ask students to explain definitions in their own words.				
	1.3c. I ask students to justify their own thinking.				
	1.3d. I ask students to clarify their own thinking.				
	1.3e. I provide directions for students.				
	1.3d. I provide explanations for students.				
	1.3e. I provide new labels for diagrams and other figures.				
	1.3f. I draw on students' previous experiences as a basis for explaining concepts.				
Elaborate	1.4a. I expect students to use labels provided in class.				
	1.4b. I expect students to use definitions provided in class.				
	1.4c. I expect students to use explanations provided in class.				
	1.4d. I encourage students to apply concepts in new situations.				
	1.4e. I encourage students to extend concepts in new situations.				
	1.4f. I encourage students to apply skills in new situations.				
	1.4g. I encourage students to extend skills in new situations.				
	1.4h. I remind students of alternative explanations.				
	1.4i. I refer students to existing evidence (data), asking questions such as "What do you already know?"				
Evaluate	1.5a. I observe students as they apply new concepts.				
	1.5b. I observe students as they apply new skills.				
	1.5c. I assess student knowledge.				
	1.5d. I assess students' skills.				
	1.5e. I provide students with formative feedback to enhance their thinking.				
	1.5f. I provide students with formative feedback to enhance their skills.				
	1.5g. I look for evidence that students have changed their thinking.				
	1.5h. I look for evidence that students have changed their behaviors.				
	1.5i. I allow students to assess their own learning.				
	1.5j. I allow students to assess their own group-process skills.				
	1.5k. I ask open-ended questions, such as "What do you know about *x*?"				

Adapted from the Connecticut State Department of Education, NSES Standards of Teaching, BSCS 5E Inquiry Model and MCPS Science

1.6 Please select THREE answers and RANK order them from FIRST (1) to LAST (3):

For me, the three experiences and/or resources that most informed my understanding of how to teach in an inquiry-based manner was:

___ experience in the classroom
___ workshop/professional development
___ colleague in science discipline area
___ colleague NOT in science discipline area
___ completing the BEST portfolio
___ BEST mentor
___ BEST induction seminars
___ student teaching
___ college coursework
___ book
___ website
___ Connecticut Common Core of Teaching
___ National Science Education Standards
___ Other (please name) ______________________

PART II: Factors Influencing Inquiry-based Instruction

Directions: Below are questions about factors (underlined) that may be important to the practice of inquiry-based instruction in the science classroom. Please **circle** the response that best describes your opinion about the importance of each factor and respond to the following question.

2.1 How important is the factor "time" (e.g., the length of the class period) in your decision to practice inquiry-based instruction in your science classroom?

Extremely Important *Reasonably Important* *Somewhat Important* *Not at all Important*

2.1a I have the time to practice inquiry-based instruction in my science classroom.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

2.2 How important is the factor "resources" (e.g., equipment, internet access, etc.) in your decision to practice inquiry-based instruction in your science classroom?

Extremely Important *Reasonably Important* *Somewhat Important* *Not at all Important*

2.2a I have the resources I need to practice inquiry instruction in my science classroom.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

2.3 How important is the factor "professional development on inquiry-based instruction" in our decision to practice inquiry-based instruction in your science classroom?

Extremely Important *Reasonably Important* *Somewhat Important* *Not at all Important*

2.3a I have access to professional development on the practice of inquiry-based instruction.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

2.4 How important is the factor "science topic(s) or concept(s) being taught" in your decision to practice inquiry-based instruction in your science classroom?

Extremely Important *Reasonably Important* *Somewhat Important* *Not at all Important*

2.4a The science topic affects my ability to practice inquiry-based instruction.

Strongly Agree *Agree* *Disagree* *Strongly Disagree*

2.5 How important is the factor "need to cover material for mandatory assessments" (e.g., Connecticut Academic Performance Test, Connecticut Mastery Test) in your decision to practice inquiry-based instruction in your science classroom?

Extremely Important *Reasonably Important* *Somewhat Important* *Not at all Important*

2.6 Please rank order the following items from greatest to least as obstacles to the implementation of inquiry-based instruction in your classroom:

- ___ time
- ___ resources
- ___ professional development
- ___ science topic/concept taught
- ___ need to cover material for mandated tests
- ___ other (please specify) ________________

PART III: Teacher Demographic Information Form

Directions: Complete the following questions. Write or select "NA" for any question that does not apply to your situation. It is important that the information that you provide be completely anonymous.

3.1 Check ☑ the year(s) you submitted a science teaching portfolio to the State Department of Education as part of the certification process in the Beginning Educator Support and Training (BEST) program:

☐ 1997 ☐ 2001
☐ 1998 ☐ 2002
☐ 1999 ☐ 2003
☐ 2000 ☐ 2004

3.2 The last full school year in which you taught (e.g., 2003-2004): ____________________________

3.3 The zip code of town you current teach in is ______

3.4 Check ☑ the school setting in which you currently teach. *(Check one only. If you teach at more than one school, check the school type where you primarily teach.):*

- ☐ Middle/Junior High school
- ☐ High School
- ☐ Other ______________ *(please specify)*
- ☐ NA

3.5 Check ☑ the science subject(s) that you currently teach:

- ☐ biology/life science
- ☐ chemistry
- ☐ physics
- ☐ earth science
- ☐ general science
- ☐ Other ______________ *(please specify)*
- ☐ NA

3.6 Check ☑ the following description that characterizes your current science-teaching assignment. *(Check one only.)*

- ☐ Departmentalized by subject matter
- ☐ Interdisciplinary team
- ☐ Co-teaching in regular classroom
- ☐ Self-contained classroom (most students are present for a full day)
- ☐ Resource room (students are present for two hours or less per day)
- ☐ Part-time special class (students are present for more than two hours per day, but less than a full day)
- ☐ Other ______________ *(please specify)*
- ☐ NA

Thank you very much for your participation in this survey. Please return this survey in the addressed, stamped envelope.