Using Forensic Science as a Context to Enhance Scientific Literacy

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ABSTRACT

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Major reform documents have promoted the use of inquiry-based curriculum to achieve scientific literacy. Forensic science is an authentic subject that can be used to link the science classroom to a real-world working environment. Given the nature of the subject, forensic science fosters student interest and can be used as a tool to promote scientific literacy.

This mixed methods analytical study investigated the use of inquiry-based instruction in the context of a forensic science curriculum and examined its influence on the use of higher-order thinking skills and the development of scientific literacy characteristics. Twenty-four high school students participated in a 6-week inquiry-based forensic science unit designed by the researcher. The Five E inquiry-based instructional model (Bybee & Van Scotter, 2007) was used. Students completed mini-evaluations and group journal entries, and participated in focus group discussions and classroom observations.

Qualitative results indicated three major learning outcomes related to the achievement of scientific literacy: 1) the value and benefits of group work and discussion in the problem-solving process; 2) the importance of using higher-order thinking skills in the evaluation and analysis of information; and 3) connections between classroom learning and real-world applications. Five major characteristics of the forensic science curriculum that supported student engagement included: a) opportunities for students to participate in relevant and realistic real-world learning situations through role-playing; b) the goals and objectives of the lessons requiring students to take charge of their own learning; c) the unit objectives’ focus on problem-solving skills and
deep understanding of science content and processes; d) knowledge construction occurring through social negotiation and collaboration; and e) students reflecting on their thoughts and ideas during the learning process because of self-reflection opportunities embedded within the curriculum.

Quantitative analysis of data revealed an increasing level of higher-order thinking across the sequence of mini-evaluation topics and an enhanced use of cognitive skills as the forensic science curriculum progressed. The findings from this study indicated that forensic science can be used as an avenue to promote the development of scientific literacy. The results are beneficial for educators and curriculum developers interested in designing curricula that support scientific literacy objectives in the classroom.
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I would like to thank all of the very special people in my life who have supported me throughout my entire educational experience. First of all, I would like to thank my parents who have always stressed the value and importance of education. Even though my father is no longer alive, I want to thank him for always caring and providing me with all of the affection that he could until his last breath! I can still feel his love today after 30 years. I hope I made you proud, Dad! I want to thank my mother for her unconditional love and support. Without her love, prayers, and blessings, I would never have been able to fulfill my dream.

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G. B-R.
DEDICATION

I would like to dedicate this dissertation to my mother who I love so very much. I would like to thank her for encouraging me to pursue my dreams and for being such a strong and independent woman and role model. She has always quietly supported my many endeavors and for that I am eternally grateful. I hope that one day I can also be an inspiration to my children as she has been to me. Thank you, Mom!
Chapter I
INTRODUCTION

My Experience as a Student

As a child, I remember family telling me how important it was to go to school and do well so that I could get an education. Getting good grades was a priority for me as it was considered a great disappointment to not do well at school. This was probably one of the major reasons that I stayed motivated and interested in school because I could not bear to upset my family and be a failure.

When I remember my experiences as a student, I recall most of the academic classes being filled with lectures and notes and the teachers doing a lot of the talking. At the time, it was a competitive atmosphere and students were not encouraged to help each other as this was considered cheating. Group work, sharing ideas, and talking to each other were frowned upon.

The quiet classroom was considered the ideal learning environment and teachers were always pleased when we were good—quiet—and did what we were asked to do. Our thought processes and critical thinking skills were not encouraged or stimulated through classroom discussions with teachers or peers. Very few connections were made between the information learned in the classroom and the way in which it could be useful in our lives. We were not allowed to brainstorm or say what we felt or thought about ideas or concepts. Tests were memory-based and required that we memorized large amounts of information just so we could regurgitate it and get a good grade. Being “smart” was a measure of how much one could
remember and not how much one understood or was able to think about and question the information being presented.

Even though I learned to do what I needed to be successful in the academic classroom, I remember being very bored and disengaged. I did not enjoy going to school because I often lost interest after the first 30 minutes of being there. I learned how to memorize material, but I did not learn how to think critically about information or to relate it to unknown situations. I did not learn how to be skeptical or to question information presented to me, as disagreeing with the teacher was a punishable offense. Whenever a test was over, I forgot the meaningless information and moved on to learning more unrelated facts just so I could get a high grade.

**My Journey as an Educator**

When I first started teaching, I resorted to being taught the way that I was taught. I first tried lectures and worksheets and all of the other practices that my teachers had taught me. Saddened by these practices, I saw myself reflected in the faces of my students—the boredom, the disinterest, the fact that they were just there to get through the day and do what they had to do. As an educator, I felt very dissatisfied and unfulfilled teaching and seeing my students suffer through school. I wanted the students to be excited and interested in what they were learning. I wanted them to look forward to coming to class, and to not only be entertained but to learn how to be thinkers and to take away tools with them that they could use and develop throughout their education.

I started exploring different ways that students could be motivated in the science classroom and started experimenting with active learning strategies. At that time, education reform placed emphasis on active engagement in the form or inquiry-based learning and the
integration of technology. I remember going to many district workshops that were focused on changing the way science instruction was presented to students and encouraging teachers to use inquiry to promote active engagement and learning.

However, whenever I would experiment with a lesson or two, I often struggled and it ended up being chaotic as I myself did not know how to structure this type of instruction effectively. Even though I understood the principles, I found it very difficult to implement them in the classroom. It seemed so different from what I was familiar with. Fellow teachers shared similar sentiments with me as we would often vent to each other about the difficulties we experienced while trying to implement inquiry lessons. Students themselves also often became frustrated because they were not accustomed to engaging in prolonged instruction that required deep thinking and analysis.

Even though I used curricula designed for active engagement and inquiry-based instruction, a majority of students became bored and started acting out because they could not relate to the topics and did not find the subject matter personally interesting. This I believe was one of the major problems. My experience helped me to realize that in order to get maximum student engagement, the strategies associated with inquiry lessons needed to be used in conjunction with topics that student were interested in and excited about.

As a living environment middle school teacher, grades 6-8, I embarked on a mission to discover what topics and activities students were most interested in learning about and participating in. I realized that most students enjoyed topics like reproduction, nutrition, and ecology probably because they could see the relationship of these topics to their lives. They also enjoyed preparing for the science fair and engaging in activities that involved group work such
as performing labs. Computer use for web quests as well as watching documentaries also caused very little resistance on their part.

Yet these activities only seemed to be an excuse to pass the time painlessly rather than productively. Most of the labs were “cookbook” labs allowing very little opportunity for students to use their higher-order thinking skills. Even though students would look at the documentaries, the nature of classroom discussions was very superficial and did not demonstrate deep reflection or understanding. Many times students would rush through the web quests so that they could have extra class time to “surf” the web. I knew deep down that I wanted more for my students and that there had to be ways of providing a more fulfilling educational experience for my students and myself.

It was not until my teaching position as a high school science teacher of Forensics that I realized how curious students were about the subject. From the minute they entered the classroom, they were ready to learn. As an educator, I found this enthusiasm refreshing and wanted to take advantage of its potential to educate my students. Television shows such as CSI (Crime Scene Investigation) and Forensic Files had just come out, and there was such excitement about the subject and using science in a practical way to solve problems.

At the same time that I got the job teaching high school forensic science, I had started my Ph.D. program in science education and I was reading relevant literature for my core courses on inquiry-based learning and scientific literacy. I had seen the capability of forensic science to engage students in the classroom, and because of the nature of the subject, I realized how perfect it was not only to motivate students but also to support the development of scientific literacy objectives in the classroom.
Purpose of the Study

The National Science Education reform stresses the importance of the use of inquiry to promote the development of scientific literacy in the science classroom (American Association for the Advancement of Science [AAAS], 2001; National Research Council [NRC], 2000). Inquiry-based classroom instruction has been shown to develop students’ critical thinking skills and to encourage independent thinking and lifelong learning (Llewellyn, 2005; Reagan, Case, & Brubaker, 2000). These are essential features that define a “scientifically-literate” individual (DeBoer, 2000).

Currently, two major challenges are associated with the implementation of inquiry-based instruction to achieve scientific literacy. The first challenge is “What kinds of instructional practices are best for supporting inquiry-based learning?” (Anderson, 2002; Harris & Rooks, 2010) and the second is “What curricula design support student engagement and the development of scientific literacy?” The following study was designed to address these two challenges.

One promising aspect of inquiry-based learning is the use of “authentic tasks” in order to engage students in activities that simulate the work of real scientists in ways that are meaningful for students (Lehrer & Schauble, 2006). These tasks are proposed as a way of helping students to relate scientific ideas to their real-world experiences and have the ability to reform the classroom into places where students are able to develop functional knowledge and deep understandings (Harris & Salinas, 2009). Forensic science lessons have the ability to be both “inquiry-based” and “authentic,” thus providing a setting to help educators deal with the challenges that arise in classrooms that aim to produce scientifically-literate students.
Throughout the literature are reports of studies using forensic science for inquiry-based learning and for student achievement and student motivation; however, studies providing evidence that forensic science can be used to promote scientific literacy and student engagement in the high school classroom have not been conducted. As a result, the present study was conducted to investigate the potential benefit of using forensic science in an inquiry setting to achieve scientific literacy in a high school classroom.

**Research Questions**

This study examined the influence of inquiry-based constructivist activities using forensic science to develop scientific literacy among a population of science students in grades 10-12 in a suburban high school. Forensic science has become increasingly popular as a context for engaging students in learning science because it requires students to apply and, in some cases, combine the content knowledge of biology, chemistry, and physics in a practical setting for the purpose of solving a problem. In a constructivist classroom, students’ cognition is the result of “mental construction” (Staver, 1998). The constructivist framework acknowledges that all students come to the classroom with a different set of beliefs and values, and provides opportunities for them to make meaning of new information based on previous knowledge and existing scientific knowledge (Bransford, Brown, & Cocking, 2000).

The research questions addressed in the study are:

1. How do inquiry-based forensic science lessons, taught within a constructivist classroom, promote the advancement of scientific literacy for students in grades 10-12?

   a) What are the major learning outcomes that emerge from students participating in the forensic science inquiry-based unit?
b) What is the achievement progression of higher-order thinking skills for the class of students?

2. How can curriculum be designed to support the development of scientific literacy objectives?
   a) What characteristics of the inquiry-based forensic science curriculum support student engagement and contribute to the learning process of students?
   b) How can these characteristics be used to design curricula that promote scientific literacy objectives?

This study presents potential value for educational theory and practice as it encourages students to learn concepts in science and engage in processes used by scientists in order to develop critical thinking skills. These three characteristics have been linked to the development of scientific literacy.

**Structure of Dissertation**

The dissertation contains six chapters. The findings are reported in separate chapters as two different research papers. The first chapter included an explanation of the purpose of the study as well as the research questions. Chapter II presents the literature review which provides the reader with an overview of the overall theoretical framework of constructivism as well as the current state of educational reform with respect to inquiry-based learning, scientific literacy, curriculum development, and forensic science. Chapter II contains a description of the methods applied to obtain data for the study, including details about the participants, the setting, data collection sources and procedures, and data analysis. Chapters IV and V address each of the research questions in the form of two separate papers. Finally, the conclusions and implications for the study are discussed in Chapter VI.
Chapter II

LITERATURE REVIEW

The review of the literature includes a discussion of the current research that has been done in inquiry-based learning and its relationship to student engagement, scientific literacy, and forensic science. Prior to this, however, I discuss the overall theoretical framework that is used in this study—Constructivism.

**Constructivist Theory**

Piaget (1896-1980) developed the theory of cognitive constructivism which is based on the idea that humans do not immediately understand information they have been given. Instead, they build knowledge through experience. Experiences enable them to create “mental models” in their heads. These models change and expand based on their experiences.

Lev Vygotsky (1896-1934) developed his theory of social constructivism from the roots of constructivism. He believed that children develop cognitively when they are allowed to engage in collaborative learning. Vygotsky defined the “zone of proximal development” as the ability of students to solve problems beyond their actual development level under adult guidance and in collaboration with other peers. He emphasized the influence of cultural and social contexts in learning and supported a discovery model of learning.

The theory of social constructivism suggests that students learn concepts or construct meaning about ideas through their interactions with and interpretations of their world, including
essential interactions with others (Lave & Wenger, 1991). According to social constructivist theory, students work in learning and knowledge building communities, benefitting from each other’s strengths and social support (Jonassen, 1995; Stepanek, 2000a, 2000b).

Teachers play an important role in the constructivist classroom. Teachers and students collaborate in the learning process and students are required to generate knowledge rather than merely accept it (Haury & Rillero, 1994). As a result, the teacher’s job is to facilitate learning and to provide support and guidance whenever necessary. The teacher contributes practical knowledge, content knowledge, and pedagogical content knowledge (Shulman, 1986). In a constructivist classroom, students actively construct their knowledge and understanding; they do not absorb the understandings of their teachers (Marlowe & Page, 1998).

Constructivist instructional methods include strategies that involve active engagement such as problem-based learning, inquiry activities, and dialogues with peers and teachers to make sense of materials and hands-on laboratories. When students are intellectually involved in performing these tasks, they “construct” their own knowledge, allowing effective learning to take place (Ward, Dubos, Gatlin, Schulte, D’Amico, & Beisenhertz, 1996). Many researchers have stated that permitting students to interact and reflect on learning experiences allows them to exhibit, understand, and construct new critical thinking processes (Brooks & Brooks, 1999; Gagnon & Collay, 2001).

Learning Theory

A review of the literature on how students learn revealed the following main principles related to curriculum design, and cognitive, developmental, and motivational factors (Vosniadou, 2001). The three main principles that have emerged from research relate to designing curriculum
that enable students to learn include creating environments in which the learner is active in constructing knowledge (Elmore, Peterson, & McCarthy, 1996; Piaget, 1978; Scardamalia & Bereiter, 1991). Research on the brain and learning (Bransford, Brown, & Cocking, 2000) supports that students learn in environments where making sense of data and reflecting on the findings are fundamental. This allows opportunities for students to participate in learning as a social activity (Collins, Brown, & Newman, 1989; Brown, Ash, Rutherford, Nakagawa, Gordon, & Campione, 1993; Rogoff, 1990; Vygotsky, 1978), and provides opportunities for students to engage in activities that are related to real life and are culturally relevant (Brown, Collins, & Duguid, 1989; Caine, Caine, McClintic, & Klimek, 2005; Heath, 1983).

Moreover, seven principles based on cognitive factors have been identified as important for learning to occur in the classroom. These include the fact that new knowledge is constructed on the basis of prior knowledge (Bransford, Brown, & Cocking, 2000); people learn by using strategies that help them solve problems (Mayer, 1987; Palinscar & Brown, 1984); learners must have opportunities to be reflective and monitor their learning (Marton & Booth, 1997; Pintrich & Zeidner, 2000); learners should have opportunities to incorporate new learning with prior knowledge and develop the ability to adjust their beliefs based on learning experiences (Driver, Guesne, & Tiberghien, 1985; Vosniadou & Brewer, 1992; Vosniadou & Carretero, 1999); learning is more likely to happen when instruction is designed for understanding rather than for memorization (Halpern, 1992; Perkins, 1992); students engage in meaningful learning when the lessons are centered around situations that they can relate to in real life (Bereiter, 1997; Bransford, Brown, & Cocking, 2000); and learning requires time to occur so that information can be processed and skills practiced (Bransford, 1979).
Furthermore, research has also shown that developmental and individual differences as well as motivational differences affect the way people learn. Howard Gardner (1991) stressed the importance of taking the many different facets of human intelligence into consideration in the learning process. Learning has also been linked to two different types of motivation— intrinsic and extrinsic. High grades and positive feedback from the teacher can be used to extrinsically motivate students, whereas intrinsically-motivated students complete the assignment, without having an external reward, for personal satisfaction (Deci & Ryan, 1985; Dweck, 1989; Lepper & Hodell, 1989; Spaulding, 1992).

**Inquiry-Based Learning, Scientific Literacy, and Science Education Reform**

Inquiry-based science teaching and learning are rooted in the constructivist instructional model of education. Inquiry-based activities are designed to promote a student-centered classroom in which students are actively engaged in the learning process. Problem-based learning is a specific branch of inquiry-based learning that requires students to work in small groups to investigate meaningful problems. Students first identify what they need to learn in order to solve a problem, and then they generate and implement strategies to find a solution. The activities are realistic and have many solutions that students can reach by using various methods. Students are usually actively engaged in constructing their knowledge and the teacher is responsible for engineering the learning by guiding the process and encouraging reflection (Barrows, 1996; Hmelo-Silver, 2004).

The American Association for the Advancement of Science (AAAS) (1993) has emphasized the need for nationwide science reform curricula that include inquiry in the classroom, which results in the production of a scientifically-literate population. Inquiry-based
instruction as recommended by Project 2061 (AAAS, 1993) encourages students to work in groups to test ideas, collect data, and form conclusions based on evidence obtained, and to communicate their results. Reformers propose the method of instruction as a means of dealing with the current problems that exist in American education, and they identify ways in which students can “learn how to learn” and become better trained to deal with the demands of the working world (Barron & Darling-Hammond, 2008).

The definition of scientific literacy puts an emphasis on teaching students to think and make decisions based on facts rather than teaching them rote memorization of many unrelated scientific facts. The goal of achieving scientific literacy is closely tied to constructivist teaching methods and the inquiry-based approach that is promoted in most current science education reform efforts.

**Inquiry-Based Learning**

Current reform efforts stress the importance of promoting student learning in science classrooms by using inquiry-based, structured lessons and activities to relate classroom instruction to students’ lives. Research studies have shown that students’ interest and motivation in science can be increased by relating scientific material to situations in their lives (Novak, 2002; NRC, 1996). Research has also shown that student interest, engagement, and motivation are improved when inquiry-based lessons are administered in the science classroom (Engle & Conant, 2002; Mistler-Jackson & Songer, 2000; O’Neill & Polman, 2004). Student-centered learning that promotes active engagement, hands-on learning, and the use of technology are also important factors that promote student learning in the science classroom.
There has been a significant amount of research on inquiry-based science courses and their positive influences on student achievement in the classroom (Driver, Asoka, Leach, Mortimer, & Scott, 1994; Gibson & Chase, 2002; Schneider, Marx, Krajcik, & Soloway, 2001). For instance, Schneider et al. (2001) investigated the performance of students in project-based science classrooms on a national measure of science achievement. A sample of 142 10th and 11th grade students enrolled in the project-based curriculum (PBS) completed the 12th grade 1996 National Assessment of Educational Progress (NAEP) science test. The study showed that students participating in the PBS curriculum outscored the national sample on 44% of the test items, thus showing a positive correlation between inquiry-based curriculum and science achievement.

Similarly, Wilson, Taylor, Kowalski, and Carlson (2010) conducted a laboratory-based randomized control study to examine the effectiveness of inquiry-based instruction. Fifty-eight students, 14-16 years old, were randomly assigned to one of two groups. Both groups were taught by the same teacher towards the same learning goals. However, the control group was taught by traditional teaching strategies whereas the other group was taught from inquiry-based materials organized around the Biological Science Curriculum Study (BSCS) Five E (5E) instructional model (Bybee & Van Scotter, 2007) (Figure 1). The findings of the study indicated that the inquiry-based group reached significantly higher levels of achievement than the students experiencing commonplace instruction. This effect was consistent across the learning goals, knowledge, reasoning, and argumentation immediately following instruction as well as four weeks later.
A study conducted by Roth and Roychoudhury (1993) demonstrated that, over time, 8th grade general science and 11th grade physics students learned how to select research problems and plan and design investigations to answer their questions. Students also learned how to identify and search for specific relationships between variables as well as to transform and interpret data related to their questions. During successive inquiries, students’ interpretation and analysis of data increased in sophistication.

Studies in forensic science taught in inquiry-based ways have also been done. For example, Noga (2007) conducted a dissertation study on the effects of an inquiry-based forensic science curriculum on 6th grade students’ interest and achievement. The results showed a significant positive relationship between experiencing a forensic science curriculum and student academic achievement and interest. Statistical data obtained from the study provide sufficient evidence that engaging, hands-on inquiry-based forensic curriculum helped students achieve considerable academic achievement gains.

Looking at the students’ inquiry-based skill development, Wu and Hsieh (2006) conducted a study on 58 6th grade students in a middle school to investigate the effects of a series
of inquiry-based learning activities on the students’ abilities to perform the following four inquiry skills—identifying causal relationships, describing reasoning and process, using data as evidence, and evaluating explanations. The statistical results showed that, overall, the students’ inquiry skills were significantly improved as they participated in the series of learning activities, even though there was a variation in the level of competency achieved.

Marx et al. (2004) reported the results of their study in which they collected data from about 8,000 students who participated in a 3-year inquiry-based and technology-infused curriculum unit as part of a district-wide systemic reform effort in science education. The results showed statistically significant increases in curriculum-based test scores and the strength of the effects for each year of participation. The findings of this study indicate that students who are historically low-achievers in science can succeed in standards-based, inquiry-based science when the curriculum is carefully developed and aligned with professional development.

Finally, Nuangchalerms and Thammasena (2009) conducted a study to investigate the effects of inquiry-based learning activities. Participants of the study were 10 2nd grade students who participated in an 8-lesson plan unit. Students were required to take a 20-item achievement test, a 20-item analytical thinking test, and a 15-item questionnaire on learning satisfaction. The results of the study revealed that inquiry-based learning activities promoted the students’ cognitive and analytical thinking skills as well as their learning satisfaction.

The studies discussed above contribute to the body of literature that has examined the effects of inquiry-based curriculum on student achievement in science. They have examined and indicated many positive effects of inquiry-based curriculum in science education. Most of these studies, however, were conducted in the middle school and only limited studies of inquiry-based activities have been carried out in the high school. Even though a large amount of literature
encourages the use of forensic science in the classroom as a means of engaging and developing students’ critical thinking skills, no studies have conducted research to investigate the effects of a forensic science curriculum on the development of students’ critical thinking abilities and its link to scientific literacy. Therefore, this current study was designed to address these important gaps in the literature.

In the following section, I review the literature pertinent to questioning used in inquiry science teaching. One of the most familiar approaches to assess students’ higher-order questioning, or critical thinking, is the use of Bloom’s Taxonomy.

**Bloom’s Taxonomy**

A major goal of science education has been to improve students’ higher-order thinking skills (Resnick, 1987). Bloom’s taxonomy (Appendix A) is a six-level classification system that uses observed student behavior to infer the level of student achievement for higher-order thinking skills. Bloom (1969) created this taxonomy to show the scaffolding of thought processes in critical thinking (Appendix B). The taxonomy levels include knowledge, comprehension, application, analysis, synthesis, and evaluation. Each of the six stages was designed to give educators and students the essential principles for critical thinking. The taxonomy also provides examples of what to do in each stage of critical thinking. Each of these stages is described in detail in the Findings chapters.

**Curriculum Development**

Project 2061’s review of middle school curriculum materials concluded that none of the nine middle school programs that they examined helped students to learn the science standards in a complete and comprehensive way (American Association for the Advancement of Science...
The materials superficially covered too many topics and overemphasized technical vocabulary. It was also found that curriculum materials did not build on student learning research because they failed to take into account students’ prior knowledge, lacked coherent explanations of phenomena, and failed to support students in developing explanations of phenomena (Kesidou & Roseman, 2002). It has been found that the dominant model of curriculum development in science tends to overemphasize the performing of activities and to underemphasize the mastery of science concepts and the process of scientific inquiry (Bybee & Van Scotter, 2007). Analyses of state and local district standards which are used by curriculum developers have been criticized for their shallow coverage of many topics (Schmidt, Wang, & McKnight, 2005). Curricular materials aimed at supporting reform efforts in the development of scientific literacy need to be carefully designed to achieve this goal.

Students enter the science classroom with preconceived ideas. Therefore, learning there requires well-designed, realistic activities that challenge learners’ prior conceptions, encouraging them to reorganize their personal thoughts (Driver et al., 1994). Furthermore, functional understanding occurs when they are exposed to science curricula that involve active construction of knowledge as well as those driven by topics and situations that are meaningful to their lives (Bransford, Brown, & Cocking, 2000).

In a constructivist classroom, students structure and monitor their metacognitive skills to help them develop a deeper understanding of critical science concepts (Staver, 1998). Students are engaged learners and are required to use their analytical and problem-solving skills to tackle investigative questions though classroom activities such as dialogues with peers, and to engage in hands-on laboratory activities. In other words, students are required to do science in order to
learn science. As they engage in activities that model the work of scientists, they develop a better understanding of the process of scientific inquiry (Bybee & Van Scotter, 2007).

The Biological Science Curriculum Study (BSCS) Five E instructional model (Bybee & Van Scotter, 2007) is a constructivist lesson design plan. It was used as a template to design the forensic science lessons used in this study. This model involves creating lessons that contain the following five stages: Engagement, Exploration, Explanation, Elaboration, and Evaluation (Figure 1). Each of these stages is described in greater detail in the Findings chapters. These stages were used in the context of the forensic science unit used in this study.

**Forensic Science in the Classroom**

The nature of forensic science provides an ideal setting that makes students intuitively feel it is important to find answers that will help them solve a mystery (Duncan & Daly-Engel, 2006). Students are provided with multiple opportunities to practice science as inquiry and to develop their critical thinking skills. The National Science Education Standards states the “process of science require[s] that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science” (NRC, 1996, p. 105).

Forensic science taught through inquiry-based activities engages students in critical thinking skills. The content naturally lends itself to constructivist inquiry-based learning because students are constantly required to ask questions, evaluate evidence, and use critical thinking to consider alternative explanations in the context of forensic science (Colburn, 2000). Crime scene activities provide hands-on activities as well as “minds-on” experiences. Even though the inquiry-based activities are presented in the context of forensic science, the ultimate goal is for
students to make sense of complex problems that require logical reasoning and involve numerical data, evidence, and uncertainty.

The recent popularity of forensic science has been derived from the media and the many shows that are linked to the subject. A recent National Science Teachers Association (NSTA) Survey indicated that 77% of middle and high school teachers teach forensic science in the science classroom because of shows like CSI (Crime Scene Investigation) (NSTA, 2004). CSI, Bones, and Forensic Files are television shows which portray forensic science as mysterious and exciting. The crime scene team is represented as glamorous and the methods used to analyze evidence consist of the latest technology which is used to solve the crimes within the episodes.

Student interest is captured through complicated plot lines that encourage them to actively partake in figuring out what happened in each episode (Johnson, 2005). The themes of the episodes are centered on unusual murders and real-life crime scenarios which involve these murders and sophisticated experiments which are misleading; however, they also contribute to sustaining student interest and engagement (Mardis, 2006). Shows like CSI have led to the creation of many popular forensic science degree programs at the college and university level (Perkins, 2004). The number of jobs in the field has also increased and continues to expand (Occupational Outlook Handbook, 2005).

The nature of forensic science makes it ideal for dealing with the problems of teaching science as students are engaged in inquiry-based activities (Funkhouser & Deslich, 2000). The approaches that are chosen to implement inquiry-based forensic science activities are most effective when the activities are presented in a form that most closely resembles real-world forensic cases. Problem-based activities that require students to conduct scientific research are
effective because they help students to understand the realities of science by making them an active part of the scientific process (Handler & Duncan, 2006).

**Focus of This Study**

Educators are constantly faced with the challenge of engaging students in learning science and scientific concepts. Many students become disinterested in science classes because they are unable to see the relevance and importance of the subject to their lives. A majority of teachers resort to teaching the way they were taught, which usually involves using traditional pre-reform instructional methods to convey information and skills that students need to pass exams. These traditional methods include teacher-centered instruction that is fact-based and involves the memorization of information that is isolated and unrelated to each other and that usually lacks connections to students.

Even though a major goal of educational reform has been the achievement of scientific literacy, research has shown that students are being taught in preparation for standardized testing (Bentley, Ebert, & Ebert, 2000; Grossen, Romance, & Vitale, 1994; Rescher, 2000). The results of exams and tests of pre-reform teaching measure how well students have learned to recall information and take tests rather than reflect their scientific literacy. Many of the students who do well on science exams are still unable to think critically and judge the merit of information presented to them. Students who have not been taught how to approach the exams properly are usually disinterested in pursuing science further.

Students perceive the information that they learn in science classrooms as separate from the scientific knowledge and skills they need to know to make decisions that affect their lives. The development of independent thinking is not facilitated.
Furthermore, there are three main areas where difficulties have been identified in inquiry-based learning. These areas include disciplinary understanding, general academic skills, and management (Barron & Darling-Hammond, 2008). Disciplinary understandings include difficulties with students being able to generate meaningful “driving questions” and evaluating questions to determine if they are appropriate for the problem being investigated (Krajcik et al., 1998). Many students experience difficulties when they are required to construct explanations and tend to generate incoherent explanations from personal ideas (Driver, Guesne, & Tiberghien, 1985). Learners experience difficulties when they are required to develop logical relationships between evidence and explanations (Kuhn, Amstel, & O’Loughlin, 1988). Students who are not accustomed to thinking and applying knowledge in these ways often struggle, tend to become frustrated, and give up. Management issues have also been reported in the literature as students often find it hard to work together, manage their time, and sustain motivation when confused (Achilles & Hoover, 1996; Edelson, Gordon, & Pea, 1999). These challenges contribute to the lack of the development of scientifically-literate students, which is an important goal of ongoing science education reform.

To address the challenges discussed above, this study contributes to providing meaningful science learning experiences to students. This is done by examining the effects of a series of inquiry-based forensic science activities on the development of high school students’ critical thinking skills and the achievement of scientific literacy. Once again, the research questions addressed in the study are:

1. How do inquiry-based forensic science lessons, taught within a constructivist classroom, promote the advancement of scientific literacy for students in grades 10-12?
a) What are the major learning outcomes that emerge from students participating in the forensic science inquiry-based unit?

b) What is the achievement progression of higher-order thinking skills for the class of students?

2. How can curriculum be designed to support the development of scientific literacy objectives?

a) What characteristics of the inquiry-based forensic science curriculum support student engagement and contribute to the learning process of students?

b) How can these characteristics be used to design curricula that promote scientific literacy objectives?

The study may contribute to recent research on inquiry-based learning, particularly for high school classrooms, and provide information about the effect of inquiry-based forensic science activities on students’ ability to use their critical thinking skills. As a result, the study is intended to provide important information about ways to promote student engagement and to develop critical thinking abilities in high school students. By identifying effective ways to engage learners in critical thinking, such as forensic science, as in the case of this study, educators can assess the learners’ level of involvement and encourage the use of critical thinking activities that promote the development of scientific literacy. The objectives of this research may contribute to the body of knowledge intended to help teachers and curriculum developers design lessons that encourage student engagement and promote scientific literacy.
Chapter III

METHODOLOGY

In this section, I describe the overall methodology for the study, which is mixed methods. I also describe the setting, participants, data collection, and data analysis; greater detail is given in the Findings chapters of the study. Finally, I discuss the ethical considerations that were undertaken to do this study.

Mixed Methods Methodology

A mixed methods approach is used for the study. Mixed methods research is formally defined as the class of research where the researcher combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study. According to this methodology, researchers collect multiple data using different strategies, approaches, and methods in such a way that the resulting mixture or combination is likely to result in complementary strengths and non-overlapping weaknesses (Johnson & Onwuegbuzie, 2004). The mixed methods approach is used to collect data that eliminate bias and help the researcher develop a better understanding of the questions addressed in the study. This approach employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand the research problems (Creswell, 1998).

The concurrent triangulation approach for mixed methods was selected for this study. Two different methods are used in an attempt to confirm, cross-validate or corroborate findings
within a single study (Steckler, McLeroy, Goodman, Bird, & McCormick, 1992). Separate
quantitative and qualitative data collection was used as a means to offset the weaknesses of one
method with the strengths of the other method (Creswell, 2003). The quantitative and then the
qualitative data collection are presented in separate sections, but analysis and interpretation
combine the two forms of data to seek convergence among the results (Creswell, 2003).

**Quantitative Methods**

The quantitative component of the study includes the scores from mini-evaluations
(Appendix B). Three main units—Fingerprinting, Blood, and Crime Scene—were covered for
the duration of the study. Each unit consists of a maximum of three major activities designed
according to the Biological Science Curriculum Study (BSCS) Five E inquiry instructional
model (Bybee & Van Scotter, 2007).

Mini-evaluations (Appendix B) were given at the end of each of the Five E lessons as the
evaluation part. The Evaluation portion of the Five E lesson design served the purpose of being
the mini-evaluations and was designed to measure students’ abilities to use critical thinking and
higher-order skills to solve problems. These mini-evaluations were designed to see how students
approach the problems they were asked to solve and whether they used lower-order or higher-
order thinking skills to approach the questions.

The data collected from the mini-evaluations went through both quantitative analysis and
qualitative analysis. Two to three questions that students addressed in groups at the end of each
of the lessons were given to them as short-response questions. They were analyzed quantitatively
by using the Evaluation Rubric (Appendix C) and Bloom’s Theoretical Matrix (Appendix D) to
provide a numerical score. This score was used to provide numerical data for statistical analysis.
As a measure of inter-rater reliability, another rater (a forensic science teacher) was trained on how to use the rubrics by seeing examples of the codes and grades given on a sample of student work. Both I and the other teacher then practiced assigning a score using the rubrics on another sample of student work. This practice was not a part of the actual data analysis. After training was complete, the rater and I independently coded a random set of the 20 mini-evaluations. The scores given were then compared to each other after coding was complete for consistency. There was a 90% agreement on the assignment of scores on the mini-evaluations.

**Qualitative Methods**

Qualitative data were collected in the form of mini-evaluation worksheets, group journal entries, focus group discussions, and classroom observations. Participants were encouraged to be honest at the beginning of the study. They were told that there was no one “correct” response. Student worksheets from the mini-evaluations and group journal entries which required students to justify and explain their thought processes were collected and analyzed. Students were encouraged to write down questions that arose as they engaged in the learning activities. Group journal entries (Appendices E, F, and G) were completed at the end of each unit and also provided opportunities for students to reflect on the learning activities and further develop their thoughts and ideas. Both worksheets and group journal entries served as guidelines for focus group discussions which were designed to understand the students’ thought processes in more depth.

Classroom observations were conducted for each of the mini-evaluations. The researcher circulated the room and took notes as groups completed the evaluation portion of the lesson. Each group was observed for three to five minutes per mini-evaluation. General observations of body language that indicated listening to each other (eye contact, body posture); focus (minimum
off-task conversations, on-task and working on completing the assignment, frustrated by activity, bored and not participating, easily distracted); and verbal participation (thoughtful, reflective ideas, relevant questions appropriate asked, participation passive/active) were recorded.

The written responses for mini-evaluations, group journal entries, and recorded notes from classroom observations were read through and the data were coded and then classified according to emergent themes that resulted as students progressed through the forensic science activities.

The use of focus groups is a qualitative research methodology that can be used to obtain information about the opinions, perceptions, attitudes, beliefs, and insights of a small group of people (Kitzinger & Barbour, 1999). This methodology is helpful in understanding how people regard a specific experience or event (Krueger, 1994). Focus groups (Appendix H) were used to discuss questions, and particular attention was paid to the way students selected and controlled variables, planned procedures, interpreted patterns of evidence, and constructed explanations during the inquiry-based activities of the forensic science curriculum.

Three focus group sessions over the 6-week period were conducted—one at the end of each unit (Appendix E). Each focus group consisted of six students who belonged to diverse backgrounds (i.e., race, ethnicity, learning styles, and achievement). The students were selected by their group members to be the “speakers” of the group for the entire study. The “speakers” were required to explain and elaborate the experiences and concerns that came up as their group participated in the forensic science inquiry-based unit. Focus group discussions were designed so that students could discuss, explain, and elaborate on how they arrived at the decisions they made as they engaged in the learning process. This allowed me to decide whether or not the
activities promoted student engagement and what aspects of the curriculum promoted the development of scientific literacy.

In review, this study utilized a mixed methods approach with the collection of both quantitative and qualitative data. The goal of this mixed methods design was to learn how well students’ engagement in inquiry-based forensic science lessons promotes their science literacy. All data were collected in the researcher’s forensic science class and took place over a 6 week period of time. There were three lessons per unit. Students completed one mini-evaluation at the end of each of the three lessons for the Fingerprint and Blood units. They completed two mini-evaluations for the Crime Scene unit, one at the end of the first lesson and one at the end of the third lesson. This resulted in a total of eight mini-evaluations for the 6-week period of the study. These short-response questions were designed to test students’ abilities to use higher-order thinking skills to solve problems.

Students participated in focus group interviews throughout the study. Finally, classroom observations were recorded in the form of researcher notes as a way of observing student interactions in the classroom while engaging in the forensic science lessons for the duration of the study. The researcher audio-taped interesting conversations that occurred as students were observed. The research design and research questions are reviewed in Table 1.

**Setting and Participants**

Green Field High School (pseudonym) contains 1,027 student—40% Caucasian, 25% African American, 18% Hispanic, and 17% Asian. Twenty-four students enrolled in the course agreed to participate in the study—10 males and 14 females. Students were from a mid- to low-socioeconomic status. The forensic science class is an elective class that students take for 16 weeks (1 semester, or one half-year). The majority of students who enroll in the class need an
Table 1

*Data Design Grid*

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Quantitative</th>
<th>Qualitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How do inquiry-based forensic science lessons taught within a constructivist classroom promote the development of scientific literacy for students in grades 10-12?</td>
<td>▪ Mini-evaluations</td>
<td>▪ Mini-evaluations ▪ Group journal entries ▪ Focus groups</td>
</tr>
<tr>
<td>a) What are the major learning outcomes that emerge from students participating in the forensic science inquiry based unit?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) What is the achievement progression of higher-order thinking skills for the class of students using cumulative plots?</td>
<td>▪ Mini-evaluations</td>
<td></td>
</tr>
<tr>
<td>2. How can curriculum be designed to support the development of scientific literacy objectives?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) What characteristics of the inquiry-based forensic science curriculum support student engagement and contribute to the learning process of students?</td>
<td>▪ Focus groups ▪ Group journal entries ▪ Classroom observations</td>
<td></td>
</tr>
<tr>
<td>b) How can these characteristics be used to design curriculum that promote scientific literacy objectives?</td>
<td>▪ Focus groups ▪ Group journal entries ▪ Classroom observations</td>
<td></td>
</tr>
</tbody>
</table>
extra year of science credits and prefer not to take chemistry or physics to satisfy the requirement. These students are typically mixed-achievement students, are in the medium- to low-achieving range, and have a history of needing to repeat Living Environment, Earth Science or both. As a result, they choose to take a combination of two science elective courses in order to graduate. A small percentage of the students who enroll in forensics have already completed their science credits for graduation and decide to take the class for enrichment purposes.

The forensic science class meets for 42 minutes every day, 5 times per week. It is designed to integrate principles of biology, chemistry, and physics in the practical setting of forensic science case studies. Students are expected to use the skills that scientists use such as observing, collecting, and analyzing as well as to develop content knowledge of the science subjects on a need-to-know basis in order to evaluate evidence associated with the case study scenario.

**Data Analysis Overview**

According to Onwuegbuzie and Teddlie (2003), there are seven stages of conceptualization of the mixed methods data analysis process. These stages include data reduction, data display, data transformation, data correlation, data consolidation, data comparison, and data integration. These seven stages were used to analyze and interpret the data collected in the study.

Quantitative data from the mini-evaluations were reduced using descriptive statistics. Bias was diminished by using a scoring rubric that was used to generate scores for student responses to the mini-evaluations. The mini-evaluations were evaluated using the rubric by the researcher and another rater. An inter-rater reliability of 90% agreement was established. The
data obtained were displayed using charts, tables, and graphs. Quantitative data were then transformed into narrative data and analyzed.

The qualitative data collected from the mini-evaluations, group journal entries, focus groups, and observations were initially analyzed using aspects of grounded theory (Charmaz, 2006; Strauss & Corbin, 1990). Data were first read though “line-by line” (Charmaz, 2006) and a list of re-occurring themes and ideas was assembled. These themes were then placed into categories based on patterns and relationships. The categories were correlated and then combined to form new consolidated data sets based on the sub-questions being addressed in the study. More detail on the process of quantitative and qualitative data analysis is given in the Findings chapters.

**Data Analysis Rigor**

Methodological triangulation was used to cross-check data, eliminate (or decrease) bias, and ensure that results and findings were consistent within multiple data sources. Triangulation data included responses from mini-evaluations, group journal entries, and focus group discussions. Common themes that emerged from a line-by-line coding of these three sources of data were reported to ensure consistency in the findings.

In addition to this, credibility and validity for qualitative research approaches were established using several elements of quality criteria (Creswell, 2003; Guba & Lincoln, 1989). For example, Guba and Lincoln recommend six elements to check the credibility and validity of qualitative research. The following four methods were employed in the study:

**Persistent observation.** According to Guba and Lincoln (1989), the researcher needs to perform sufficient observation in order to decide the characteristics in the situation that are most important to the issue being addressed. I kept a researcher journal that contained observations
and field notes for the duration of the 6-week period. Students were observed during mini-evaluation activities, and notes and observations were recorded for each of the activities. The main goal of the observations was to record notes that address the effects of the activities on student engagement and the impact on the students’ critical thinking skills. Questions that students asked as they worked together were also recorded.

**Progressive subjectivity.** Progressive subjectivity has been defined as the process of monitoring the researcher’s own developing construction (Guba & Lincoln, 1989). I was able to adhere to this criterion through the use of another researcher journal in which I recorded what I expected to find before I started any of the activities or observations; I then recorded what I saw. At the end of each of the units, I wrote down my construction of what I thought was happening. These notes were then discussed with a peer debriefer (another forensic science teacher). The role of the peer debriefer was to notice if I was restating what I expected to find or whether I was providing accurate interpretations of the data obtained from the participants as the study progressed. Group journal and focus group questions were also reviewed along with the journals to make sure that I was not asking questions to influence student responses and obtain answers that I expected to find. Questions were designed for students to revisit, reflect, clarify, and further explain previous responses to questions.

**Peer debriefing.** Both Creswell (2003) and Guba and Lincoln (1989) recommend peer debriefing as a method to ensure credibility. This process has been described as engaging in a discussion about the results, conclusions, and analysis with another peer who has little bias in the study. The role of the peer is to ask questions that help the researcher further evaluate the results of the study and to provide constructive feedback. The data obtained from this study were
discussed with both a fellow teacher and dissertation advisor in order to review and ask questions about the study and to ensure consistency with the findings.

**Member checking.** Guba and Lincoln (1989) define member checking as the process of testing hypotheses, data, preliminary categories, and interpretations with participants in the study. Member checking has been described as the most important technique for establishing credibility. Both the focus group interview data and the analysis of the mini-evaluation observation data were discussed with participants informally to verify that what was recorded was the intention of the participants and not the researcher. Preliminary or emergent categories and themes generated from the data analysis were discussed in focus groups to ensure that the interpretation of the data obtained was accurate and reflected students’ comments and reactions.

**Ethical Considerations**

All procedures were conducted according to the policies published in the Institutional Review Board (IRB) booklet obtained from Columbia University. A detailed description of the activities involved was submitted for IRB approval (Appendix I). Pseudonyms were used for all students and for the school to protect the identities of the participants in the study and to ensure confidentiality.

A consent form was prepared asking for student permission to participate in the study (Appendix J). A student participant/parent letter was given to all parents explaining the objective of the research, risk factors, and the fact that students would not be required to participate in the study if they did not want to. It was clearly stated in the proposal that students would not be penalized for refusing to participate in the study and that their grades would not be affected.
because of lack of participation. Students were also informed that they could withdraw from the study without any penalty.

**Limitations**

Limitations of the study arise as the study involves a small sample size of high school students in grades 10-12. This sample of students may not be reflective of larger populations of students from different grade levels. However, the idea of generalizability to the extent of creating inquiry-based activities for high school students, promoting inquiry-based science, and scientific literature are relevant to reform-based teaching in school science. Also, the study was conducted for a 6-week period and covered three inquiry-based units (Fingerprinting, Blood, and Crime Scene Analysis) that are composed of two to three lessons each, n = 8 total lessons for the forensic unit. Each lesson contains one inquiry-based activity. Extending this time period and including more lessons would result in a more precise understanding of the questions addressed in the study.

Students were asked to complete a group journal entry after they completed each unit, in which they were required to reflect on the activities with the help of a guided worksheet (Appendices G, H, and I). This was consistent with the social-constructivist framework for the study as all students in the group were required to participate in the discussion and contribute to the group journal entry. However, the students did not complete individual journal entries. As a result, evidence of individual student learning and development of ideas was not collected. In future studies, this would be an interesting element of the study to pursue.

The teacher serving the dual role of instructor as well as researcher may lead to unintentional subjectivity and difficulty in recording accurate observations and field notes. The
Concurrent Triangulation Strategy (Greene et al., 1989; Steckler, McLeRoy, Goodman, Bird, & McCormick, 1992) was used to collect and analyze data in the study. This process involves the collection of both quantitative and qualitative data simultaneously. Both sets of data were then compared to see if they supported each other or if they contradicted each other (Creswell, 2003). The main goal was to combine the different strengths and non-overlapping weaknesses in order to develop a better understanding of the research problem (Patton, 1990).

The concurrent triangulation method of collecting data has the benefit of requiring a shorter data collection time period; however, it requires a greater expertise in comparing the results of two different methods. The researcher could therefore encounter difficulties in resolving discrepancies that may arise in the results (Creswell, 2003). To address this issue, I documented the process of conducting research via a researcher journal. This process allowed me to keep track of my thinking and how I progressed as a researcher in conducting this study.

In the following two chapters, I present the findings of the dissertation study. They are presented in the format of two publishable papers, with the first chapter addressing research question number one and its sub-questions, and the second findings chapter addressing research question number two and its related sub-questions.
Chapter IV
FINDINGS

USING INQUIRY-BASED FORENSIC SCIENCE TO ADVANCE SCIENTIFIC LITERACY FOR HIGH SCHOOL STUDENTS

Abstract

This mixed methods study examined the effects of a series of inquiry-based forensic science activities on higher-order thinking skills and the achievement of scientific literacy by 24 high school students. Data included mini-evaluations, group journal entries, and focus group discussions. Three major learning outcomes relating to scientific literacy emerged: 1) the value and benefits of group work and discussion in the problem-solving process; 2) the importance of using higher-order thinking skills in the evaluation and analysis of information; and 3) the connections between classroom learning and real-world applications. These findings indicate that forensic science inquiry-based activities are a resource that can be used to promote the development of scientific literacy in high school students.

Key Words: Scientific literacy, forensic science, inquiry-based instruction

Introduction

A major goal of reforms in science education has been the attainment of scientific literacy. Both of the primary science reform documents, the National Science Education
Standards (NRC, 2000) and the Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 2001), suggest the use of an inquiry-oriented approach to K-12 science instruction that emphasizes problem-solving and critical thinking in real-world contexts in order to consider students as being scientifically literate (Gengarelly & Abrams, 2009). Specifically, the National Science Education Standards define a scientifically-literate person as one who:

…can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means a person has the ability to describe, explain and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately. (p. 22)

This statement supports the idea that scientific literacy is a way of thinking critically about information and that people who are scientifically-literate possess skills that they can use to solve problems. The characteristics of a scientifically-literate adult include being able to use clear and accurate communications skills in order to determine the difference between unsubstantiated and relevant arguments (American Association for the Advancement of Science [AAAS], 1993). A major emphasis is placed on applying problem-solving skills to everyday life (Wright & Wright, 1998). This definition differs from traditional science education perspectives that often emphasize memorizing scientific facts and/or principles to the exclusion of scientific ways of thinking. It can be encouraged by allowing students to become actively engaged in the learning process and having them participate in problem-solving activities which include designing experiments and developing projects.
Studies have shown that as children get older, their interest and attitudes towards school in general, and toward specific subject areas such as mathematics, arts, and science, tend to deteriorate (Eccles & Wigfield, 1992; Hoffman & Haussler, 1998). Many students learn information and test-taking skills superficially in order to pass examinations, and a large number of students become disinterested and unmotivated in the science classroom. Researchers have shown that adolescents’ academic motivation declines over time (Anderman & Maehr, 1994). As a result, students do not fully develop the necessary skills that enable them to use scientific knowledge to make decisions that affect their lives and thus become scientifically-literate.

Inquiry-based methodology is effective in fostering scientific literacy; however, the challenge of getting students to become engaged and excited about learning science in the classroom remains problematic. Researchers have maintained that American high school students are not fully engaged in classroom learning (Newmann, 1992; Yair, 2000). This is a problem as it has been found that student engagement has consequences for students’ academic achievement (Finn & Cox, 1992).

Even though inquiry has been highly endorsed by educational leaders, research has shown that many teachers still resort to traditional teaching methods such as teacher-centered activities, whole class lectures, and textbook-based activities (Bentley & Alouf, 2003a, 2003b). One reason for this is that the effective implementation of inquiry-based instruction is often quite challenging. It is often very difficult for teachers to keep student interest for extended periods of time. Another challenge is getting students to participate effectively when they are required to solve complicated problems (Harris & Rooks, 2010). Overwhelming feelings of frustration are also common as students are required to assume personal responsibility for learning and intellectual effort (Blumenfeld, Kempler, & Krajcik, 2006).
It is very important to present the content of science lessons to students in a way that generates curiosity in the task they are going to perform. If students are not interested in the content related to what they are required to do, then they are less likely to engage in any learning process. Research has shown that when students are able to make connections between their everyday experiences and the class materials, they are more likely to find value and meaning in their classroom science activities (Moje & Hinchman, 2004). When students are able to see real-world authentic applications to their learning, they are more ready to explore deeper meanings. Excitement and student enthusiasm are generated when students perceive learning as meaningful and interesting. Questions that students intuitively want to explore create a sense of mental alertness and readiness to learn (Caine, Caine, McClintic, & Klimek, 2005).

Forensic science is a subject that creates an atmosphere for, and is conducive to, enhancing student interest. Students are required to use scientific information as well as to engage in the process of inquiry in order to solve problems in a real-world setting. Forensic science allows students to use scientific concepts and information along with the process of inquiry to develop their problem-solving skills. Connections can be made between the scientific information and its relevance to everyday life. This allows learning to become meaningful to the students and thus enables them to practice skills such as asking questions, formulating and testing hypotheses, collecting data, making inferences, and analyzing, reviewing, and critiquing explanations using scientific evidence. These skills are consistent with the skills associated with some current definitions of scientific literacy.
Theoretical Framework

Constructivism is premised on the belief that learners actively create, interpret, and reorganize knowledge in individual ways (Windschitl, 2000). The constructivist framework acknowledges that each student comes to the classroom with a different set of beliefs and values, and it provides opportunities for the learner to make meaning and create knowledge from previous knowledge. This educational theory is based on the belief that students’ cognition is the result of “mental construction” (Staver, 1998). Students integrate new ideas with prior knowledge in order to make meaning or reconcile discrepancies (Bransford, Brown, & Cocking, 2000).

Constructivist and social-constructivist approaches to science instruction consider inquiry to be an essential component of student learning. These activities require students to ask questions, search for information, design investigations, analyze data, and make conclusions, creating artifacts and sharing and communicating findings (Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998; National Research Council [NRC], 2000). These phases are not steps that students perform in a sequential fashion as aspects of inquiry interact in complex ways. When students engage in explanatory activities and inquiry learning, the intention is that they will develop a set of intellectual skills enabling them to construct understandings about science (Windschitl, 2000).

Inquiry-based science teaching and learning are rooted in the constructivist instructional model of education. Inquiry-based activities are designed to promote a student-centered classroom in which students are actively engaged in the learning process. Constructivist instructional methods include strategies that utilize active engagement such as problem-based
learning, inquiry activities, and dialogues with peers and teachers to make sense of materials and hands-on laboratories. When students are intellectually involved in performing these tasks, they “construct” their own knowledge, allowing effective learning to take place (Ward, Dubos, Gatlin, Schulte, D’Amico, & Beisenhertz, 1996). Brooks and Brooks (1999) and Gagnon and Collay (2001) have stated that allowing students to interact and reflect on learning experiences allows them to exhibit, understand, and construct new critical thinking processes.

This method of instruction has been proposed by reformers as a means of dealing with the current problems that exist in American education and has been identified as a way in which the production of scientifically-literate citizens can be achieved. The American Association for the Advancement of Science (AAAS) (2001) has emphasized the need for nationwide science reform curricula that include inquiry in the classroom and result in the production of a scientifically-literate population.

**Forensic Science Learning**

There are many advantages in using the nature of forensic science activities to promote student learning. First, forensics itself is inquiry-based and naturally engages the learner in problem-solving activities. It is “authentic” because many of the activities simulate the types of work that forensic scientists need to perform in their line of work. The nature of forensic science provides an ideal setting that makes students intuitively feel that it is important to find answers that will help them to solve a mystery (Duncan & Daly-Engel, 2006). Students are provided with multiple opportunities to practice science as inquiry and to develop their critical thinking skills. The *National Science Education Standards* state that the “process of science require[s] that
students combine processes and scientific knowledge as they use scientific reasoning and critical
tinking to develop their understanding of science” (NRC, 1996, p. 105).

Second, forensics is a multidisciplinary subject because it embodies concepts in many
areas including biology, chemistry, genetics, medicine, psychology, and law (Funkhouser &
Deslich, 2000). The lessons integrate the different science subject matter areas to solve crime-
based problems in the form of a crime. The activities and content used in forensic-based learning
incorporate several of the criteria stated in the National Science Education Standards. These
include the following standards: “Science as Inquiry,” “Unifying Concepts and Processes,”
“Physical Science,” “Life Science,” “Science and Technology,” and “The History and Nature of
Science.” During forensic science lessons, students learn about unifying concepts and procedures
in terms of evidence models and explanations; they are required to evaluate evidence and
propose models and explanations based on the results of their investigations. Students learn to
link different isolated elements of a situation.

Forensic science, taught through inquiry-based activities, engages students in critical
thinking skills. The content naturally lends itself to constructivist inquiry-based learning as
students are constantly required to ask questions, evaluate evidence, and use critical and logical
thinking to consider alternative explanations in the context of forensic analyses. The actual
processes that are involved in solving a crime are intriguing and generate excitement and interest
among students. Students are required to apply methods of science without formally learning
“the steps of the scientific method,” but rather as they are engaged in a naturalistic process of
learning that emerges as students are challenged to learn the skills and information they need to
know in order to solve the case.
Students are expected to observe, collect, analyze, evaluate, classify data, look for relationships, and form and test hypothesis related to conclusions about what happened at the crime scene. Students are also expected to defend conclusions based on their own empirical evidence (Funkhouser & Deslich, 2000). Moreover, students are required to think critically and logically about relationships between evidence and explanation, while constructing and analyzing alternative explanations and communicating scientific arguments (NRC, 1996).

**Scientific Literacy and Learning in Classrooms**

Many students who do well on strictly knowledge-based science exams, however, may be unable to think critically and judge the merit of information presented to them. Students who have not been taught how to approach the exams properly are usually disinterested in pursuing science further. When students are required to complete assignments based on worksheets and recall textbook information, they tend to lose interest because the information is often rote and the students are not challenged to improve their critical thinking skills and develop a deeper understanding of the material. Students therefore perceive the information that they learn in science classrooms as separate from scientific knowledge and skills that they need to know in order to make decisions that affect their lives. The development of independent thinking is not sufficiently facilitated.

Furthermore, many students experience difficulties when they are required to construct explanations. They tend to generate incoherent explanations from personal ideas (Driver, Guesne, & Tiberghien, 1985) rather than develop logical relationships between evidence and explanations (Kuhn, Amstel, & O’ Loughlin, 1988). These challenges contribute to the lack of
the development of scientifically-literate students—an important goal of the science education reform movement.

To address the challenges discussed above, this study contributes to providing meaningful science learning experiences to students. This was done by examining the effects of a series of inquiry-based forensic science activities on the development of high school students’ critical thinking skills and the achievement of scientific literacy related to forensic-based content.

The research question and sub-questions for this study are: How do inquiry-based forensic science lessons, taught within a constructivist classroom, promote the advancement of scientific literacy for students in grades 10-12?

a) What are the major learning outcomes that emerge from students participating in the forensic science inquiry-based unit?

b) What is the achievement progression of higher-order thinking skills for the class of students using cumulative plots of achievement curves?

**Method**

**Setting and Participants**

The study took place in Green Field High School (pseudonym), a suburban high school in the northeastern United States. The school demographics were 1,027 students—40% Caucasian, 25% African American, 18% Hispanic, and 17% Asian. Twenty-four students (10 males and 14 females) in grades 10-12 were enrolled in the forensics science course at the high school, and were also participants in this study. These students were mixed-achievement students, with the majority of students considered to be in the medium-to low-achieving range.
The forensic science class is an elective class that I have taught for the past six years and is presented for 16 weeks during the academic year. The forensic course is a selective elective in which mid- to low-achieving students enroll because they need additional science credits to graduate. These mid- to low-achieving students who prefer to take two science elective courses rather than Chemistry or Physics. Most of the students have a history of repeating either the Living Environment Regents or the Earth Science Regents or both. The forensic science course elective provides students with half of a science credit toward their graduation requirement.

**Research Design and Data Collection**

The overall approach for this study was a mixed methods approach. Mixed methods research is formally defined as the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study. According to this methodology, researchers collect multiple data using different strategies, approaches, and methods in such a way that the resulting mixture or combination is likely to result in complementary strengths and non-overlapping weaknesses (Johnson & Onwuegbuzie, 2004). The mixed methods approach is used to collect data that eliminates bias and helps the researcher develop a better understanding of the questions addressed in the study. This approach employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand the research problems (Creswell, 1998).

During six weeks of classes, data for the study were collected in the forensic science course. Each unit was made up of three activities designed according to the Biological Science Curriculum Study (BSCS) Five E inquiry instructional model (Bybee & Van Scotter, 2007). For each unit, students completed three mini-evaluations, one at the end of each lesson, except for the crime scene unit in which they completed a total of two mini-evaluations. This resulted in a
total of eight mini-evaluations for the 6-week period of the study. These mini-evaluations were short-answer response questions that were collected and analyzed to reveal students’ abilities to use higher-order thinking skills to solve problems. Mini-evaluations (Appendix C) were given at the end of each of the Five E lessons as the evaluation part. The evaluation portion of the Five E lessons was designed to measure students’ abilities to use higher-order skills to solve problems. The mini-evaluations were two to three questions to which the students gave responses in groups at the end of each of the lessons.

Student mini-evaluation worksheets and journal entries were completed for the forensic unit. Students were asked to justify and explain their thought processes. They were also encouraged to write down questions that arose as they engaged in the learning activities.

The student worksheets served as a guideline for focus group discussions and were designed to allow the researcher to understand the students’ thought processes in more depth. Focus groups were used to discuss questions, and particular attention was given to the way students selected and controlled variables, planned procedures, interpreted patterns of evidence, and constructed explanations during the inquiry-based activities in the forensic science curriculum. There were a total of six groups consisting of four students each who participated in the mini-evaluations and group journal entries. One member from each of these six groups was chosen by their group to represent them in focus group discussions. Each focus group consisted of students who belonged to diverse backgrounds (i.e., race, ethnicity, and achievement). A total of three focus group sessions were held over the 6-week period, conducted at the end of each unit. Focus group discussions were designed to discuss and explain how students arrived at decisions they made as they participated in the learning activities and to further elaborate on the responses made in their group journal entries. The speaker was able to explain and elaborate on
the experiences and concerns that came up as their group participated in the forensic science inquiry-based unit. Still, all members of the group had opportunities to share their thoughts in the group journal entries.

Finally, as the researcher for the study, I kept a researcher journal of classroom observations and this aided in providing additional insights into the themes that emerged from the data.

**Data Analysis**

The mini-evaluations were used for quantitative analysis and qualitative analysis. Specifically, they were analyzed quantitatively by using the evaluation rubric (Appendix C) and Bloom’s Theoretical Matrix (Appendix D) to provide a numerical score. First, the answers were categorized according to the major objectives using Bloom’s Theoretical Matrix (Appendix D) and then a score was given from the evaluation rubric (Appendix C) for each mini-evaluation based on which thinking skill was utilized. Scores of 1, 2 or 3 were given for the categories of Knowledge=1, Understanding=2, and Application=3. These skills were considered the lower-order thinking skills category. Scores of 4, 5 or 6 were given for the categories of Analysis=4, Synthesis=5, and Evaluation=6. These skills were considered the higher-order thinking skills category. Inter-rater reliability was achieved by having another rater provide numerical scores on 20 randomly chosen mini-evaluations using the same rubric.

The scores from the mini-evaluations were used to plot a bar graph (Figure 1) and an Ojive curve (Figure 3), which were then used for statistical analysis of the data (see Figures below).

Qualitative data were analyzed using standard procedures of grounded theory analysis (Charmaz, 2006). Data in the form of mini-evaluation worksheets, group journal entries, focus
group interviews, and classroom observations were collected, transcribed, organized, and analyzed. Initial coding consisted of reading through the data “line-by-line” in order to establish re-occurring themes and ideas. These themes were then re-read and placed into categories based on relationships and connections. Emergent themes were next correlated and combined to form new consolidated data sets related to the sub-questions being addressed in the study (Miles & Huberman, 1994). For example, as student responses were read through, the following themes were repeated that emerged from the responses: “frequent discussions necessary to figure out what happened,” “compromising to come up with best answer,” “second opinions and professional input needed,” “evolution of different ideas into new theories,” and “working together helps thinking process.” These themes were grouped in the category “value of group work in problem-solving” which related to the sub-question—major learning outcome-scientific literacy. Three groups based on analyses of major learning outcomes and scientific literacy emerged from the qualitative data. As the data were read “line-by-line,” notes were made in the margin to keep record of the researcher’s interpretation of the data.

Data analysis was done throughout the 6-week data collection process. The different data sources (mini-evaluation worksheets, group journal entries, focus group discussions, and classroom observations) were compared with each other for triangulation of emergent themes. Persistent Observation, Progressive Subjectivity, Peer Debriefing, and Member Checking (Guba & Lincoln, 1989) were four elements of quality criteria used to check the “credibility” and “validity” of the qualitative research.

Findings
Three major learning outcomes related to the attainment of scientific literacy emerged from the analysis of the data collected in this study; namely: a) the value and benefits of group work and discussion in the problem-solving process; b) the importance of using higher-order thinking skills in the evaluation and analysis of information; and c) the connection between skills and information learned in the classroom and its application to real-life situations outside the classroom. Each of these findings is described in greater detail in the following sections.

The Importance of Collaborative Work When Trying to Resolve Problems

As students discussed their experiences while they participated in the forensic science unit, they repeatedly mentioned the importance of collaborative effort. The benefits associated with collaboration that emerged from the focus group discussions and classroom observations included three major emphases: a) group members provided each other with different perspectives and opinions which helped them to consider the many different aspects of the problem; b) group work was also considered important as it provided students with evaluations of their own analysis as well as gave them an opportunity to evaluate others’ interpretations and solutions to problems; and c) group work helped to motivate each other and cut down on the monotony and overwhelming effect of the problems that have to be solved.

First, group members provided each other with different perspectives and opinions which helped them to consider the many different aspects of the problem. For example, Teresa described the approach to solving a problem as consisting of a combination of many different ideas that eventually evolved into a new theory. The fact that group members have different opinions and that, as group members, it is important to acknowledge the different opinions and to be open-minded was recognized by both students as being an important part of the problem-solving process. Teresa also acknowledged that she did not have the “correct answer” and that
discussions and the ability to be open-minded were important aspects of the problem-solving process. She further acknowledged that she experienced limitations when trying to figure out everything by herself:

Teresa: Well, it helps because group members give different theories and hypotheses basically for what may have occurred and it may be a completely different theory from yours—for instance, me and another speaker had similar thoughts when we brought it together it ended up being something completely different, so yeah…

Teacher: Did it help to discuss it?
Teresa: Yeah, because in a way it is like how this piece of evidence corresponds to what happened—how is this link to that—what may have occurred—how did the books fall like what may have occurred—was there a fight maybe it was just like an anger-raged person that knocked over the books. There are lots of different factors that were involved and other people help you to look at those things because at the first try and, you know, really notice because you can’t really think of everything at once.

Ron and Mary also supported these ideas as they discussed the importance of connecting ideas as well as the limitations associated with independent work. Both students discussed the value of getting different perspectives when solving problems:

Ron: Yeah, I agree you know how evidence a, b, and c connect and somebody else knows how b, c, and d connect and then you talk about it, adds on that little piece you get to connect ideas, it really helps out.
Mary: Yeah, I said there can be many answers and they can all solve one question and when you get the perspective from everybody you will be like okay, this makes sense to put it all together—there’s your answer.

Thus, group work was important in helping students develop and consider alternative ideas and perspectives.

Second, group work provided students with evaluations of their own analysis and provided an opportunity to evaluate other people’s interpretation and solutions to problems. For instance, Tony expressed that he thought group work provided opportunities for students to recognize and evaluate both the strengths and weaknesses of each other’s ideas and thoughts:
Tony: Teamwork does help a lot I believe because…one investigator might look over something or misinterpret it, and a fellow investigator can point it out or maybe make corrections if they misinterpreted it so they could interpret it correctly.

Even though Tony acknowledged that evaluating each other’s ideas was an important part of the problem-solving process, Ron expressed the difficulties that were associated with combining ideas to come up with a theory of what happened and the importance of evaluating one’s own opinion as well as other people’s views when figuring out what happened:

Ron: That is true there is only one exact story that pertains to each crime scene but once again it’s really hard be able to like tell that story from little pieces of evidence that are left behind because you may think one piece of evidence goes in one direction, but when you talk to someone else and discuss it may go in a completely other way, you know it’s really hard to come up with one whole connecting story.

Thus, the students realized the benefits as well as the challenges that arise as a result of group work.

Third, group work helped to motivate each other and to cut down on the monotony and overwhelming effect of the problem that has to be solved. Ron and Mary both accepted the difficulties that they experienced as they worked throughout the blood unit and the ways in which team work helped to motivate them and help them to figure out what they had to do in order to complete the task:

Ron: We encountered problems with the bloodstain pattern analysis activity. It was very hard to use your intuition and actually create the situation about the blood with reasoning, trial and error and teamwork, and discussing timing, you are able to figure it out.

Ron acknowledged that the forensic science unit presented challenges, and that recreating crime scene situations was not straight-forward and required a combination discussion and teamwork to figure out the problem. Trial and error implied that initial attempts at solving the problem may
have been incorrect and that revisiting the problem was also an important part in the problem-solving process.

Similarly, Mary expressed how having more people to discuss the problem helped with cutting down the monotony of the task as well as helped in planning out a strategy to approach the problem:

Mary: The group, you have a lot more hands a lot more minds to plan it out and hold the angles according to how you’re supposed to hold it in. I think it would have been a lot more if tedious if you did it by yourself, like in any office usually forensic, you have a group of team members that actually go into one case and they work it out.

**Problem-Solving and the Application of Higher-Order “Thinking” Skills**

The second major theme that emerged as students discussed their experiences with the forensic science unit was that the problem-solving process was a complicated process that often required rethinking and re-evaluation. Closely connected to the previous theme of the importance of group work, students discussed the fact that there can be a variety of valid solutions to one problem; therefore, it was important to take time to consider all the information before making decisions. Careful analysis and processing of information were necessary to fully understand the problem and come up with a solution.

Tony acknowledged that the nature of a crime scene was complicated and that many different factors have to be taken into consideration because the same information may have different interpretations. The importance of revisiting the information to make sense of it, and the realization that the process of solving a problem takes time to think through and to process information, was communicated by Tony:

Tony: I really don’t think it’s possible to look at a crime scene and automatically determine what happened ‘cause there’s always unknown variables and you really just can’t let what seems logical to you might happen might seem
illogical to someone else so you should always look [at] it with a fresh perspective if you come back the next day and say maybe you thought this yesterday, but today maybe this will work out where this one fell short.

Ron also expressed that events that occur at a crime scene take time to reveal themselves and that problem-solving was a slow process that required time and patience:

Ron: It’s really difficult to decipher that story with the—with only like key bits of evidence—like you get one piece of the story another small piece you get—rather than everything at once.

Theresa, Mary, Frank, and Ron discussed and gave examples of how misconceptions arise when evaluating data and how important it was to test the evidence before making inferences about its nature. As a result, the students learned not to make quick judgments but to take time to consider the evidence carefully before making conclusions. In the excerpt below, the students discussed many ideas related to careful analysis and the time required to look carefully at data before making decisions regarding one of the crime scene scenarios or problems they worked on in class. Lauren was the character in the scenario:

Teresa: …like the white powder everyone thought it was cocaine except for one person thought it was sugar and in fact it turned out to be powdered sugar.
Mary: …because of Lauren’s addiction to cocaine, they immediately thought okay, Lauren is involved with cocaine there was powder all over the place so some how. Lauren and Marcus, maybe they were both involved in cocaine usage but in the end it turned out to be that he was just eating donuts.
Frank: Also the ginger ale bottle with all the, we thought it had the ginger ale but it had Vodka in it.
Teacher: How do you know it had vodka in it?
Frank: You had to send it to the forensic lab.
Ron: …like the kit wrapper, sometimes you think evidence is completely unimportant after it is shown in a new light like after the toxicology report you realize you know it shows who was there—it provides the DNA sometimes—it’s more important than it seems, you know.

As the students participated in the focus group discussions, many of them expressed the opinion that there can be many explanations and solutions to the problem being analyzed. Both Tony and Teresa acknowledged that when analyzing a crime scene, a variety of logical
explanations can exist and these explanations may not be completely correct but can have an element of truth in them that is valid and needs to be considered. The idea that there was only one correct answer to the problem was understood; however, importance was also given to the fact that many different possible solutions must be carefully analyzed so that false inferences and conclusions are not made. Tony expressed the importance of considering the different ways evidence could have been produced and the importance of applying common sense and being skeptical while looking for clues within the data:

Tony: I say no because there can be many variations that could be at the crime scene in that you think can be explained but in actuality not what actually happened—not the only what results from—let, let’s say someone got shot in the chest but there was blood on the ceiling, how did that happen? Well, certain factors can be attributed to something behind the person that got shot and the blood ricocheting off of it and spread it on the ceiling and it wouldn’t be explained by a gunshot to the chest but maybe items or location of the person would result in evidence that normally you wouldn’t see or expect.

Teresa also agreed that there are many different possible explanations for the evidence and that the whole process involves making inferences based on the given information:

Teresa: I agree there’s definitely no way there could be one theory—is first of all you don’t really know what happened, so basically you are inferring everything based on the evidence and the sequence of evidence and events might differ in length—for instance, you can find two bullet casings under a computer and a knife in the corner, but you don’t know what happened—first, you may find the bullet casings first but the stabbing could have happened before there could’ve been a trail of blood—you don’t know it’s just basically the sequence and evidence so you need to take everything into consideration and look at it from different points of view.

The examples shared by both students exhibited the complex thinking process that the task required them to engage in as they tried to figure out the importance of the evidence in the problem-solving process.

Theresa and Mary discussed the importance of being aware of many different ways of phrasing questions and obtaining information in order to confirm suspicions, as well as being
sensitive to the fact that not all answers the suspects provided were necessarily the truth. They learned that such information received must be carefully thought about and critically linked to other information before coming up with an interpretation of the data and making inferences with respect to the problem being solved:

Mary: I think as a detective you have to play little mind games with the suspect and not ask them exact questions, but kind of like throw your thoughts in there and to try to get a better understanding and so instead of saying what time did this happen, you can kind of put in, like so did this happen on this day and they can really think about the question.

Theresa: Well, sometimes you have to put yourself in the shoes of the person that committed the crime if you were going to commit a homicide what would you do to cover up your tracks. It’s like I found the blood stain on the window and maybe she escaped through the window.

Frank and Tony discussed the deceptive nature of both physical and testimonial evidence and the importance of being aware of these different types of evidence and able to process and extend their thinking beyond the information provided. For example, the importance of extending their thought process by trying to figure out what was going on in the mind of the murderer was helpful to them in solving the problem. This again revealed the importance of thinking critically and using higher-order thinking skills to make judgments about the data:

Frank: The evidences that are there are there to throw you off—you have to understand that—that they are there to tell you a completely different story so you have to understand those evidences and try to think them out…

Tony: …and you also have to pay attention to the people you are interviewing—you don’t want to be played as a sucker—you do not want to fall into their lies and traps if they are trying to deceive you because they want to be free of all charges and do not want to be a suspect anymore—carefully pick apart what they are saying and then try to match them to an alibi—trying to match it to what they were doing at a certain time—you just don’t want to be lied to because that can throw off the entire investigation.

Thus, as this theme revealed, students were able to think critically about science and data. They realized the importance of being careful and looking at information carefully as they made decisions about evidence and drew conclusions based upon the evidence.
Connections between Classroom Learning and Real-World Applications

Finally, the third theme involved students being able to see the relevance between the content learned and problem-solving skills practiced in the classroom to different situations outside the classroom in the real world. Mary, Theresa, Tony, and Candy were able to see how the processing skills that they practiced were also used in fields of psychology, criminal justice, politics, and medicine:

Mary: You can also use it in the field of psychology evaluating certain people and their situations you have to understand and analyze and apply theory to real-life situations.

Theresa: You could also use this in court cases if you were lawyer or a DA and you were trying to convict somebody you could put the evidence in a way that would make it easier to try the person.

Tony: You could also use it in politics you have to understand what’s going on in the world.

Candy: Also in the medical field they are able to understand situations from a patient and apply what they have learned in school remember it and use it on patients that might come in.

In addition, Mary, Ron, and Tony made a connection between the values of the problem-solving skills that they practiced in the classroom to the analytical skills used by forensic scientists in the actual field of forensic science. This role-playing helped to make the learning more purposeful and eliminated the experience of just doing labs for the sake of doing work. Students were able to identify with what it was like to be a real forensic scientist.

Mary: Like at a crime scene analyzing the blood drops and the direction of where the blood came from.

Ron: Yeah, indeed, like if you were to become a forensic crime scene investigator the skills of recognizing patterns, blood splatter patterns that help identify how the victim was killed location and origin of the blood source.

Tony: I said like if you want to become an FBI forensic analyst is the skills you learned in this course would help you to succeed in the field. For instance, as I mentioned previously, the heights at which the blood was dropped, the surface on which the blood struck and other things.
As a result of the value of the skills practiced in the classroom, the students realized that the development of problem-solving skills was an important part of the learning process that could be extended into their personal lives. For example, Ron was able to connect the problem-solving processes practiced in the classroom to skills that were used when solving personal problems. This extension illustrated that he connected learning skills used in the classroom to his life in a meaningful way. As he stated, “Well, if for instance you had a friend with a problem, you have to recognize certain patterns if it keeps occurring—you have to understand what’s going on—also analyze and apply what you know what’s going on.”

Throughout the forensic science unit, students were provided with opportunities to practice processing skills as well as to use the forensic science knowledge together with their critical thinking skills to resolve problems. Tony used a combination of the knowledge that he learned about fingerprint detection methods in class and his common sense to explain how he would choose the best method of detecting prints at a crime scene. In his explanation, he described the multiple factors that needed to be taken into consideration before deciding which method to use was the best:

Tony: You would probably have to take into consideration where the print is located like if it’s on a wall as compared to like a couch, the structure of a wall—you would have to use something that sticks to nonporous substances as compared to a couch—which the print may be absorbed into a little bit so it’s a little harder to detect—you will probably get a partial print so you would have to use different methods that pertains to different surface locations.

Rob, Frank, and Candy also explained how they would match an unknown print to three suspect prints. All three of them used the knowledge that they acquired to describe how they would go about making the match between the prints. For Rob, he would look for the “most obvious most basic one” and “the first questions you must ask yourself is the print that you are
trying to compare to the other three matches the same category that they belong to like arch, loop or whorl because if it doesn’t, then that could really rule it out automatically.” Frank agreed with Rob’s approach and added: “And then you got to label the unknown print just to match all points and ridge patterns and then look at the three suspects and see which one is the closest.” Finally, Candy added, “You have to find like specific patterns the bridges and all that to see if it like matched in the same position as in the unknown print.” Thus, these three students’ comments reflected the thought processes and skills they learned throughout the forensic science curriculum in problem-solving.

**Scores for Higher-Order Thinking**

The second part of the findings is based on the analysis of the mini-evaluations using Bloom’s Theoretical Matrix (Appendix D) designed to classify students’ thinking skills. The rubric was based on three major objectives: collecting and organizing data, formulating and testing hypothesis, and predicting trends and making inferences. Briefly, the six areas of Bloom’s categories are as follows.

*Knowledge* is described as the recall of previously learned material and requires that the learner brings to mind the appropriate information. Activities such as remembering definitions and recall exercises are associated with this level. *Comprehension* is an awareness of what the material means. Activities that can be used to illustrate comprehension include compare and contrast, interpret facts, paraphrasing, and cause and effect. These two levels—*Knowledge* and *Comprehension*—are considered lower-order categories.

*Application, Analysis, Synthesis,* and *Evaluation* are all considered to be higher-order thinking categories. *Application* uses data, principles, and theory learned to answer a question. Activities include classification, development, and problem-solving. *Analysis* is described as
breaking down material into its constituent parts so that organizational structure may be understood. Activities for this level include recognizing and explaining patterns and differentiating between parts and wholes. *Synthesis* involves recombining parts created during an analysis to form a new entity different from the original one. Activities include development of proposals and creation of patterns and predicting conclusions. Finally, *Evaluation* is the ability to judge the value of material for a given purpose based on criteria and rationale. Activities include assessments, critiques, and making recommendations (Bloom, 1969). The lessons designed for this study contain activities that require students to use and develop the higher-order thinking skills of the taxonomy.

First, the responses to the mini-evaluation questions were categorized according to the major objectives and then a score was given for each mini-evaluation based on which thinking skill was utilized. Students were given a numerical score based on the knowledge and skills they used to respond to the mini-evaluation questions. Scores of 1, 2 or 3 were given for the categories of Knowledge=1, Understanding=2, and Application=3. These were considered as the lower-order category. Scores of 4, 5 or 6 were given for the categories of Analysis=4, Synthesis=5, and Evaluation=6. These were considered as the higher-order thinking skills.

Next, the scores were used to plot cumulative bar graphs and to perform a time-series analysis of the students’ thinking skills over the 6-week period (Figure 1). The cumulative bar graphs show that the highest scores from the mini-evaluations were generated from “Crime Scene Evidence Analysis and Evaluation” and “Crime Scene Observations and Inferences,” where both had a rubric score of 6 (Figure 1). These two activities occurred at the end of the forensic science unit and were the most realistic activities in terms of assuming the role of a forensic scientist.
One reason for incorporating forensic topics into science curricula is to enhance students’ use of cognitive skills. The data reported here (Figure 2) support this assumption. Out of a total of 48 responses, 27 responses (56%) were in the higher-order category of 4 and above. Forty out of 48 responses were in the category of 3 and above (83%). These data support the enhanced use of cognitive skills throughout the unit on forensics.

![Figure 1. Cumulative Bar Graph. This shows Rubric Score (ordinate) of Each Group (abscissa) for the Sequential Mini-Evaluations (bars) as follows: a, Fingerprint Classification; b, Latent Print Detection; c, Ridge Pattern Analysis; d, Blood Pattern Experiment; e, Bloodstain Analysis; f, Bloodstain Crime Scene Analysis; g, Crime Scene Observations and Inferences; and h, Evidence Analysis and Evaluation.]

The mean rubric scores ± SE for each of the forensic Mini-Evaluations (compiled across the six class periods) presented in ascending order are: Ridge Pattern (2.33 ± .33), Bloodstain Crime Scene (3.17 ± .40), Bloodstain Analysis (3.17 ± .45), Fingerprinting (3.83 ± .40), Bloodstain Pattern (4.17 ± .48), Latent Prints (4.33 ± .33), Crime Scene Observation (4.67 ± .42), and Crime Scene Evaluation (4.83 ± .48). The data are also presented as a bar graph (Figure 2) to exhibit the pattern of mean scores. Both of the Blood Stain Mini-Evaluations yielded the same
mean score, but overall the graph exhibits an overall increasing level of higher-order thinking across the sequence of Mini-Evaluation topics.

![Mean Score of Mini-Evaluations](image)

*Figure 2. Bar Graph Showing Mean Rubric Scores of Each Mini-Evaluation of a Forensic Topic*

Some learning experiences used in this study yielded less use of cognitive skills than others. For example, four of the eight learning experiences resulted in mean scores ranging between 2 and 4. These learning experiences were Ridge Pattern Analysis, Bloodstain Crime Scene, Blood Pattern Analysis, and Fingerprinting.

Students achieved the lowest score on the “Ridge Pattern Detection Activity.” The average rubric scores for this activity ranged from 1 being the lowest to 3 being the highest, resulting in a mean score of $2.33 \pm 0.33$. Students were required to use their acquired knowledge to match a suspect print to three prints with the same general pattern. They also had to use their knowledge of ridge patterns to justify their choice.
The “Bloodstain Crime Scene Analysis” resulted in students getting mid to low scores. Three groups got a score of 4 (Groups 1, 4, 6); one group got a score of 3 (Group 2); and two groups got a score of 2 (Groups 3, 5). The mean score for this activity was 3.17 ± 0.40. In this activity, students were provided with a crime scene sketch showing bloodstain evidence and were required to use their acquired knowledge to figure out how the blood splatter was created at the scene of the crime.

Most of the groups also got low scores for the “Bloodstain Pattern Analysis”. Group 2 received a score of 5; four groups (Group 1, 3, 4, 6) received a score of 3; and one group (Group 5) received a score of 2. For this activity, the students were required to re-evaluate their own experimental design and to discuss how their predictions of bloodstain patterns were different from their results. The mean score for this activity was 3.17 ± 0.42.

In the “Bloodstain Pattern Experiment,” students were required to design experiments to investigate the effect of height, angle, and surface on bloodstain patterns. This activity was very hands-on and students were given the liberty of using resources such as the computer and textbooks to choose materials to design and carry out their experiments as well as to research previous designs of experiments in order to evaluate and modify them and come up with their own efficient design. From this activity, three groups (Groups 2, 5, and 6) received a score of 5; two groups (Group 1 and 4) received a score of 4; and one group (Group 3) received a score of 2. This resulted in an overall mean score of 4.17 ± .48.

The “Fingerprint Classification” was an activity in which students got mixed scores: Groups 1 and 4 got a score of 5; Group 5 got a score of 4; and Groups 2, 3, and 6 got a score of 3. This activity required students to come up with a way in which to classify fingerprints based on different characteristics present in the prints. The mean score was 3.83 ± .40.
Four of the eight mini-evaluations had a mean rubric score higher than 4. Bloodstain Pattern Experiment, Latent Print detection, Crime Scene Observation, and Crime Scene Evaluation and Analysis yielded the most use of cognitive skills in increasing order.

The Latent Print detection activity provided students with a chart that described five different ways of obtaining latent prints from a crime scene. Students were given six different scenarios and had to choose an appropriate technique to obtain the latent print from the crime scene. They were required to justify their choice using the pros and cons of each technique and its relevance to the scenario. From this activity, three groups (Groups 3, 4, 5) received a score of 5, two groups received a score of 4 (Groups 1, 6), and one group received a score of 3 (Group 2). This resulted in an overall mean score of 4.33 ± .33.

For the “Crime Scene Observations and Inferences” activity, students were required to observe the crime scene and make inferences about the evidence based on what they saw, observed, and discussed. As shown on the graph (Figure 1), Group 3 scored 6; Groups 1, 4, and 6 scored 5; Group 2 scored 4; and Group 5 scored 3. This resulted in a mean score of 4.67 ± .42.

The “Crime Scene Evidence Analysis and Evaluation” students were required to examine lab reports and use their witness testimony and crime scene observations to recreate what they think happened based on the evidence presented to them. As shown in Figure 1, Groups 2 and 6 scored 6; Groups 3 and 4 scored 5; and Group 1 scored 3. The mean score for this activity was the highest, 4.83 ± .48. It was also the last activity of the unit and the study.

Finally, an Ojive curve (Figure 3) that plots cumulative rubric scores for each sequential learning activity was generated. This curve, on the whole, showed a steady state increment. As students moved from one lesson to the next, their rubric score was about the same. Yet, the mean
data showed an average increase from 3.8 to 4.83, which is a 1.0 unit gain. One out of six points means an average of 17% increase from beginning to end of total possible score.

![Figure 3. Ojive Curve Showing Cumulative Rubric Scores for Eight Sequential Learning Experiences](image)

**Discussion and Implications**

Overall findings support that including forensic science inquiry-based topics enhances students’ active involvement in learning and can improve their use of critical thinking skills and scientific literacy. The data from the focus group interviews revealed three major learning outcomes that emerged from the 6-week forensic science study: 1) students realized the importance and benefits of group work in the problem-solving process; 2) they acknowledged the significance of analyzing data thoroughly using higher-order thinking skills; and 3) they were able to make connections between skills learned in the classroom and real-world applications.
These learning outcomes are consistent with the development of characteristics that describe a scientifically-literate person cited throughout the literature (DeBoer, 2000).

After performing a thorough review of the history of scientific literacy in science education, Deboer (2000) stated:

There are many ways to be scientifically literate. As this historical review has shown us, there is no single right way to teach science, and within some fairly broad limits it probably doesn’t matter much which path is taken. The important thing is that students learn something that they will find interesting so that they will continue to study science both formally and informally in the future. (p. 597)

The findings of the study indicated that forensic science inquiry-based activities provides an avenue in which student interest is promoted and further study is encouraged. The “many ways” referred to in the above quote indicate that scientific literacy is summarized in nine statements, six of which are relevant to the findings of the study.

Participation in the forensic science inquiry activities gives students multiple chances to practice and thereby develop six of the nine characteristics that define a scientifically-literate individual. These include: practicing knowledge and skills that help them in the world of work; allowing them to see the application of science and science-related skills in the real world; equipping them with skills that help them become capable of making informed decisions about science-related social issues; helping them to develop scientific ways of thinking including the validity of data, objectivity, bias, tentativeness, and uncertainty; critically following reports and discussions about science in the media; and acknowledging the interdependence of science and technology.

The forensic science curriculum promotes scientific literacy by creating a science community in the classroom in which students are able to mimic the work of real forensic scientists. Important ideas linked to the attainment of scientific literacy emerged from the data as
students engaged in problem-solving scenarios. Skills such as working together to figure out problems, listening to different interpretations of the same data, evaluating each other’s arguments by using evidence to support beliefs, and combining ideas to form comprehensive explanations about science-related issues are all linked to the attainment of scientific literacy (DeBoer, 2000).

Being able to realize the value of the skills practiced in the classroom and their relationship to other fields in the real world as well as in the scientific working world and personal life is another important idea that has been linked to scientific literacy.

An additional important characteristic that links to the attainment of scientific literacy is that the problem-solving process requires careful analysis of facts based on evidence. This process requires time, patience, and effort and, many times, even re-evaluation in order to come up with valid conclusions (DeBoer, 2000).

According to Zeidler, Simmons, and Howes (2005), scientific literacy encourages skepticism, open-mindedness, and critical thinking. It allows for ambiguity and the quest for data-driven knowledge. These attributes are developed in students as the forensic science activities are infused with opportunities to question and judge the value of information. A central idea that permeates the inquiry-based unit and promotes these attributes is that there are multiple answers and ways to solve the problems. This creates an atmosphere of uncertainty that encourages students to question their ideas and look for alternative solutions. Students are also encouraged to be accepting of new ideas and questions that emerge as they progress through the unit. Uncertainty is treated as avenues for learning and for further exploration. Students are also provided opportunities to work together to explore possibilities and come up with unique ideas and plans.
The ability to reflect on their ideas and change them based on re-evaluation was a common occurrence throughout the unit. This free exchange to learn promotes a sense of ownership and self-confidence that supported the learning process and was consistent with a social-constructivist framework which recommends learning through the use of group work, sharing personal experiences, and making decisions through group consensus that leads to improved assimilation of knowledge.

A fundamental idea of science education reform efforts is that of creating a “learning community” with the shared purpose of making sense of scientific ideas and practices (NRC, 1996). Students are encouraged to share their ideas and learn from each other. As the students in the study engaged in the learning activities, they learned that one of the most valuable resources that they had was each other. The students supported each other through group work and formed teamwork relationships so that everyone worked together to build on their prior knowledge and expand their thinking to develop ideas further.

Furthermore, other constructivist-centered aspects include the use of open-ended activities that provide opportunities to think critically about information, to question observations, and to be active learners engaged in the process of learning science. According to constructivist learning theory, when students are involved in explanatory activities, they develop intellectual skills that enable them to construct understandings about science (Gagnon & Collay, 2001; Staver, 1998). The value of conversation and listening to each other’s ideas require mediating activities that enhance scientific literacy.

Authentic tasks in inquiry classrooms have been shown to engage students in scientific activity in ways that mimic how scientists conduct their work. The tasks are designed to be appropriate and meaningful for students (Lehrer & Schauble, 2006). The 6-week unit was
“authentic” as it simulated a real-world work environment in which the students researched and learned information they needed to know in order to accomplish a task. The work being performed was similar to the work performed by forensic scientists. This is a role that the students willingly assumed because they deemed it exciting and intriguing. The students were also required to be familiar with and use technology such as the computer and lab testing equipment in ways similar to how forensic scientists use these tools to find answers to problems as they “work a case.” The activities encouraged the students to participate in “science as practice” (Duschl, Schweingruber, & Shouse, 2007)—an important recommendation made in the National Research Council’s recent report on teaching and learning science in K-8 classroom if students are to advance in science understandings.

The development of higher-order thinking skills is an important quality of the constructivist framework and an objective of scientific literacy, or as John Dewey (1915) referred to it, “critical reflective thought.” For example, the quantitative data showed that students overall developed their higher-order thinking skills, which tended to increase as they progressed through the forensic science unit; this was particularly evident with data from the mini-evaluations, i.e., as students progressed through the unit, their ability to use higher-order thinking skills cumulatively improved. There was a steady increment on the whole as students moved from one lesson to next. The mean data showed an average increase from 3.8 to 4.83. This gain of 1.0 unit, or an average of 17% increase from beginning to end of the total possible score, is promising in terms of students’ ability to develop higher-order thinking skills in science classrooms.

Like previous studies done with inquiry-based science courses and students, this study supports the positive influences that inquiry-based science learning may have on student
achievement in the classroom (Driver, Asoka, Leach, Mortimer, & Scott, 1994; Gibson & Chase, 2002; Schneider et al., 2001). This is especially the case when the learning is real-life and student-centered, and the science content is sufficiently challenging and based on naturalistic problems that students find motivating.

However, the 6-week unit also presents challenges: the students realized that forensic science was not as “glamorous” as it is presented in the media and on television shows. The process of solving a crime scientifically is actually very complicated and requires a significant amount of effort on their part. Students are also not accustomed to open-ended problems with more than one answer and so they are often caught in the trap of trying to figure out “the right answer.” As a result, many students get frustrated easily and have to be encouraged to keep focused and use as many resources as they can to analyze information presented to them. Likewise, students are not accustomed to using higher-order thinking skills to process information and so initially many get discouraged and want to give up rather than revisit and process the sometimes multi-faceted information.

As a teacher and researcher, I also had challenges: I had to be open and I did not always know the answers to students’ questions. I also did not have all the skills to help students develop their higher-order thinking skills—skills I am developing as well. This style of teaching proves to be very demanding and requires a significant amount of energy and patience as the teacher learns cooperatively along with the students.

Conclusion

This study employed a mixed method approach to examine the major learning outcomes relating to scientific literacy that emerged from data on students participating in a 6-week
forensic science unit. Focus group discussions and mini-evaluations were analyzed and findings relating to higher-order thinking skills and scientific literacy were examined. While many studies have examined the effects of inquiry-based studies on student achievement, only a few studies have been done in the high school with an inquiry-based forensic science curriculum. The present study indicates that an inquiry-based forensic science curriculum promotes the development of scientific literacy by developing three major learning outcomes for high school students. These outcomes are: recognizing the value of collaboration and group work, using higher-order thinking skills to analyze information, and making connections between school science learning and the use of science knowledge and skills in the real world.

As a part of the learning process, students also experience frustrations and realize the amount of effort required when participating in an inquiry-based learning. The “glamour” and “excitement” associated with forensic science as portrayed in the media is unmasked as students participate in the forensic science lessons. In essence, the thinking and process skills needed to engage in science learning require time and effort, and the amount of work that forensic scientists are required to do to process a case gains deeper appreciation.
Chapter V

CURRICULUM DESIGN TO SUPPORT THE DEVELOPMENT OF
SCIENTIFIC LITERACY OBJECTIVES

Abstract

The following study was designed to examine what elements of a forensic science curriculum promoted student engagement and the achievement of scientific literacy. Twenty-four high school students participated in a 6-week inquiry-based forensic science unit. The study was a mixed methods study which required students to complete mini-evaluations, write group journal entries, and participate in focus group discussions; in addition, classroom observations were made. Findings indicated five major characteristics of the forensic science curriculum that promote student engagement and support the learning process of the students as they participated in the inquiry-based forensic science unit.

Key Words: Scientific literacy, forensic science, inquiry-based instruction

Introduction

The design of a curriculum to promote the development of scientific literacy has been an important project for curriculum developers. Scientific literacy is defined as the ability to use scientific principles and processes in evaluating information and making decisions. Moreover, a strong foundation in science strengthens the skills that people use every day, like solving
problems, thinking critically, and working cooperatively in teams. As a result, a curriculum designed to promote the development of such skills needs to provide multiple opportunities for students to practice and engage in activities that help them develop such skills. Analyses of state and local district standards which are used by curriculum developers have been criticized for their shallow coverage of many topics (Schmidt, Wang, & McKnight, 2005). Curricular materials aimed at supporting reform efforts in the development of scientific literacy need to be carefully designed to achieve this goal.

According to Bybee and Van Scotter (2007), a curriculum should be rigorous, focused, and coherent in order for it to be effective. A “rigorous” curriculum contains instructional materials and teaching practices that help create a classroom that promotes the following: a learning sequence that allows enough time for students to explore concepts in depth; and opportunities to represent their understanding in different formats and enable students to build conceptual understanding and make connections between concepts. A “focused” curriculum contains fundamental scientific concepts and inquiry abilities and develops them in depth. A “coherent” curriculum contains lessons structured so that activities are designed for students to make progress towards understanding key ideas of scientific investigations.

Research in cognitive science indicates that three major principles have been developed for implementing an effective science curriculum (Bransford, Brown, & Cocking, 2000; Donovan & Bransford, 2005). The first principle states that science curriculum must engage students in a process of conceptual change. The second principle states that in order for competence in science to be achieved, science curriculum must include a foundation of factual knowledge, a conceptual framework, and a framework to organize scientific knowledge. Finally, the third principle states that the science curriculum must include experiences that require
metacognition and provide students with opportunities to engage in metacognitive practices such as think-aloud, problem-solving, and group work (Martinez, 2006).

Maday (2008) suggested that student motivation and engagement can be increased by designing lessons that make learning more authentic. This type of instructional practice should focus on three criteria: a) acknowledging students’ current levels of understanding and experience; b) developing activities that foster deeper understanding of new information; and c) connecting content to personal or public issues. Varied ways of achieving the desired learning objective should also be provided for students. Researchers agree that it is important for students to receive appropriate feedback, which helps them learn from mistakes and motivates success (Maday, 2008; Wiggins & McTighe, 2007).

Further, Wiggins and McTighe (2007) suggest that teachers design activities that are both engaging and effective. Engaging activities are a) varied, b) allow for student choice and personalization, c) are built upon meaningful challenges, d) provide opportunities for collaboration, and e) foster investigative approaches. Effective activities are focused on relevant goals, have a purpose that is evident and meaningful to the student, provide learning incentives, and are teacher-facilitated to ensure student success (Wiggins & McTighe, 2007). Thus, activities need to be carefully designed and structured in creative ways so that students’ engagement is facilitated while at the same time they are able to come up with reasonable solutions.

The National Science Education Standards focus on the development of scientific literacy through the use of inquiry-based lessons (NRC, 2000). Inquiry encourages the development of knowledge as students are encouraged to understand the way in which scientists approach problems and construct knowledge based on carrying out investigations. As a result,
students model the work of real-life scientists and attain scientific knowledge by asking questions, formulating hypotheses, planning and conducting investigations, and analyzing and communicating results.

Inquiry-based methods of teaching are effective in fostering scientific literacy; however, the challenge of getting students engaged and excited about science remains a problem to be solved. Researchers such as Newmann (1992) and Yair (2000) maintain that American high school students are not fully engaged in classroom learning. This is a problem as it has been found that student engagement has consequences for students’ academic achievement (Finn & Cox, 1992). It is very important to present the content of lessons to students in a way that generates interest in the task they are going to perform. If students are not interested in the content related to what they are required to do, then they are less likely to engage in the learning process. Excitement and student enthusiasm are generated when students perceive learning as meaningful and interesting. The key, therefore, is to present activities and information in a format that motivates and encourages students to learn.

Student engagement has been defined as sustained behavioral involvement associated with positive emotional responses towards the learning task (Chapman, 2003). These responses include exerting intense effort and concentration towards the learning task. Enthusiasm, optimism, curiosity, and interest are examples of positive emotional responses. When students are engaged, they pay close attention to ongoing classroom activities and are interested in the content of classroom lessons; they may also experience heightened states of awareness, confidence, and performance (Uekawa, Borman, & Lee, 2007).

Studies done to investigate how classroom activities foster student engagement have shown that student engagement is closely linked to task difficulty. For example,
Czikszentmihalyi and Robinson (1990) defined maximum student engagement as “flow.” Students are said to experience “flow” when they are fully engaged. This occurs when their individual ability and skill level required by classroom activities match. Nakamura and Csikszentmihalyi (2002) also state that in order for students to feel competent, the task challenge must be appropriate and not overwhelming.

Another factor that has been shown to increase student engagement is group work and collaboration. (This was also found in the previous chapter.) Through group discussions with other peers, students are able to express themselves and explore possible solutions to presented scenarios. This provides them with opportunities to construct meaning from information and enhance the value of instructional content. Problem-solving tasks and collaboration simulate everyday situations that they encounter in their lives. When students interact with their peers, they are likely to be more focused (Uekawa, Borman, & Lee, 2007).

Forensic science is a subject that can be used to design curricula that meet the criteria of inquiry-based instruction, while at the same time promotes student engagement in the classroom. The nature of the lessons provides opportunities for students to use and develop their critical thinking skills as well as perform the work of real forensic scientists by engaging in scientific methods. In addition, students are very interested in the subject because of the popularity of television shows. The idea of being a detective and solving problems (crime scenes) as portrayed by television is exciting and adventurous. Students are generally willing to participate in activities that link to the subject; as a result, forensic science provides an avenue for promoting student engagement and scientific literacy.

Educators have observed that forensic science activities have resulted in increased engagement in science activity and enthusiasm for science (Colgan, 2002; Learner, 2003).
Forensic science activities have also helped students think critically like scientists by analyzing the world around them (Dickie & Percival, 1989). Teachers who incorporate components of forensic science, such as crime scenes in classroom learning, report that students view these activities as more than just schoolwork; rather, they see them as a way to solve problems in everyday life by using science (Brooks, Green, Kleck, & Muench, 1995).

Considering the discussion thus far related to inquiry and student engagement, the following study was designed to investigate what characteristics of an inquiry-based forensic science curriculum support student engagement and contribute to the learning process of students in a science classroom. An account of students’ experiences as they participated in the inquiry-based curriculum is presented to get an idea of the difficulties and benefits they experienced in this process. Thus, the primary research question and sub-questions for this study were: How can curriculum be designed to support the development of scientific literacy objectives?

a) What characteristics of the inquiry-based forensic science curriculum support student engagement and contribute to the learning process of students?

b) How can these characteristics be used to design curriculum that promote scientific literacy objectives?

In the following section, the theoretical framework for this study is presented. The theoretical framework for the study helped to frame and guide the study and its design in order to address the research questions.

**Theoretical Framework**

Learning in the science classroom requires well-designed, practical activities that challenge learners’ prior conceptions, encouraging them to reorganize their personal thoughts
In a constructivist classroom, students structure and monitor their metacognitive skills to help them develop a deeper understanding of critical science concepts (Staver, 1998). Students are engaged learners and are required to use their analytical and problem-solving skills to tackle investigative questions through classroom activities such as dialogues with peers and hands-on laboratory activities. Students are required to do science in order to learn science. As they engage in activities that model the work of scientists, they develop a better understanding of the process of scientific inquiry (Bybee & Van Scotter, 2007).

The forensic science curriculum used in the study was designed for high school students in grades 10-12, using a social constructivist framework. A social-constructivist framework relies on social interaction of students in the construction of knowledge (Vygotsky, 1978). Students are required to use their prior knowledge and critical thinking skills to work together to figure out the solutions to problems. Students are actively engaged in the learning process as they are required to constantly re-evaluate their understanding and interpretations of problem-based situations. Moreover, students are encouraged to critique each other’s ideas, providing a means of feedback and a way to expand their thoughts and ideas.

The theoretical understanding of social constructivism was coupled with the Biological Science Curriculum Study (BSCS) Five E instructional model (Bybee & Van Scotter, 2007) in the development of the forensic science curriculum used in this study. The Five E model is a constructivist lesson design plan that contains the following five stages: Engagement, Exploration, Explanation, Elaboration, and Evaluation (see Figure 1 in Chapter II).

The Engagement stage is the first stage. Students make connections between present and past learning experiences. This stage involves creating interest and eliciting responses that uncover what students know or think about the subject.
The *Exploration* stage allows students to work together without direct instruction from the teacher. Students are provided with opportunities to get involved with the activity, problem or materials. The teacher’s role is to ask questions that redirect students’ investigations when necessary and to provide support. The teacher acts as a facilitator.

The *Explanation* stage encourages students to put their ideas and definitions into words. Communication begins between peers or with facilitators or within the learner themselves. The teacher asks students to justify and clarify their explanations.

The *Elaboration* stage encourages extending concepts and skills in new situations. Students are encouraged to extend their thinking and make connections to generate further inquiry and new understanding.

The final stage, *Evaluation*, allows the teacher to determine whether or not the learner has attained understanding of the concepts and knowledge. Students are also provided with opportunities to assess their own learning and group process skills. Open-ended questions are structured to encourage students to think. Tools such as teacher observations, which can be structured by checklists, student interviews, and portfolios, are used to assess student learning.

Once more, the intent of this study was to examine what elements of a forensic science curriculum promoted student engagement and the achievement of scientific literacy. The method for this study is described in the next section.

**Method**

**Setting and Participants**

All data were collected in the researcher’s forensic science class over a 6-week period of time. The forensic science class is an elective course that students take; they receive half of a
science credit if they pass it and counts toward their science credits for graduation. The course is taught for 16 weeks. As the teacher of the course, I have taught the forensic science course for the past 6 years, and have been teaching at Green Field High School (pseudonym) for 7 years. Green Field has a diverse student population of about 1,027 students: 40% Caucasian, 25% African American, 18% Hispanic, and 17% Asian. For this study, students enrolled in the forensic science course were participants. In total, 24 students participated in the study: 14 females and 10 males, of diverse racial/ethnic backgrounds and learning abilities ranging from low to medium.

**Data Collection**

This mixed methods study (Creswell, 2003) used mini-evaluations (Appendix B), student worksheets, and group journal entries (Appendices E, F, G), as well as focus group interviews (Appendix H) and classroom observations to understand how the forensic science curriculum promotes student engagement. The open-ended responses from the mini-evaluations asked the students to justify and explain their thought processes while engaging in the forensic science curriculum. The students were encouraged to write down questions that came up as they engaged in the learning activities on worksheets and in their science journals.

Group journal entries were made by students at the end of each of the units. The students were provided with a guided reflection sheet that contained questions for them to discuss and respond to. The questions were designed so that students would be required to reflect on the activities in which they participated for each unit and clarify responses and observations of mini-evaluations.

Focus groups discussions (Appendix H) were conducted for another form of data collection in this study. A total of three focus group sessions were held over the 6-week period of
the study. Each focus group had six students. The focus group discussions were designed so that students could discuss, explain, and elaborate on how they arrived at the decisions they made as they engaged in the learning process. They were also asked to discuss the benefits and difficulties that arose as a part of the learning process and the strategies they used to overcome problems and changes that were revealed as they progressed through the learning activities. The focus groups allowed me to understand the cognitive strategies the students used as they participated in the forensic science curriculum; as the researcher, I was able to get a better understanding of the students’ experiences and concerns in learning in inquiry-based ways through the curriculum.

Classroom observations were recorded in journal entries for each of the mini-evaluations. I as the researcher circulated the room and observed each group for three to five minutes with respect to body language, focus, and verbal participation. Students’ reactions to the activities were recorded. This consisted of students commenting that they were having difficulties with the activities, remarks on their interest and engagement, notes on interesting questions, and whatever other relevant comments that came up.

**Data Analysis**

Student mini-evaluation worksheets, group journal entries, focus group interviews, and classroom observations were collected, organized, and analyzed using standard principles of grounded theory (Charmaz, 2006). Recurring themes and ideas were established by initial coding which consisted of reading through the data “line-by line” and interpreting student responses. As the researcher read and interpreted the data, notes were made in order to establish patterns within the data. The themes established from the data were then re-read and grouped into categories
based on connections to each other and to the research questions being investigated (Miles & Huberman, 1994).

For example, the following themes emerged repeatedly from a “line-by line” (Charmaz, 2006) reading of student work and responses: “active minds required,” “constantly evaluating and re-evaluating information,” “coming up with own lesson plan,” “revising initial plans to improve the outcome,” and “teacher and textbook resources.” These ideas were grouped in the category “independent thinking/empowerment,” which was further classified as “self-directed learning” related to the sub question—characteristics of forensic science curriculum/student engagement. Data from student worksheets, group journal responses, focus group discussions, and classroom observations were compared to each other for triangulation of emergent themes.

Elements of rigor employed included “Persistent Observation,” “Peer Debriefing,” “Progressive Subjectivity,” and “Member Checking” (Guba & Lincoln, 1989). A research journal in which I recorded notes and observations as well as student questions was kept for the 6-week period of the study (Persistent Observation). I also kept a separate journal in which I recorded what I expected to find before I started the study. I then recorded the data and my construction of what was happening based on my interpretation. These notes were discussed with a peer debriefer (another forensic science teacher) whose role was to notice if my interpretation was subjective and accurate (Progressive Subjectivity).

The data obtained from the study were discussed with both the peer debriefer and my dissertation advisor in order to review and ask questions about the study and to ensure consistency with the findings (Peer Debriefing). Finally, data and analysis of the data were informally discussed with the participants to verify if the collected data were accurately recorded and interpreted. Preliminary or emergent categories and themes generated from the data analysis
were discussed with focus groups to obtain the reaction of participants to the interpretation of the data obtained from their discussions. These elements of quality criteria were employed to ensure the “credibility” and “validity” of the qualitative research.

**Findings**

Five major characteristics of the forensic science curriculum promoted student engagement and supported the learning process of the students as they participated in the inquiry-based forensic science unit. These included: a) the forensic science curriculum provided opportunities for students to participate in relevant and realistic real-world learning situations through role-playing; b) the goals and objectives of the lessons placed the students in charge of their own learning; c) the unit objectives focused on problem-solving skills and deep understanding of science content and processes; d) knowledge construction was designed to occur through social negotiation and collaboration; and e) the students were encouraged to reflect on their thoughts and ideas during the learning process because the curriculum had activities that fostered self-reflection opportunities.

**Real-World Learning Situations and Role-Playing**

The forensic science curriculum provided opportunities for the students to participate in relevant real-world learning situations. Each unit was structured to contain at least one real-world case study environment. This was done via case studies and role-playing in which students were asked to emulate forensic scientists through the hands-on activities and thinking processes promoted by the forensic curriculum. The students played the role of forensic detectives and were allowed to perform similar duties to those performed by a forensic detective. For example, the students were encouraged to solve problems and apply higher-order thinking skills as a part
of the learning process. One group’s response to a question in the curriculum asked students to examine a crime scene sketch and explain how the bloodstain pattern in the sketch was formed.

We think that body one died from a head trauma as there is a pool of blood around his head and no other bloodstains but transfer stains on the wall. He was probably struck with a blunt object and the killer or the weapon touched the walls. The killer then walked over to victim three, explaining the blood drops on the floor. Then he stabbed victim three because there is cast off bloodstains and contact patterns around the wall from being repeatedly stabbed. Victim 2 was probably standing against the wall and then shot. That’s why there are no bloodstains in the middle of the wall and between the marks. The killer then left the footsteps walking towards the door.

Also in this group’s journal entry, the students shared that coming up with the response was actually quite challenging and required time, discussion, and careful analysis of the crime scene sketch. In addition, they shared that they enjoyed how they were “working a case” and they got to pretend that they were “forensic blood splatter analysts.”

The forensic science curriculum was designed so that the activities were also hands-on and would create an active learning environment where students acquired and discussed information that was necessary to accomplish their task. As a result, learning from the curriculum required that the students get information and understand the information for a purpose as opposed to just learning lots of information for the sake of taking a test.

Again, the role-play and the real-world scenarios were realistic enough to motivate students to engage with the curriculum and activities. The classroom learning environment was transformed from a school setting into a real-world working environment. For example, students—Mary, Candy, and Frank (all pseudonyms)—expressed that they enjoyed the hands-on nature of the activities and doing the same work as “real detectives.” They enjoyed performing the tasks that required them to think and be active learners rather than passive learners. Some additional comments from students in a focus group were as follows:
Mary: I enjoyed the crime scene because it was very hands-on and involved and I very much liked that I was like a real detective. I got information from different suspects and all that.

Teresa: I agree.

Candy: Yeah, I agree also.

Frank: I enjoy collecting evidence from the crime scene which helps you to try to piece together the story and everything so that was pretty cool and working like a detective and looking for every little detail and trying not to destroy any evidence that can really throw you off so try to figure that out too that was very cool.

Frank: My favorite part was using different kinds of methods to collect fingerprints it would help us because when we classify we can separate them in different groups and we can see how real detectives do it which is pretty cool.

Candy: Oh um …my favorite activity going back to the first students [comment] and what she said dusting for fingerprints I really like that because it actually forced you to use your skills and apply it to a real-life situation.

From classroom observations of the crime scene activities, the students seemed to enjoy pretending, role-playing, and performing the tasks usually done by detectives. The students became interested as soon as they entered the library, which was set up as a crime scene, with the yellow “crime scene tape” blocking off the crime area. Exclamations like “This is so cool” and “We should do more of this” were noted as I moved around and observed students looking intently for clues and information. The students were engaged and excited, and constantly thinking about the task assigned—to solve the crime. Many student questions were generated from their initial observations. They were very interested in figuring out what had happened.

The students were engaged in tasks performed by scientists, such as making observations, suggesting interpretations, establishing hypotheses, and questioning their own suggestions and thoughts. The students were encouraged by the nature and design of the crime scene learning activity to discuss and interject their thoughts. They were required to combine their prior knowledge as well as the knowledge acquired from the classroom in order to make sense as real crime scene detectives.
Students in Charge of Their Learning

The activities in the curriculum created a learning atmosphere that was purposely designed to allow students to derive the learning objectives by working together under the teacher’s facilitation. Individuals were presented with learning activities that encouraged them to share and develop their ideas so that their initial thoughts adapted and changed throughout the learning process. This forensic science curriculum activities presented students with opportunities to be independent thinkers, to build on their prior knowledge, to construct new knowledge, and to develop their critical thinking skills.

Ron and Mary both described the learning environment as being very different from the traditional classroom in which knowledge was transferred from teacher to student rather than constructed by the students. The curriculum allowed students to take more ownership of the learning process, and the classroom environment was changed to accommodate this type of student learning. For example, Ron mentioned “coming up with your own lesson plan.” He was referring to learning in the forensic science class as self-directed learning. This type of learning made students feel empowered to learn because they were able to create the lesson plans for the class: “It’s not you, a textbook, and a teacher. It’s you and other group members coming up with an idea on your own. It’s your own lesson plan.” Mary discussed that as a student, she and her peers were the ones who would come up with ideas on how to improve their plan for learning. She found that the teacher was a good person to facilitate the learning process, but that really the student collaboration was an essential part of the learning process in the classroom:

Mary: One of the challenges I encountered was actually creating angles to drop the blood as we really didn’t understand what angle was supposed to create what kind of blood drop it all the same—at first got—but when we asked our teacher, she came over and actually helped us to think it through and after discussing it with other group members revising our initial plan, we
were able to come up with a plan to drop the blood. We had to change the plan a couple of times based on the results we got from each trial.

From the classroom observations of the fingerprint classification activity and the blood drop angle design experiment, it was clear that students were not accustomed to taking control of the learning process. Both the classroom observations and the group journal entries indicated that the students struggled with these two activities. Both of these activities required students to devise a plan to organize and investigate relationships and to change their plan based on the results and feedback from each other and the teacher. Even though they were willing at first to try to do their best, many of them got frustrated and discouraged and started looking “for the right way to perform the experiment” or “the correct way to organize the print patterns.” The initial responses of four of the six groups were to give up and call me over to “tell them what to do” so that they could get the “right answer.”

Many students in these groups, who were challenged with taking an active role in directing how to go about doing the experiments, gave up and then started engaging in off-task conversation. In one journal response from one group, the students expressed being “overwhelmed and discouraged” when they were asked to design the fingerprint classification system. Another group commented, “It was very confusing, we did not know where to begin, and the prints had so many different patterns. I really did not enjoy this activity.” From the blood unit activities, one group wrote in their journal, “We could not figure out how to drop the blood from different angles; after trying repeatedly, it became very annoying and we just gave up.”

Observations of the class performing the fingerprint classification activity and the blood drop at different angles activity provided me with very important information. Students were not accustomed to taking the lead in planning or taking ownership in directing what to do in their learning. It was genuinely very difficult for them come up with a plan to investigate a problem. It
was equally challenging for them to accept that not getting the activity right the first time was part of the learning process and that making revisions to their own plan based on their experience and feedback was also an important part of the learning process. Initially, many students did not have enough patience and confidence to realize that their frustrations were a vital part of the learning process. The “immediate solutions” were not realistic as they demonstrated superficial rather than deep understanding of the process of science inquiry.

Even though the students struggled with the fingerprint and blood drop activities, after these two units concluded, Frank and Candy described the learning process for them as students. They discussed that the process usually required many attempts and revisions before coming up with satisfying results. These revisions provided learning opportunities for the students to develop an understanding of science and to acquire new skills and information for conducting good trials. Both shared that being in charge of planning the test trials over several times revealed shortcomings in their groups’ initial attempts at solving the problem:

Frank: Well, when the plan didn’t work out when we were using 10, 20, 30, 40 (different heights that the blood was dropped from in cm), we decided to go big. We used is 20, 40, 60 and that pretty much gave us pretty much the same results and then there was a lot of human errors so we went more big, we tried earning 30, 60 that gave us better results. We were more accurate.

Candy: Yeah, with the…um…experiment with the angles, there is a lot of human error so we had to repeat the process several times so we can actually feel satisfied with our results without getting messed up.

Therefore, the re-evaluation process allowed students to come to the realization that it was important for them to think about information and to consider possible areas of error.

**Problem-Solving Skills and Deep Understanding**

The activities in the forensic science unit were open-ended and structured to provide students with multiple opportunities to solve problems using higher-order thinking skills and to
develop a deeper understanding of the material presented to them. Many of the activities did not have one correct answer, and a variety of different approaches could be used to come up with possible solutions to the problems. In a discussion with Mary and Candy, both girls expressed the importance of thinking carefully about information and not just accepting information at face value. By engaging in this “minds-on” process of learning science, students developed their critical thinking skills and gained a deeper understanding of science as a process of solving problems: Furthermore, the students who participated in the focus group discussion expressed the importance of analyzing and processing information carefully rather than accepting quick answers and information for its face value.

For example, Mary and Candy acknowledged that the data needed to be carefully analyzed in order to reveal meanings that were not obvious. These meanings usually extend beyond the facts and realizing that initial thoughts and inferences may be incorrect is an important part of the process. Mary and Candy both stated the importance of thinking carefully about information and not just looking at the surface content of the information provided. The importance of being open-minded and flexible with opinions about data interpretation was a common comment made by students, as indicated below:

Mary: You learn to analyze things a lot more carefully before making judgments because there is usually a deeper—something much more deeper because when you analyze it at first, you’re like okay this is what happens and this is what it is that is it—then when you really get information different sorts of information like maybe that’s not how it happened at all.

Candy: I agree—you have to analyze all that the information because what seems like a suicide could turn out to be a homicide but they made it seem like a suicide.

Students were put into situations where they were expected to make connections between different sets of data they analyzed in order to develop a better understanding of the whole picture. The mini-evaluations and classroom observations showed that students were not
accustomed to using evidence to back up their claims. A good example of this occurred while observing and interpreting the crime scene assignment. In the initial activity when students went to observe the crime scene, they started making inferences based on what they saw; however, when they were provided with the lab report and witness testimony, the students had to re-create the crime scene using specific pieces of evidence, connecting together the different elements in solving the problem. In some instances, this proved to be quite challenging as many students had the tendency to go with their initial “feelings” rather than scientific evidence. Also, many of the groups added elements of fiction in their re-creation to make the story more interesting, and they had to be redirected to find evidence that supported their claims. Excerpts from student responses to the crime scene evaluation and the bloodstain analysis that contain elements of fiction include:

Carol and Marcus went to the library late to drink alcohol and Lauren was stalking Marcus and wanted to give him a letter. He saw the letter and Carol ripped it up. Marcus said, “I will never be with you again,” so Lauren goes crazy and pulls out a knife and tries to stab Marcus and accidentally cuts herself. Lauren and Carol were throwing books at each other. A Kit Kat wrapper fell out from Lauren’s pocket and Carol touched it by accident while reaching for a book. Lauren finally stabbed Marcus three times and Carol ran away. Lauren put sugar on his nose so people would think he overdosed on drugs.

Three guys shared a house. One of the three guys just returned home after hitting the gym. A little while later, someone broke in a struggle. Body 1 was stabbed, head bashed in from a knife/desk. Body 2 was against a wall while he was shot in the head. Body 3 was possibly strangled with the telephone cord. The murderer then dropped the weapons used and walked out of the house.

Both of these responses included elements of fiction such as “Lauren stalking Marcus” as well as Marcus’s statement, “I will never be with you again.” There was also no evidence to support that “Carol ripped up the letter” or “Lauren went crazy.” The bloodstain analysis activity did not contain any evidence to support the fact that “three guys shared the house” or “one of the guys had been to the gym” or “someone broke into the house.” These were all elements of fiction that the students included as a result of their imagination.
The students were reminded throughout the analysis activity that they had to support their claims with scientific evidence. This provided a valuable learning experience as students began to develop their higher-order thinking skills. The forensic curriculum thus required that they revise their initial interpretations based on critically thinking about information that they discovered or what was presented to them. For example, Tony and Rob expressed the importance of being open to new ideas that emerged from the data and the analysis process. They discussed the importance of having an open mind and thinking critically about data so that they did not get misguided by information that was purposely meant to deceive them:

Tony: We had to predict who actually committed the crime and then by observing the crime scene and evaluating the evidence you could actually piece what you learned from the crime scene and maybe your predictions will come true as to who you suspected or maybe it will take a turn and someone else that you would not have expected it since the evidence pointed to him now you’re going to suspect them.

Ron: Well, with like interviewing once again you have to compare that with the coroner’s time of death—sometimes what people would say throw you off and you would think one thing happened and then the coroner’s time of death would come and it’s a whole extra hour you know.

Tony: Sometimes you have to evaluate the alibis for the suspects because sometimes what they say may not actually correspond to what the coroners say—like if the person says they were there from 6-8 [p.m.] but they were there at 9 [p.m.], then they don’t have an alibi for that so you can probably determine the person’s lying.

Observing the students as they worked in groups to process the crime scene and reading their responses in the mini-evaluations, I saw that they were faced with tasks that required them to make informed judgments about the value of data and look for evidence to validate their thoughts. When students were asked to use what they had discovered to figure out what had happened, they debated with each other about the relevance and significance of the collected and observed data. This process resulted in students ranking and prioritizing their thoughts and opinions about what they saw and applying their prior knowledge to make sense of their
observations. They also had to make decisions about the validity of witness testimony and use it in conjunction with observations, lab reports, and witness testimony to re-create what they thought happened at the crime scene. These practices required the students to use higher-order thinking skills to develop a deeper understanding of data presented to them.

Knowledge Construction through Social Negotiation

The forensic science activities were presented to the students in order to promote knowledge construction rather than knowledge reproduction. The students engaged in activities that encouraged social negotiation and collaboration, which allowed them to take ownership and voice during the learning process. All activities were group-based and open-ended, and students were continuously encouraged to consider alternative viewpoints and multiple perspectives for the same problem.

One recurring theme that emerged from the three group journal entries was the value of talking to each other to figure out problems. The students also mentioned how they supported each other when dealing with the challenges they faced in working to solve the crime scene problems. For example, the following excerpts from group journal entries illustrate the benefits the students received from working in a group:

Teamwork is an important factor in solving complex problems because someone on your team may find a piece of evidence that you did not see, they may bring in new interesting perspectives or may analyze the evidence differently especially when you are tired and have given up.

Working in a group makes it a little easier to figure out what could have happened because some people are better at figuring out one aspect than another.

Because we worked in groups we were able to piece together clues and analyze data quickly and more efficiently. It really helped to listen to ideas of the other people in the group as the task was so open-ended.
Working in groups to figure out problems and allowing them to use multiple resources to make sense of information kept students interested and engaged in the curriculum. The information they needed to solve the case was available to them via forensic textbooks and the internet, and they were able to “talk through” hurdles that came up as they worked their way through trying to understand information. As a result, information emerged on a “need-to-know” basis.

As they were trying to solve problems and figure out what happened, the students were also learning information in order to use it. This made the learning more meaningful because the information they acquired was necessary for a particular purpose at the time that they needed it. Their understanding and retention of the information were enhanced because they were purposeful in gathering information based upon questions that arose as they participated in the various activities of the curriculum.

During the crime scene focus group, Teresa and Tony discussed the importance of group work in problem-solving and knowledge construction. Teresa discussed the way in which theories evolved and the importance of other people’s opinions in this process. She also discussed the limitations of her own perspectives and the way in which multiple perspectives helped to create a reflective learning environment in which ideas evolved and generated new understandings of information:

Teresa: Well, it helps because group members give different theories and hypotheses basically for what may have occurred and it may be a completely different theory from yours—for instance, me and another speaker had similar thoughts when we brought it together it ended up being something completely different.

Tony and Candy also stated the importance of multiple perspectives in terms of students helping each other to understand the limitations of their own interpretations and as a means of providing feedback on learners’ understanding:
Tony: Yeah teamwork does help a lot I believe because and one investigator might look over something or misinterpret it and a fellow investigator can point it out or maybe make corrections if they misinterpreted it—so they could interpret it correctly.

Teacher: So when you get to that point when you feel very overwhelmed, you really don’t know what to do—how would you deal with that like what do you?

Candy: You have to talk to your team members as they always have points of view—when I worked with my partner, she would come up with things that I did not even think of so you have to take that into consideration—you have to collaborate to come up with a story.

From observing the students in their interactions during the activities, it was observed that a majority of students had different ideas that related to their interpretation of the data. Most of their interpretations were based on what they observed and their prior knowledge. Again, by working in groups and sharing their ideas, both as individuals and as a group, the students were forced to come up with evidence to support their opinions and at times to re-consider what they originally thought.

The process of discussing, debating, and evaluating each other’s ideas and combining the various perspectives served as a means of peer feedback and resulted in richer interpretations and more developed ideas. The practice of social negotiation to solve problems provided students with opportunities to construct knowledge by sharing and developing their thoughts and perspectives. This kept them interested and engaged in the tasks presented to them, and also helped them to overcome frustrations in solving problems. The group work provided the students with a source of support as they negotiated ideas, worked through problems, and thought about information with different perspectives.

**Metacognition and Self-Reflection**

Finally, one of the most important aspects of the forensic science curriculum was the way activities were constructed to allow students to reflect multiple times throughout all three units
on their own learning process. For example, students were asked to reflect on their experimental designs and to describe the pros and cons of their approaches (Blood Unit). They were asked what further improvements they could make to the experiments that they designed after they had performed the experiment (Fingerprint Unit). The students were also asked how their predictions differed from the results they got and to make suggestions for why this was so (Blood Unit). This reflection process helped students to think carefully about the activities they were engaged in and to develop their critical thinking skills.

Mary described her experiences in learning in the Crime Scene Unit. This unit required her to constantly reflect and reconsider inferences made through the various activities in the unit. The process required her to actively think about the evidence as she worked through the crime scene. Mary commented on this point: “Because there are some things that don’t belong at the crime scene and you think that it is important when it is really not.” She continued to explain that in the process of taking notes about the crime scene at various points, “you take it down—you know writing it this is here, this is there,” but when she returned to the notes, “when it all comes back to the story, it had nothing to do with what you were looking for.” She had to think about her thinking (metacognition) and what she was learning in the curriculum in order to make good notes to tell the story of the crime scene.

Rob also shared his opinion about how important it was to revise initial ideas based on evidence that becomes available later on. He talked about the “Kit Kat wrapper,” which was a wrapping from a Kit Kat chocolate bar that was accidentally left behind. The wrapper contained fingerprints (thumbprint and index fingerprints) and saliva (DNA) that confirmed the presence of one of the suspects at the crime scene:

Rob: Like the Kit Kat wrapper—sometimes you think evidence is completely unimportant after it is shown in a new light like after the toxicology report—
you realize you know it shows who was there—provides the DNA—sometimes it’s more important than it seems you know.

Tony and Mary described the complicated nature of the crime scene in terms of the investigator having to take into consideration the many different meanings and interpretations of data. Tony described the importance of taking time to reflect on initial ideas and thoughts, while Mary reflected on the importance of considering many views to come up with a solution:

**Tony:** I really don’t think it’s possible to look at a crime scene and automatically determine what happened causes there’s always unknown variables and you really just can’t let what seems logical to you might happen might seem illogical to someone else so you should always look at it with a fresh perspective—if you come back the next day and say maybe you thought this yesterday but today maybe this will work out where this one fell short.

**Mary:** With the crime scene when you are investigating the suspects there are so many different points of view that you have to get it all together into one story to try and understand—like okay this person says one thing this person says that but it is not really connecting—I’m missing someone and it just gets very frustrating because you want to solve it but you don’t want to be wrong.

Opportunities for self-reflection throughout the forensic science curriculum promoted student engagement. The students had to re-evaluate their initial ideas and thoughts as well as share their thinking in all activities, including the difficulties and challenges that they experienced. Candy expressed the need to “be satisfied” with the final results of the experiment, but students learned that the learning process takes time and that it was not always easy to come up with a quick solution or answer to a problem.

The students appreciated the fact that they were allowed to make adjustments to their initial plans and designs without being penalized for getting it “wrong” the first time. As they were graded on the final product, they took advantage of the numerous times within the curriculum to re-think, reflect on, and revise their initial plans and ideas. Many of the groups handed in reflections of what went wrong and what they could do in the future (group
assessment) to improve the efficiency of their plans. Examples of things the students mentioned they would do differently included: perform the experiment multiple times; doing a trial run and then adjusting the heights and angles in smaller/larger increments; using different surfaces at different heights and angles; being more careful to articulate when performing experiments; using a wider variety of materials; using real blood instead of simulated blood; and researching previous experiments done to test the same variables. Therefore, students’ final reflections to questions in the curriculum revealed that they did make use of the opportunity to reflect on their initial plans and designs. These final plans showed their learning from the curriculum.

Discussion

Science education for all students is seen as curricula that can be lived and to which the students can relate. The forensic science curriculum provides multiple opportunities to promote student engagement and facilitate the development of scientific literacy in activities that are based on real-world science understandings. Student engagement is supported by five major elements of the structure of the inquiry-based forensic science curriculum, as represented in the findings from the study. These include providing opportunities for students to participate in realistic real-world learning situations through role-playing; placing students in charge of their own learning; focusing on problem-solving skills and understanding of science content; constructing knowledge through social negotiation and collaboration; and reflecting on thoughts and ideas during the learning process.

According to Bell (2007), science educators have identified three domains of science that are important for the development of scientific literacy. Incorporating these three domains into science instruction requires that the idea of “science” as simply a body of knowledge must be
readdressed to incorporate a broader view in which the development of scientific knowledge and the nature of knowledge itself are addressed.

These three domains refer to science as being a body of knowledge, a set of processes, and a way of knowing (nature of science). Multiple opportunities for students to develop these understandings are presented in the forensic science curriculum. The body of knowledge refers to scientific facts, concepts, theories, and laws that have been developed throughout the history of science education. Scientific methods and processes refer to the different ways that scientists use to generate knowledge and refer to skills such as observing, measuring, inferring, predicting, and hypothesizing. The third domain refers to the nature of science and includes the realization that scientific knowledge is based on evidence; it can change over time and includes elements of creativity. This domain helps students develop accurate views of what science is by developing an understanding of the types of questions that science can answer, the difference between science and other disciplines, and the strengths and limitations of scientific knowledge (Bell, 2008).

The results of the study indicate that the forensic science curriculum provides students with ample opportunities to experience and practice skills defined in these three domains that have been linked to scientific literacy. Science as a body of knowledge is addressed by the curriculum as the three major units require that students develop an understanding of knowledge as well as current techniques and technology used to analyze evidence. Content knowledge discussed as students progress throughout the curriculum included the Fingerprint Unit (the role of DNA in organisms, different techniques used to identify latent prints including technology in the form of chemical tests such as superglue fuming, iodine fuming, Ninhydrin, AFIS); the Blood Unit (chemical composition of blood and body fluids, genetics, properties of blood spatter,
trajectory and patterns); and the Crime Scene Unit (information available from autopsy, types of evidence—biological and chemical processes associated with the decomposition of a dead body—determining time of death, cause of death, drugs and poisons, the role of insects and bacteria in decomposition).

The students were given opportunities to acquire and understand domain-specific knowledge of biology, chemistry, and physics as well as to experience repeatedly the way in which knowledge from these areas are often integrated, based on the context of its application to forensic science problems. An example of this was in the crime scene when students were expected to use their knowledge of biology, chemistry, and physics to evaluate different types of lab reports and photos linked to physical evidence found at the crime scene. The students developed an appreciation of both domain-specific scientific knowledge as well as the way in which knowledge from the different disciplines is integrated into real-world applications.

Opportunities are embedded in a lived curriculum—crime scene cases, problems, experiments—where students use their prior knowledge and established scientific knowledge to engage in the processes of science, such as resolving problems, making investigations or drawing conclusions based upon the evidence found at the crime scene. As they participate in these activities, the important realizations associated with the nature of science (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) are also addressed and experienced.

The findings indicate that students realize that scientific knowledge is evolutionary and subject to change in light of new evidence. Students are encouraged to be skeptical of information. Even though creativity is encouraged, the importance of supporting their ideas with empirical evidence is stressed throughout the curriculum. The curriculum also presents multiple opportunities for students to make observations and to link these observations to inferences.
based on connections with other ideas and previous encounters. These criteria match the principles that have been consistent with the key ideas linked to the nature of science and its association with the development of scientific literacy (Bell, 2007).

Implications of the Study

Three additional points are discussed in reference to the findings of the study with regard to implications for the study. First, a curriculum that invites students to pretend and engage in role-playing as a part of the learning process is engaging and exciting for them. This finding on students’ role-play connects to the work of Maday (2008), who suggests that to improve student motivation and engagement in learning, presenting learning in a real-world setting does motivate student learning. Making observations, suggesting interpretations, establishing hypotheses, and questioning thoughts and solutions are the work, processes, and activities that real scientists engage in to solve problems. Students feel like forensic scientists. The idea that they are assuming the role of a forensic detective on a mission to solve a case is appealing and adds a sense of excitement and interest to learning school science. The scenarios or cases in the three units of the curriculum allow students to learn information for a purpose and on a “need-to-know” basis as they ask questions and construct ways to re-create the crime scene. Students are given the chance to engage in a “coherent” curriculum in which the activities are designed towards understanding the key ideas of scientific investigations. Because the problems simulate real-world situations, a connection between the classroom and real life is reiterated constantly throughout the curriculum.

Second, the forensic science activities are structured to support independent thinking and student empowerment. Conceptual understanding is developed by providing students with enough time to make connections and represent their understandings in different formats (Rigor).
This allows them to take ownership of their learning by providing opportunities for the learning objectives to evolve as the curriculum progresses.

This proves to be good in terms of student-centered learning, yet not so good for the same reason. Student engagement is promoted by providing students with the freedom to plan and direct their learning plans or activities. However, the choice is a challenge to students who are not used to taking charge of their learning. As a teacher, it is interesting to note how accustomed students are to being “told what to do” in order to come up with the “correct answer.” Because students are not accustomed to taking control of their learning, they become very discouraged, overwhelmed, and frustrated. This is an area of curriculum development that requires attention to support the teacher as facilitator, yet assist students in being student-directed in their learning.

Third, the forensic curriculum poses the challenge of getting students to use their higher-order thinking skills to think about solutions to problems based upon evidence. Fundamental science concepts are explored and inquiry abilities are developed (Focus). This also presents a challenge as many of the students are not accustomed to backing up their claims with evidence and using higher-order thinking to think through problems as a part of the process. This finding is consistent with the findings reported by Driver, Guesne, and Tiberghien (1985), who claim that students who participate in inquiry-based curriculum usually experience difficulties and tend to generate incoherent explanations from personal ideas. Kuhn, Amstel, and O’Loughlin (1988) also maintain that learners participating in inquiry-based curriculum experience difficulties when they are required to develop logical relationships between evidence and explanations.

Even though they are intrigued at first by the glamour of forensic science, students realize that in order to develop strong claims, several trials and careful attention are required to develop logical relationships between evidence and explanations. The experience provides students with
reflection opportunities to compare the way in which forensic science is portrayed in the media to the reality of solving a real-world forensic case.

The structure of the forensic science curriculum to promote student engagement helps to fill the gap for students in developing higher-order thinking skills as they talk to each other in order to solve complex problems. The idea of social negation is the idea of social constructivism, where students work collaboratively and build knowledge in social interaction. This way of learning provides a source of support and insight that helps students deal with the challenges presented by the problem-solving process of the curriculum. In addition, students are given the opportunity to reflect on and receive feedback from both teachers and other students to revise their initial plans, which helps give value to social negotiation and group learning. In turn, this keeps the students engaged, allows them learn from mistakes, and motivates success (Maday, 2008; Wiggins & McTighe, 2007).

Conclusion

This study employed a mixed method approach to examine what characteristics of a 6-week, inquiry-based forensic science curriculum support student engagement and the development of scientific literacy. Student worksheets, mini-evaluations, group journal entries, focus group interviews, and classroom observations were examined and the findings related to student engagement and curriculum design.

The study indicates that the inquiry-based forensic science curriculum promoted student engagement by possessing the following five characteristics: 1) providing opportunities for students to participate in relevant and realistic real-world learning situations; 2) allowing students to engage in self-directed learning; 3) providing chances for problem-solving; 4)
supporting knowledge construction through social negotiation; and 5) including activities that foster metacognition.

The forensic science curriculum also presents students and teachers with challenges because they are not accustomed to self-directed learning. Seeking the “right procedure or answer from the teacher” is a tendency that students resort to after initial attempts are unsuccessful. The teacher’s urge is to “rescue the students and to tell them the correct way or answer”; therefore, teachers must practice not to feel this urge. Another challenge for students is for them to consistently use higher-order thinking skills to back up claims with evidence.

Many students want “quick answers,” but having patience and taking time to think through problems are skills that require practice because students are not accustomed to doing these tasks. This could be partly because they are constantly under time pressures when preparing for and taking exams. The forensic science curriculum provides multiple opportunities for students to realize that in order to develop strong claims, they may have to complete several trials and give careful attention to the data.

Student engagement and the development of scientific literacy are supported by students participating in the forensic science curriculum because these activities mimic the work of real scientists. The forensic science inquiry-based setting presents lessons in an intriguing manner that requires students to be active thinkers and to use their critical thinking skills to question the value of information provided to them. Developing problem-solving skills in a scientific context is an important skill that can be used to help students judge the value of information presented to them in the real world. If students are better critical thinkers, they are more likely to question and validate information presented to them outside the classroom, especially via media accounts and portrayals of science in the news.
Chapter VI

FINAL DISCUSSION, IMPLICATIONS, AND CONCLUSION

Engaging students in learning science and scientific concepts has been a serious challenge for many educators. Teacher-centered instruction that involves the memorization of a large number of facts unrelated to each other and that usually lack connections to students’ lives has led students to learn information and adapt test-taking skills superficially in order to pass examinations. These practices also contribute to a large number of students becoming disinterested and unmotivated in the science classroom. Students do not fully develop the necessary skills that enable them to use scientific knowledge to make decisions that affect their lives and thus do not achieve the goal of becoming scientifically-literate.

This dissertation study was designed to examine the effects of a series of inquiry-based forensic science activities on the development of high school students’ higher-order thinking skills and the achievement of scientific literacy. Twenty-four high school students participated in a 6-week inquiry-based forensic science unit. The study used mixed methods which required students to complete mini-evaluations and group journal entries, and participate in focus group discussions. The research questions for study were:

1. How do inquiry-based forensic science lessons, taught within a constructivist classroom, promote the advancement of scientific literacy for students in grades 10-12?
a) What are the major learning outcomes that emerge from students participating in the forensic science inquiry-based unit?

b) What is the achievement progression of higher-order thinking skills for the class of students using cumulative plots of achievement curves?

2. How can curriculum be designed to support the development of scientific literacy objectives?
   
a) What characteristics of the inquiry-based forensic science curriculum support student engagement and contribute to the learning process of students?
   
b) How can these characteristics be used to design curriculum that promote scientific literacy objectives?

In this final chapter of the dissertation, I discuss the overall findings and implications for this study. Finally, I offer some ideas for further research.

**Forensic Science, Scientific Literacy, and Higher-Order Thinking**

The findings from this study indicate that three major learning outcomes relating scientific literacy emerged (Chapter IV). These include: first, collaborative work is important when trying to resolve problems; second, solutions to problems require rethinking and re-evaluation; and third, skills practiced in the classroom are linked with its relevance to different experiences in real-life situations and the use of science knowledge in order to form judgments and resolve problems. An analysis of the mini-evaluations also revealed a general progression in the development of students’ higher-order thinking skills as they participated in the 6-week unit. These findings indicate that forensic science inquiry-based activities are a curriculum resource that can be used to promote the development of scientific literacy in high school students.
An interesting question that needs to be addressed in the study is “What about the subject or subject matter of forensic science promotes student interest and enables the achievement of scientific literacy?” Students enter the classroom already excited about what they perceive the subject to be. They want to learn more about what they have seen on television as well as participate in similar activities and test their prior knowledge of forensic science that they gained from watching television. Patterns of interest are generated by the innovative technology used to analyze evidence, the nature of the crimes that are involved, and the forensic scientists’ depiction as glamorous and intelligent.

Because the shows are designed to stimulate viewer interest, students enter the classroom already motivated and excited about learning forensic science. For many students, science activities are motivational when they perceive them as being relevant to their lives (Heath, 1983) or when they receive either intrinsic or extrinsic satisfaction (Spaulding, 1992). Because of the authentic nature of forensic science, students are able to see its relevance to their world. The subject also provides an exciting, mysterious, and intriguing setting which makes students intuitively feel that it is important to find answers that will help them solve the mystery (Duncan & Daly-Engel, 2006). For students, the classroom experience is educative when they learn about something new and interesting; it offers them knowledge which they did not have prior to their engagement and an opportunity to learn a skill that can be used again in a different situation to benefit themselves.

The powerful effect of the media on student interest in science can be capitalized on by science educators in the classroom and used to facilitate the development of critical thinking. Theoretically, if the influence of popular media is incorporated into the science curriculum, it can be used to promote the development of one of the major objectives of scientific literacy: to have
students become capable of critically reviewing articles and accounts presented by the media. The experience of participating in a forensic science curriculum provides students with important insights of the actual reality of being a forensic scientist, which in fact is very different from what is portrayed by popular television shows and books.

The *National Science Education Standards* state that the process of science requires students to combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science (NRC, 1996, p. 105). Throughout the literature, the study of “science” entails that learners engage in three major areas of the discipline: possessing knowledge of the principles about current ideas and principles in biology, chemistry, and physics; practicing the application of scientific methods and processes; and developing an appreciation of “the nature of science” (Bell, 2007). The forensic science curriculum provides ample opportunities for learners to engage in such practices. Scientific literacy is developed as students constantly use processing skills (observing, inferring, predicting, evaluating) to further develop ideas within the context of existing scientific information (biology, chemistry, physics) in order to solve problems. As they do so, they develop an understanding of the nature of science (empirical evidence, tentativeness, objectivity, and subjectivity).

There are many advantages in using the nature of forensic science activities to promote science learning. First, forensics itself is inquiry-based and naturally engages the learner in problem-solving activities. It is authentic, as the subject also exists as many activities that simulate the types of work that forensic scientists need to perform in their line of work.

Second, forensics is a multidisciplinary subject as it embodies concepts in many areas including biology, chemistry, genetics, medicine, psychology, and law (Funkhouser & Deslich,
The lessons integrate the different subjects and sciences to solve problems in the form of a crime. The activities and content required to engage in the learning of forensic science satisfies the criteria stated in the *National Science Education Standards* in multiple ways. Forensic science fits into content standards of “Science as Inquiry,” “Unifying Concepts and Processes,” “Physical Science,” “Life Science,” “Science and Technology,” and “The History and Nature of Science.” By engaging in forensic science activities, students learn about unifying concepts and procedures in terms of evidence models and explanations; they are required to evaluate evidence and propose models and explanations based on the results of their investigations. Students learn to link different isolated elements of a situation.

Third, forensic science also engages students in the process of inquiry. Students combine process and scientific knowledge as they use reasoning and critical thinking skills to solve cases. Forensic science activities engage students in asking questions, planning and conducting investigations, and using appropriate tools and techniques to gather data. Students are required to think critically and logically about relationships between evidence and explanation, while constructing and analyzing alternative explanations and communicating scientific arguments (NRC, 1996).

**Implications for Teaching and Curriculum**

Past findings from research studies done in American high schools show that high school students are not fully engaged in classroom learning (Newmann, 1992; Yair, 2000). It also shows that a lack of student engagement affects student academic achievement and other outcomes (Finn & Cox, 1992). If students are not engaged and interested in what they are doing, then the
aspiration of achieving scientific literacy, which is one of the major aims of education reform, is difficult to achieve.

Students enter the classroom with preconceived ideas. Therefore, learning in the science classroom requires well-designed, practical activities that challenge learners’ prior conceptions, encouraging them to reorganize their personal thoughts (Driver et al., 1994). Furthermore, functional understanding occurs when they are exposed to science curricula that involve active construction of knowledge as well as are driven by topics and situations meaningful to their lives (Bransford, Brown, & Cocking, 2000).

The study indicates that the development of critical thinking skills is an important objective that should be encouraged in other subject areas as well as in science. If students are required to develop critical thinking skills throughout their educational experiences, then there is a better chance they will be able to evaluate information they view on a daily basis more effectively.

The findings from this study revealed that students enjoy the inquiry-based forensic science activities presented to them in a constructivist learning setting. As a result, such activities serve as a medium to capture the interest of students. Inquiry-based instruction that is rooted in a subject and activities in which students are interested can provide meaningful learning experiences for them. The interdisciplinary nature of forensic science demonstrates to students how the different branches of science (i.e., physics, chemistry, and biology) come together not as separate subjects but as connected content areas.

In addition, the study supports the development of curricula that include activities providing opportunities for students to engage in constructivist activities such as building on their prior knowledge, engaging in hands-on learning activities, and using group work to solve
problems. Students should be provided with opportunities to participate in self-directed learning and reflection activities as a part of curriculum design. Activities that provide multiple chances for students to replicate the work of real scientists are also valuable tools to be included in curriculum design.

**Implications for Science Education**

This study is indeed a promising one as it indicates that the achievement of scientific literacy in the science classroom can be attained by presenting lessons that appeal to high school science students. The findings of the study suggest that the style of presentation and the content be modified so that students are encouraged to be active thinkers and participants in science learning activities. Even though school science education is responding to reforms, there is still the tendency in the classroom for students and teachers to resort to the traditional method of education, in which lessons are lecture-based and students are passive learners. Rather than teach in an inquiry fashion to promote scientific literacy, research has shown that students are being taught in preparation for standardized testing (Bentley, Ebert, & Ebert, 2000; Grossen, Romance, & Vitale, 1994; Rescher, 2000).

Inquiry-based learning requires a change in the structure of science education. Educators, parents, and administrators are often in a rush to cover curriculum so that students can do well on state exams such as the Regents and in AP courses. Even though most educators are very supportive of using inquiry-based instruction in the classroom, many are not sure how to do so effectively. Parents are often concerned about their children being prepared properly for the state exams so that they can get into the colleges of their choice. Unfortunately, most of these exams still require that students learn content as opposed to applying their critical thinking skills. As a
result, the dilemma of achieving scientific literacy or doing well on exams arises. The repercussions for not doing well on state exams often outweigh the achievement of scientific literacy, and so ways of combining both successfully need to be supported in science education.

According to the *National Science Education Standards* (NRC, 2000), “open inquiry” activities provide the best opportunities for cognitive development and scientific reasoning. The forensic science curriculum is structured to include such activities; however, findings from the study indicate that this type of instruction presents significant challenges for both students and teachers. Students are not accustomed to self-directed learning and independent thinking, and so they often get frustrated and bored when they are required to pursue extended lessons that require them to think through problems (Chapter V). The findings from this study also indicate that students are not accustomed to deciding what questions are important when investigating a problem. Students often struggle when they are required to support their claims with evidence and are not prepared to take the time to develop logical arguments to support their claims.

Many teachers are also not accustomed to being facilitators and so the “urge” to “take charge” and solve problems for the student or to provide too much guidance are tendencies that exist on their part. Designing and administering effective “open-inquiry” lessons are difficult as students have a variety of paces and approaches to solving the same problem. The ability to adapt to different learning styles and to be open to an evolving learning process as well as using a variety of ways to assess learning are changes in the “mindset” of teachers.

**Implications for Teachers’ Professional Development**

The successful administering and delivering of inquiry-based instruction are challenging endeavors for most science educators because these are not routines that can be followed but
rather “mindsets” that need to be developed. Teachers undertaking the task of teaching in order to achieve scientific literacy through inquiry-based instruction need to be provided with adequate training and support. This can be achieved by workshops and professional development sessions that allow teachers to read and discuss appropriate literature as well as develop lesson plans that feature inquiry-based practices, student engagement, and content learning. Opportunities to “try it out” in practice are suggested.

The workshop sessions should concentrate on helping teachers to administer lessons so that sustained engagement is promoted. Students’ interest in forensic science and related activities is high because of popular television shows such as CSI and Forensic Files. However, students’ enthusiasm usually diminishes once they realize how tedious and difficult the work of a forensic scientist actually is. As a result, teachers need to be equipped with techniques that keep students engaged in the learning process, while also displaying for them the various ways that science and the work of scientists are actualized in reality.

Guidance on how to develop “coherent learning experiences” (Harris & Rooks, 2010), which contain lessons structured so that activities are designed for students to make progress towards understanding key ideas of scientific investigations, is another important element that needs to be addressed in teacher workshops or teacher professional experiences. Learning experiences need to support cognitive development and not just be an “entertaining” experience for teachers to pass along to their students.

Techniques that help with managing discussions, developing questioning techniques, and providing adequate amounts of guidance (Harris & Rooks, 2010) that also promote the scaffolding of instruction and the development of higher-order thinking skills are other important topics for teacher professional development. If these elements are not appropriately incorporated
into the learning experiences for teachers, then it becomes just a way to pass time rather than a successful learning experience for their students. In addition, teachers should also be provided with opportunities to share their experiences in the classroom as they take on reform-based science teaching practices, including their challenges and frustrations. This can ultimately be a great source of support and a means for them to learn from each other.

Further, the ways in which students are given feedback and assigned grades are also very different from the traditional grading system when teaching and learning in constructivist and reform-based classrooms. Feedback requires time to look carefully at student work and offer suggestions to further their deep conceptual learning (Bybee & Van Scotter, 2007). Teachers need to be aware of different ways to assess student work and to provide constructive feedback so that students are encouraged to continue with the learning process.

**Further Research**

Several extensions can be done to this study. The first extension would be to conduct the study over a longer period of time. Conducting a similar study with a larger sample of students for one or two semesters with more units may provide valuable data about the effect of forensic science on the development of scientific literacy and higher-order thinking skills. It would also be interesting to include a pre-test and post-test of higher-order thinking skills and to collect individual student work so that evidence of individual student learning could be analyzed.

Another study that compares a forensic science course taught in a traditional setting to one taught in an inquiry-based setting may provide insight into classroom structures and norms that need to be re-adjusted as students learn in inquiry-based ways and teachers reflect on such changes.
Finally, motivation to learn and to learn science specifically is a major area for science education research. It would be interesting to do an extension study in which the effect of a forensic science curriculum on students’ motivation and academic achievement is measured. The current study does reflect engagement in science, but to what extent, and how well are students’ motivation and engagement reflected in science test scores, particularly in higher-order thinking.
BIBLIOGRAPHY


APPENDIX A

Bloom’s Theoretical Matrix

APPENDIX B

Mini-Evaluations—6-Week Forensic Science Unit

1. Lesson Title: Classification of Prints (A)
Copies of the classification system that students devised along with their justification will be collected

2. Lesson Title: Latent Print Detection (B)
- Students will be provided with a chart that describes five different ways of obtaining latent prints from a crime scene
- Students will be given six different scenarios and will have to choose an appropriate technique to obtain the latent print from the crime scene
- They will be required to justify their choice using the pro’s and con’s of each technique and its relevance to the scenario

3. Lesson Title: Identifying Ridge Patterns (B)
- Students will then be presented with an unknown print from a crime scene
- They will be provided with three prints that all have the same basic loop pattern and will be asked to use at least 5 ridge patterns to confirm a match between the crime scene print and the suspect print
- Students will write a journal entry responding to the following questions
  - Why are ridge patterns important for use when classifying fingerprints?
  - What are some of the pro’s and con’s that you can identify with the current system for classification of prints?

4. Lesson Title: What are the factors that affect bloodstain patterns? (B)
- Students will be required to work in groups of four to design experiments to investigate how
  1. Drop size and shape are affected by height
  2. Angle of impact affects bloodstain patterns
  3. Type of surface affects bloodstain pattern
- They will be required to describe procedures and to create tables to collect data
- Students will be evaluated on the finished product that has been designed by the group
- Compare the experiment they designed with a standard investigation used to investigate the same factors

5. Lesson Title: How do height, angle and surface affect the size of a blood drop? (A)
- Students will then perform standard experiments to collect data
- They will be required to record their observations
- State relationships that discover from the experiment
- How was what you observed different from what you predicted?
- Students will be provided with an unknown pattern and will be asked to determine height from which the blood was dropped using the results from their experiment
• The above assessment will be repeated for angle and surface effect on the size of blood drops
• Students will reflect on the activity and suggest ways that they could improve the efficiency of the experiments if they had to repeat it.

6. Lesson Title: Bloodstain Crime Scene Analysis (C)
• Students will be provided with a crime scene sketch containing bloodstain evidence. They will be required to look at the picture and use their knowledge of bloodstain pattern analysis to infer what happened at the crime scene.

7. Lesson Title: Observation of Crime Scene (A)
• Student will be escorted to the site of the crime scene and will be required to make observations, record the data and collect witness testimony that they think is relevant to the case.
• Students will complete a chart in which record their observations and the data that they think should be collected.
• Students will also state how the evidence should be collected and where it should be sent for analysis.

8. Lesson Title: Evidence Collection and Witness Interview (C)
• Share their observation of the crime scene evidence with group members.
• They will be required to revisit the crime scene and collect evidence to package and send to the appropriate lab for testing.
• They will also label the evidence that they want to be tested for experimental analysis.
• Students in the class will listen and supplement the information that they collected to develop a better understanding of the evidence.
• Students will be provided with the lab reports containing the results of the lab tests on the evidence collected.
• Students will connect the information from their observations, the witness testimony, the lab reports and the background information and rank the importance of the information that they receive in terms of its relevance to the crime scene.
• Students will be expected to use the evidence to infer what they think happened at the crime scene.
• Each inference must be supported with evidence from the crime scene.
• Students will be expected to recreate and what happened at the crime scene in the form of a written report.
• Students will share what they think happened at the crime scene to the class.
• Students recreation must be supported by evaluation of the evidence.
APPENDIX C

Bloom’s Taxonomy Evaluation Rubric

<table>
<thead>
<tr>
<th>Level of Taxonomy</th>
<th>Skill Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNOWLEDGE</td>
<td>• Recalls and recognizes most of the information ideas and principles in the form in which they are learned</td>
<td>1</td>
</tr>
<tr>
<td>COMPREHENSION</td>
<td>• Understands and can interpret and summarize most of the information read, viewed or heard</td>
<td>2</td>
</tr>
</tbody>
</table>
| APPLICATION       | • Complete use of information  
• Uses methods, concepts, theories in a new situation  
• Solves problems using required skills or knowledge  
• Applies an abstract idea in a concrete situation to solve a problem | 3     |
| ANALYSIS          | • Recognizes patterns  
• Identifies and sees hidden  
• meanings  
• Understands relationships and can make connections | 4     |
| SYNTHESIS         | • Uses old ideas to create new ones  
• Generalizes from facts  
• Relates knowledge from several areas  
• Predicts, drawing conclusions | 5     |
| EVALUATION        | • Compares and discriminates between ideas  
• Assesses value of theories, presentations  
• Makes choices based on reasoned arguments  
• Verifies value of evidence | 6     |
APPENDIX D

Bloom’s Taxonomy Theoretical Matrix

<table>
<thead>
<tr>
<th>Objective</th>
<th>Knowledge</th>
<th>Understanding</th>
<th>Application</th>
<th>Analysis</th>
<th>Synthesis</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Collect and Organize data</td>
<td>1. Declarative Knowledge</td>
<td>1. Ability to categorize patterns by comparing and contrasting</td>
<td>1. Determine an appropriate way to group data based on characteristics that distinguish patterns</td>
<td>1. Ability to organize data into subdivisions based on similar and different patterns within major groups</td>
<td>1. Organizes data so that hidden value and meaning could be identified.</td>
<td>1. Judging the finished product in terms of effectiveness for the task assigned</td>
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<td></td>
<td>2. Skill in explaining different ways in which to collect data</td>
<td>2. Recognize patterns and trends from data collected</td>
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<td>2. R-evaluation of the data collection technique and organization process</td>
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<td></td>
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<td>3. Summarize different ways to organize data</td>
<td>3. Determine which data is relevant to collect</td>
<td>2. Understands relationships and connections in data collected</td>
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<td>3. Implementation of alternative ways to improve initial attempt</td>
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<td>4. Ability to match the correct collection and organization technique to generic data presented to them</td>
<td>4. Determine an appropriate way to group data based on characteristics</td>
<td>3. Explanation of choice based on knowledge attained from previous lessons</td>
<td></td>
<td>4. Critique the value of the data collected</td>
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<td></td>
<td></td>
<td>5. Ability to compare and contrast previous predictions to actual data</td>
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<td>5. Justification of inference based on evidence in drawing.</td>
</tr>
<tr>
<td>B. Formulate and Test questions/hypothesis</td>
<td>1. Declarative knowledge of definitions of ridge characteristics, experimental procedures, scientific questions</td>
<td>1. Stating a question that can be investigated/formulating a hypothesis that can be tested</td>
<td>1. Use of knowledge of experimental design to make connections between hypothesis and materials required to design appropriate test to answer question formulated</td>
<td>1. Write appropriate sequence of steps in design to address questions being investigated</td>
<td>1. Design an appropriate experiment to test hypothesis/answer question</td>
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<td></td>
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<td>2. Name procedures and materials used and identify conditions for use</td>
<td>2. Ability to use acquired knowledge in a new situation to solve a problem</td>
<td>2. Discuss pro’s and con’s of using ridge characteristics to distinguish prints</td>
<td>2. Generalizes from facts discovered</td>
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<td></td>
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<td>3. Procedural knowledge of the process of experimentation</td>
<td>3. Select correct matching print using location of ridge characteristics as evidence</td>
<td>3. Ability to explain choice made based on inferences from the reading</td>
<td>3. Propose a valid alternative way in which to analyze evidence</td>
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<td></td>
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<td>4. Procedural knowledge of different procedures used to detect latent prints</td>
<td>4. Ability to select/determine appropriate detection method for latent print</td>
<td>4. Explanation of choice for detection method</td>
<td>4. Devise a way to improve current method of detection</td>
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<tr>
<td>C. Predict trends and make inferences</td>
<td>1. Declarative knowledge of the definition of inference</td>
<td>1. Understand how to develop trends from newly presented data and how to extract information from raw data collected in general contexts</td>
<td>1. Ability to extract useful and relevant information from data</td>
<td>1. Relates knowledge from several areas to make connections and develop a logical scenario based on the assimilation of different theories</td>
<td>1. Critically reflecting on the design of the experiment</td>
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<td></td>
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<td>2. Procedural Knowledge of how to organize data, how to analyze data and how to predict trends from data</td>
<td>2. Ability to connect the crime scene drawing to the key in order to establish a basic idea of what they are looking at</td>
<td>2. Ability to develop appropriate trends from data</td>
<td>2. Proposal of alternative ways to improve</td>
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<td>3. Ability to decide what information is useful in general data tables in order to help develop an understanding of the crime scene</td>
<td>3. Generate logical theories based on data analysis and interpretation</td>
<td>3. Ability to evaluate the effectiveness of a technique or method used</td>
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<td>4. Predict trends in data based on patterns and relationships</td>
<td>4. Critique inferences using alternative interpretations of the same scientific evidence</td>
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<td>5. Activity to organize data and how to predict trends from newly presented data</td>
<td>5. Ranking the importance of information with respect to the inference made</td>
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<td>6. Makes choices based on reasoned arguments</td>
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<td>7. Verifies the value of evidence</td>
<td>4. Makes choices based on reasoned arguments</td>
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<td>5. Verifies the value of evidence</td>
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APPENDIX E

Group Journal Entry—Fingerprint

1. What was your favorite activity in the fingerprint unit? Why?

2. Which activity did you find most challenging? Why?

3. What were three difficulties you and your group experienced as you participated in the fingerprinting unit?

4. What helped you to overcome the difficulties?

5. Give three examples of how group work helped you to overcome the difficulties you experienced?

6. How were the lab activities in this unit different from labs that you have done in previous lab courses?

7. What characteristics of the activities kept you interested in the unit?

8. List three skills you practiced in this unit? Give an example of how these skills can be used in your everyday life.
APPENDIX F

Group Journal Entry—Blood Reflection

**Blood drop experimental Design:**
1. List three decisions your group had to make when designing the experiments?

2. What difficulties did your group encounter as you tried to design the experiments to measure the effect of height angle and surface on the appearance of bloodstain patterns?

3. How did your group overcome the difficulties?

4. What helped the group to successfully complete the experiment?

5. List three things that your group learned from this activity.

**Bloodstain Pattern analysis:**
1. Describe how your group figured out the origin (height, angle and surface) of the unknown blood drops

**Bloodstain Crime scene analysis:**
1. What difficulties did you encounter as you tried to figure out what happened to the three victims in the crime scene sketch?

2. Which question in this activity did your group find most difficult? **Explain your choice?**

3. What decisions did you have to make in order to come up with a scenario for the crime scene sketch?

4. Why do you think it is important to justify your inferences with scientific evidence and/or data from a reference source?

**Final Thought:**

Which of the three activities did your group enjoy the most? List three reasons why your group enjoyed it?

Which of the activities did your group not enjoy? List three reasons why your group did not enjoy it?
APPENDIX G

Crime Scene Group Journal Entry Reflection

1. List three decisions your group had to make in order to evaluate the crime scenes.

2. List three things you enjoyed while participating in this activity?

3. List three things that you did not enjoy about this activity?

4. What difficulties did you encounter at the crime scene while observing?

5. While evaluating the autopsy report, lab findings and witness testimony in order to figure out what happened with members

6. Describe how you and your group were able to overcome the difficulties. What additional information do you need in order to figure out what happened at the crime scene? What steps would you take in order to get this information?

7. Give an example of how group work helped you to overcome the difficulties you experienced.

8. How were the lab activities in this unit different from labs that you have done in previous lab courses?

9. What characteristics of the activities kept you interested in the unit?

10. List three skills you practiced in this unit? Give an example of how these skills can be used in your everyday life.
APPENDIX H

Focus Group Protocol Questions

1. What was your favorite activity in this unit? Why?

2. Which activity did you learn the most from?

3. Tell me three things you learned from this activity?

4. Describe three skills that you developed as a result of participating in this unit?

5. What were some challenges that you encountered in this unit?

6. Explain to me how you were able to overcome frustrations relating to these challenges?

7. How did these activities develop your ability to make decisions and question information that was presented to you? Explain
APPENDIX I

Institutional Review Board Approval Letter

T E A C H E R S  C O L L E G E  
C O L U M B I A  U N I V E R S I T Y  
OFFICE OF SPONSORED PROGRAMS  
BOX 131

Institutional Review Board
April 28, 2010
Gita Bhairam-Raza
75 Gerhard Road
Plainview NY 11803

Dear Gita:

Please be informed that as of the date of this letter, the Institutional Review Board for the Protection of Human Subjects in Research (IRB) at Teachers College, Columbia University has reviewed your study entitled "Using Forensic Science as a Context to Enhance Scientific Literacy" under expedited review.

I am pleased to let you know that your study has been fully approved.

The approval is effective until April 27, 2011.

The IRB Committee must be contacted if there are any changes to the protocol during this period. Please note: If you are planning to continue your study, a Continuing Review application must be filed six weeks prior to the expiration of the protocol. The IRB number assigned to your protocol is 10-206. Do not hesitate to contact the IRB Committee at (212) 678-4105 if you have any questions.

Please note that your consent form bears an official IRB authorization stamp. Copies of this form with the IRB stamp must be used for your research work.

Best wishes for your data collection.

Sincerely,

[Signature]

William J. Baldwin
Vice Provost
Interim Chair, IRB

Cc: File, OSP
APPENDIX J

Informed Consent Form

Teachers College, Columbia University

INFORMED CONSENT

DESCRIPTION OF THE RESEARCH: Your child is invited to participate in a research study on “The effects of inquiry based forensic science activities on critical thinking and scientific literacy”. Your child will be asked to participate in a six week forensic science unit. They will be required to participate in ten inquiry based lessons which will last eighty-minutes each, there will be 8 mini-evaluations for the unit, three forty minute group journal entries in which they further explain and develop their responses to the evaluations in each lesson and three forty minute focus group discussions in which they discuss the unit and the skills they developed as a result of participating. These discussions will be audiotaped and will be used for transcription purposes. The tapes will be destroyed six months after the study is completed. The work collected will be analyzed for the use of higher order thinking skills and its relationship to scientific literacy. The research will be conducted by their forensics science teacher Gita Bhairam-Raza. The research will be conducted at Valley Stream Central High School in their forensic science elective class.

RISKS AND BENEFITS: The research has the same amount of risk students will encounter during a usual classroom activity. If your child experiences stress or frustration due to the contents of the curriculum they may withdraw from the study at any time. Your child’s grade will not be changed in any way if he/she refuses to participate in the study. The activities are a part of the regular forensics curriculum and have been used for the past four years without collecting any data for analysis. If students do not wish to participate in the study they will be required to participate in the activities but their responses will not be used analyzed for the study.

Benefits for your child will be opportunities for them to work in groups to practice critical thinking skills which may help them to improve their problem solving skills in general. This tool can be helpful to them in other subjects as well as problems that they may encounter in everyday life. Students will also have opportunities to learn both the skills and content information used by forensic scientists.

PAYMENTS: There will be no payment given for being in this study.

DATA STORAGE TO PROTECT CONFIDENTIALITY: The records of this study will be kept private and stored in a locked filing cabinet. All worksheets will be coded according to assigned numbers. The master sheet containing the number for each student will be stored in the locked cabinet that will be accessible by only the researcher. Names of students and the school will not be included in any section of the report.

TIME INVOLVEMENT: Your child’s participation will take approximately forty minutes of class time over a six week period. No extra time out of class will be required.

HOW WILL RESULTS BE USED: The results of the study will be used for a graduate doctoral dissertation and will be presented at meetings, conferences and will be published in journals and articles used for educational purposes.
Teachers College, Columbia University

PARTICIPANT’S RIGHTS

Principal Investigator:
Gita Bhairam

Research Title: The Effects of a Forensic Science Inquiry Based Unit on the Critical Thinking Skills and Scientific Literacy of High School Students.

1 I have read and discussed the Research Description with the researcher. I have had the opportunity to ask questions about the purposes and procedures regarding this study.

2 My participation in research is voluntary. I may refuse to participate or withdraw from participation at any time without jeopardy to future medical care, employment, student status or other entitlements.

3 The researcher may withdraw me from the research at his/her professional discretion.

4 If, during the course of the study, significant new information that has been developed becomes available which may relate to my willingness to continue to participate, the investigator will provide this information to me.

5 Any information derived from the research project that personally identifies me will not be voluntarily released or disclosed without my separate consent, except as specifically required by law.

6 If at any time I have any questions regarding the research or my participation, I can contact the investigator, who will answer my questions. The investigator's phone number is 917-442-0812.

7 If at any time I have comments, or concerns regarding the conduct of the research or questions about my rights as a research subject, I should contact the Teachers College, Columbia University Institutional Review Board/IRB. The phone number for the IRB is (212) 678-4105. Or, I can write to the IRB at Teachers College, Columbia University, 525 W. 120th Street, New York, NY, 10027, Box 151.

8 I should receive a copy of the Research Description and this Participant's Rights document.

9 If audio taping is part of this research, I ( ) consent to be audio taped. I ( ) do NOT consent to being audio taped. The written, audio taped materials will be viewed only by the principal investigator and members of the research team.

10 Written audio taped materials ( ) may be viewed in an educational setting outside the research ( ) may NOT be viewed in an educational setting outside the research.

My signature means that I agree to participate in this study.

Participant's signature: ________________________________ Date: ____/____/____

Name: ________________________________

If necessary:

Guardian's Signature/consent: ________________________________ Date: ____/____/____

Name: ________________________________
Teachers College, Columbia University

Assent Form for Minors (8-17 years-old)

I ________________________________ (child’s name) agree to participate in the study entitled: “The Effects of a Forensic Science Inquiry-Based Unit on the Critical Thinking Skills and Scientific Literacy of High School Students”. The purpose and nature of the study has been fully explained to me by Gita Bhairam. I understand what is being asked of me, and should I have any questions, I know that I can contact Gita Bhairam at any time. I also understand that I can to quit the study any time I want to.

Name of Participant: ________________________________
Signature of Participant: ________________________________
Witness: ________________________________
Date: ________________________________

Investigator’s Verification of Explanation

I certify that I have carefully explained the purpose and nature of this research to ________________________________ (participant’s name) in age-appropriate language. He/She has had the opportunity to discuss it with me in detail. I have answered all his/her questions and he/she provided the affirmative agreement (i.e. assent) to participate in this research.

Investigator’s Signature: ________________________________
Date: ________________________________