ABSTRACT

Qualities of Effective Secondary Science Teachers:
Perspectives of University Biology Students

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This research was an attempt to hear the student voice concerning secondary science teacher effectiveness and to share that voice with those who impact the educational process. It was a snapshot of university freshmen biology students' opinions of the qualities of effective secondary science teachers based on their high school science experiences. The purpose of this study was to compile a list of effective secondary science teacher qualities as determined through a purposeful sampling of university second semester biology students and determine the role of the secondary science teacher in promoting interest and achievement in science, as well as the teacher's influence on a students' choice of a science career.

The research was a mixed methods design using both quantitative and qualitative data obtained through the use of a 24 question electronic survey. There were 125 participants who provided information concerning their high school science teachers. Respondents provided information concerning the qualities of effective secondary science teachers and influences on the students' present career choice. The quantitative data was used to construct a hierarchy of qualities of effective secondary science teachers, divided into personal, professional, and classroom management qualities. The qualitative data was used to examine individual student responses to questions concerning secondary science teacher effectiveness and student career choice.

The results of the research indicated that students highly value teachers who are both passionate about the subject taught and passionate about their students. High school science students prefer teachers who teach science in a way that is both interesting and relevant to the student. It was determined that the greatest influence on a secondary student's career choice came from family members and not from teachers. The secondary teacher's role was to recognize the student's interest in the career and provide encouragement, motivation, and success in support of the chosen career.

Qualities of Effective Secondary Science Teachers:
Perspectives of University Biology Students

by

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A Dissertation

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CHAPTER ONE

Introduction

Rationale

Academic performance and interest in secondary science is lower in the United States than in prior years and the choice of a science major in universities across the United States continues to decline (Business-Higher Education Forum [BHEF], 2007; Elster, 2007; National Academy of Sciences, 2005). Although gains have been observed in the number of female graduates at the university level in science (especially at the doctoral level), the largest gains have been in the number of doctoral non-U.S. citizen science graduates (Heylin, 2008). The number of American males pursuing science careers continues to decline and interest in science declines every year that a student attends school (Elster, 2007).

Research has not revealed specific reasons for the decline in the number of university science graduates or the reason high school students choose not to take science courses in college, although a lack of interest in science and scientific careers appears to be a factor (Texas Education Agency [TEA], 2007a). The emphasis on state standardized assessments in secondary science and the curriculum changes that have resulted are often blamed for stifling interest, motivation, and understanding in science (Settlage & Meadows, 2002; Stiggins, 2004; Yager, 2000). Secondary teachers lament the lack of time for ongoing projects and student research that once was used to encourage student interest. Content continues to be presented using teacher-centered methods and little time is left for explorative or application activities. Teachers have not been able to reconcile the assessment requirements, subsequent lack of instructional time, and best teaching strategies for promoting student understanding. Both teachers and students have become bored with the present system and research has not provided the needed direction for positive changes in science education. (Alsop, Bencze & Pedretti, 2005; Bybee & Fuchs, 2006).

Making the assumption that student disinterest in science is a pre-determinant of poor science achievement and a possible reason fewer are choosing a science career precludes the determination of why that disinterest might be occurring. Determining why students are disinterested in secondary and post-secondary science is very complicated. The blame could justifiably be placed on any number of sources including the public school system, the teacher preparation system, or the shortage of qualified and/or effective science teachers. Science education is a complicated system of consumers, providers and decision-makers. The decision-makers are often far removed from the actual drama of the classroom, while the teacher and student are in constant interaction. Research is needed that will examine the provider-consumer (teacher-student) interaction in the classroom from the student perspective because this interaction is a key factor in "student achievement, motivation and engagement" and too often the student perspective is not investigated (Osborne & Collins, 2001; Rodgers & Raider-Roth, 2006). Educational policy makers must realize that "teaching is essentially a consumer service" and strive to meet the expectations of students (Desai, Damewood, & Jones, 2001). Although both adults and students must share the responsibility as instructional decision makers, Stiggins (2004) believes that "in a normative sense, those adult decisions are not nearly as important in terms of their impact on learning as are the decisions students themselves make" (p. 25). Determining what interests the students and how to best use those interests to fuel the learning process is essential to educating scientifically literate students and promoting science education at every level.

The objective of this research was to amass information about high school science education and science teachers from the student perspective. It was an attempt to determine where interest fits into the big picture, if students place a premium on high school science teachers making a class interesting, or if other teacher qualities are more important. A list of qualities regarded by students as important qualities of effective science instruction was compiled first and the placement of interest in that ranking examined. The research also compared the importance of student interest to student achievement in high school science and examined the influence of the secondary science teacher on a student's career choice.

Theoretical Framework

Science is a discipline that is inherently relevant and applicable; therefore it is difficult to explain why secondary students are not interested in school science. The blame for a lack of interest may fall squarely on the shoulders of the very policies and programs put into place to address inadequacies in science. Rutherford (2005) believes that the policies and programs begun since World War II have not added up to "significant and sustained improvements in the quality of K-12 science education in America" (p. 367). The sciences at the secondary school level are viewed as isolated sources of information. Students move from one scientific discipline to another without understanding how each is dependent upon the other. The interconnectedness of the scientific disciplines at the professional level has not translated down into the public school curriculum. The sciences in education remain "discipline-bound islands of scientific information" (Rutherford, 2005, p. 370).

The lack of student interest in science at the secondary level may be to blame for lower achievement in science as well as fewer students choosing science as a major in college ([TEA], 2007a). College professors interviewed by the *Journal of Chemical Education* lament the lack of appreciation for science that students enter college with and prefer students who have developed a "lifelong interest and appreciation in science" over content knowledge (Derek, 2003, p. 1154). Although good teachers connect the "learners with significant ideas, themselves, and their world" scientific relevance is absent from many science courses and students do not see the connections of school science to their lives (Liston, Borko & Whitcomb, 2008, p. 111; Kind & Taber, 2005). The current educational system does not prepare people for science and its relationship to society and many educators believe that the emphasis should be less on subject-matter knowledge and more on major themes and concepts that allow people to engage with science as adults (Ryder, 2002).

The myriad of programs offered to solve the problem of student achievement in science seldom address student interest. Mastery of a continually growing list of content-specific objectives has overshadowed and smothered more time-consuming instructional strategies that emphasize overarching concepts and themes which often foster interest in science. Despite the requirement in Texas for forty percent of classroom time to be spent in laboratory experiences, science continues to be taught didactically and laboratory experiences are very often prescribed, step-by-step experiences instead of inquiry. Inquiry experiences and research into scientific social issues require more class time, and time is a commodity that most science teachers do not have. The balance between teaching factual information and motivating students to see the application of science is difficult for many secondary science teachers. Many of these teachers do not feel that they have the class time to include projects and long-term classroom studies that were once used to promote student interest and practical application in secondary science.

Public high schools have expanded requirements in science in an attempt to better prepare students for the rigors of college science and to meet the requirements of national standards in the preparation of scientifically literate citizens (TEA, 2007b). The 4 x 4 plan in Texas requires 2007-08 freshmen to complete high school with four years of both math and science (TEA, 2007b). Whether or not the new requirements will bolster interest and achievement in science remains to be seen as the results of this mandate will not be evident for many years. Simply requiring more science does not ensure that students will have an interest in the discipline or pursue a career in the sciences. Expanding the science curriculum may provide more choices for students, but there is no guarantee that students will remain or become interested in science. The placement of influential, qualified and effective science teachers in the classroom who connect with their students may be more important than what courses are offered.

Purpose of Study

The purpose of this study was to compile a list of qualities of effective secondary science teachers as identified by college second semester biology students and to determine the role of the secondary science teacher in promoting interest and achievement in science, as well as the teacher's influence on students' choice of a science major in college.

Significance of Research

Teacher effectiveness has become a hot topic in educational research and in professional development programs. The importance of determining teacher effectiveness comes at the heels of the *No Child Left Behind* mandate to provide highly qualified teachers in every classroom (NCLB, 2002). The next logical step should be to determine if being highly qualified translates into teacher effectiveness in the classroom. The ensuing decision is then to determine what descriptors should be used in defining an effective teacher and if those same descriptors can be used to describe teachers in all disciplines at all levels of education. Administrators, teachers, parents, and students may each describe exemplary or effective teachers differently and the qualities identified may be used to describe teachers and programs of all disciplines and at all levels of education. This is to be expected because of the different perspectives of those involved and the different leverage each group brings to the bargaining table (Liston, et al., 2008). Administrators may describe effective teachers as those who have the fewest complaints from parents or perhaps those with high achieving students (and therefore a high passing rate on state assessments). Yet high standardized test scores are not necessarily an accurate indicator of learning, especially if learning is defined as being able to "think, solve problems, and make decisions based on evidence and reasoning" (Yager, 2000, p. 54). Parents may describe effective teachers as those who promote achievement, are accessible to students, are flexible with classroom requirements, and deal fairly with their children. The definition of an effective secondary science teacher is very dependent upon who is compiling the definition. At present there is no consensus as to what characteristics should be used to describe an effective science teacher or an effective science program, and almost completely absent from the research is any attempt to determine how high school students describe an effective science teacher. Students (especially secondary) are rarely asked to describe an effective teacher even though student input should be both expected and encouraged (Desai, et al, 2001). Adults often do not believe that students have the maturity to identify effectiveness and believe that students would describe effective teachers as simply easy teachers. Students might also describe an effective teacher as one who promotes a positive, enjoyable classroom experience. Despite the emphasis on instructional strategies and content preparation, the promotion of positive, enjoyable classroom experience can actually be a predictor of content understanding (Wilson, 2006).

Science education is a complex discipline because it incorporates knowledge from many other disciplines (mathematics, the social sciences, history, and language arts) and because it is a discipline that is inherently relevant to society. This includes an understanding of the history and nature of science, knowledge of choosing and correctly using the appropriate equipment in the laboratory, knowing how to collect data, analyze, interpret, and use data, knowing how and when to apply mathematics, as well as determining how and when to communicate information while balancing the social issues involved (Educational Policy Improvement Center [EPIC], 2007). The *National Science Education Standards* and the standards promoted by the National Science Teachers Association and American Chemical Society specifically emphasize the need for students to become scientifically literate and to be able to use scientific information as adults (American Chemical Society, 2002; National Research Council [NRC], 1996; National Science Teacher Association [NSTA], 2007). The purpose of high school science courses should be to teach (and assure mastery of) the “concepts and vocabulary outlined in the standards” but then to also assure that students acquire and develop “the key cognitive strategies necessary to think like a scientist” (EPIC, 2007, p. 42). A scientifically literate populace is imperative if the citizenry of the United States is expected to make educated and informed decisions concerning future ethical and moral decisions (Osborne & Collins, 2001; Rutherford & Ahlgren, 1990)

The emphasis on standardized testing and the growing quantity of content to be mastered may be reducing the science curriculum to the mastery of facts while scientific literacy takes an unfortunate back seat. The goal of science teachers nationwide must expand to produce students who will become future scientists and students who will function as scientifically literate adults. Science education should build on a child’s initial interest and awe of the world through promoting and developing interesting methods for teaching the content that is to be mastered. Students know best what promotes and retains their interest. Science education research must include the student perspective in determining how best to accomplish both the promotion of interest and the mastery of content.

Problem Statement

The objective for this study was to compile a list of qualities of effective secondary science teachers as identified by college second semester biology students in order to determine the role of the secondary science teacher in promoting interest and achievement in science, as well as the teacher’s influence on a students’ choice of a science major in college. Determination of the core qualities of an effective science teacher is absolutely necessary to in order to promote effective science education, but to ignore the views of the science students themselves, those who are most directly impacted by science teachers, is to ignore an extremely valuable source of information. The significance of student interest for informing decisions concerning curriculum and instruction should not be ignored. If student interest is found to be an important determinant of student achievement and life-long interest in science, then the methodology for ensuring the teaching of science as an interesting, relevant discipline should become an important facet of pre-service and in-service teacher education ensuring that all students have access to the most effective science teachers.

Research Questions

- What are the common qualities of effective high school science teachers as described by college second semester biology students?
- Where does the promotion of student interest rank in the list of qualities of effective high school science teachers as described by college second semester biology students?
- What is the relationship between the promotion of student interest in secondary science and student achievement in secondary science?
- What is the relationship between student interest in secondary science and the choice of a science major in college?

Researcher's Perspective

My role in science education has evolved over the past thirty years. I have taught earth science, physical science, environmental science, biology, and chemistry at the secondary level. My teaching experience includes both public and private schools, small and large. I have been privileged to teach at the university level while working on my master's degree in biology and my doctorate in curriculum and instruction, teaching both future scientists and future science educators. Recently my role as a science teacher educator has grown to include the ongoing education and collaboration of in-service secondary science teachers. I have witnessed an evolution in both my educational philosophy and teaching methods during this time. Throughout my career as an educator I have been interested in what makes one teacher more effective than another, but my definition of effective science teaching is not the same today as when I first began teaching. My biggest concern at the beginning of my career was "what to teach" instead of truly understanding science pedagogy and how to teach for understanding and to promote interest in science. I did not understand how students learned science or what was relevant to them, and in retrospect, remorsefully admit that because of that ignorance I did not "teach" as effectively as I thought. Students are not the same as they were thirty years ago (nor are teachers), yet many of the methods of teacher preparation and science instruction have remained the same. The didactic teaching of science is perpetuated by college science teachers and many secondary teachers rely on this instructional method. It is all they know, it is all they have experienced in their own journey through science education. It is unfortunate that we cannot seem to break out of that mold.

Science knowledge has grown and continues to grow exponentially, and we have become a society that relies on at least a basic understanding of science for citizens to make informed decisions. I believe a paradigm shift is necessary in order to engage students and to promote a life-long interest and social responsibility in science. A secondary science teacher is in a strategic position to mold a student's science perspective and affect the student's entire life, including the choice of a career. This research allowed an examination of student views of secondary science teacher effectiveness and a glimpse of science education through the eyes of students to better understand how a teacher can affect a student's interest in science. The survey sample was purposefully selected and included students who already had an interest in science. The survey provided information that aided in determining what qualities of science teacher effectiveness the students observed and valued while in high school and whether those qualities included promotion of student interest. Although the surveys allowed the collection of initial data through the use of an electronic survey to be less biased, the final analysis was biased by my own experiences as a science administrator, teacher, and student. Interpretations of the surveys, especially the open-ended questions were subject to limited biases based on my experience in each of those areas.

Research Design

The research design for this study was a mixed methods design that used both quantitative data and qualitative data. The use of multiple methods strengthened the results of the study through triangulation of both types of data with information obtained from past research (Patton, 2002). The purpose of this research was to survey college freshmen biology students to determine if the promotion of student interest in secondary science was related to either the choice of a career in science or to student achievement in science. The implications may improve the understanding of effective secondary science education, provide data for future research concerning possible relationships between the qualities of effective secondary science teachers with measurements of achievement and career choices, and possibly inform curriculum policy in secondary schools. Proving causality was not attempted because of the inherent problems in dealing with humans and social phenomena (Patton, 2002).

Data Collection

It was imperative that a consensus of common attributes of science teacher effectiveness first be determined for comparison. The existing literature was examined to determine how effective science education and effective science teachers, as well as effective teachers in all disciplines, were defined. A research-driven consensus of those qualities was formulated from this literature. The consensus was used to construct a survey that was administered to second semester college freshmen biology students. The information obtained from the student surveys was used to compile a list of common attributes. There was no set number of attributes that were analyzed resulting in a list of "top ten". The results of the surveys were simply tallied and compared quantitatively and qualitatively.

The list was then analyzed to determine if it was supported by past educational research. The ranking of student interest within the list was also examined. The Delphi method of collecting data was used after the first round of surveys. This method allowed the initial survey to be modified and additional surveys as needed were formulated based upon the initial results (Skulmoski, Hartman, & Krahn, 2007). An additional semi-structured electronic survey was sent to students who indicated a negative experience with a high school science teacher (Appendix D). The purpose of the additional survey was to allow an embedded multiple-case design to be employed in analyzing those results (Yin, 2003). The questions on all surveys were based on the student's recollection of what was experienced in the secondary science classroom, because "bringing to life what goes on in classrooms" is the beginning of educational understanding through the insights and experiences of the selected students (Yin, 2005, p. xiv).

Selection of Site and Participants

In order to examine different student perspectives the sampling framework for this research was a purposeful sample of second semester freshmen biology students at Baylor University in Waco, Texas (Creswell, 1998). The sample was stratified according to age, gender, race, high school demographics (rural, suburban, and urban), science courses taken in high school and grades received in those courses. The university was chosen because the enrollment at Baylor University is diverse and composed of students from all over Texas, as well as the United States and the world. Baylor was also chosen because the researcher was a doctoral student at the university and acquaintance with professors in the biology department allowed access to biology classes in order to promote participation in the survey. The initial survey of the freshmen was administered during the 2008 spring semester. All Biology 1306 students were given the opportunity to participate (approximately 650). Students indicated their willingness to contribute further to the research by providing their name and email address in the survey, although many students chose to contribute to the initial round of research anonymously. The research used purposeful sampling as it was anticipated that the initial survey might identify students who could contribute further to the study, although there was no predetermination of the final sample size, N (Creswell, 1998; Patton, 2002). The initial survey provided information that would possibly allow the sample to be narrowed and more in-depth information obtained. No names were used in the written research and the identity of the students was protected through the use of student response numbers. A pilot study of the surveys was conducted with Advanced Placement Biology senior-level students at Midway High School in Waco in order to help identify problematic questions on the initial survey.

Data Analysis

The primary results of this research were descriptive in nature. Although quantitative information was provided as part of the analysis of differences between groups of students, the qualitative information was the heart of the research. The insights into student perspectives of effective secondary science teaching provided insights into the students themselves. It was anticipated that the answers to the open-ended questions would provide an understanding and perhaps a theory for explaining the quantitative results.

The open-ended questions were analyzed for emerging patterns of information. A grounded theory approach was used in order to propose an explanation for the resulting variations in patterns of data (Patton, 2002). The answers to the open-ended questions provided insights into the hearts and minds of the students because the responses were very honest and direct. Pattern matching, or pattern recognition, was first applied to establish categories of data (Patton, 2002). A constant comparative data-analysis procedure was then applied to identify primary and secondary data themes rendered from the narrative data (Creswell, 1998; Dye, Schatz, Rosenberg & Coleman, 2000).

CHAPTER TWO

Literature Review

Research Problem

School districts strive to have one hundred percent “highly qualified” teachers as defined by the *No Child Left Behind Act* (NCLB, 2002). This mandate presents three requirements in order for teachers to be considered highly qualified; a bachelor’s degree, state teacher certification, and the demonstration of subject matter competence in each subject taught (United States Department of Education, 2007). The *NCLB* standards for quality teachers are based solely on prior experience and education. The implication is that school employers can look at an application and choose the best teacher simply by comparing experience in the classroom and the number of degrees attained. There are no guidelines for comparing personal or other professional qualities. National documents and standards, such as those presented by the National Science Teachers Association, specify the need for professionally prepared highly qualified teachers using a much more extensive list of qualifications (NSTA, 2007). “Input” measures include teaching experience, advanced degrees, content area preparation, professional development, and licensing exam scores, yet there is little research that provides evidence that these exact measures, and not some other factors, contribute to student achievement (Cochran-Smith, 2005; Imig & Imig, 2006; NSTA, 2007).

Currently the primary standard for measuring school and teacher effectiveness, as well as student learning, is student achievement. The general public and school district leaders compare state assessment scores and school rankings to determine whether a school has effectively promoted student learning. There is no question that schools should be held accountable for student education and that student achievement is included as a part of that accountability, but the present trend of using only student achievement to determine teacher effectiveness is rife with problems. There are many other factors that must be considered when determining teacher effectiveness, and factored into the equation should be the issue of how administrators, teachers, parents, and students describe effective teachers. Each views teacher effectiveness from a different perspective, yet all agree that the teacher is the critical link to improved student learning and student success (Cochran-Smith, 2005; Darling-Hammond, 2000; Liston, et al., 2008). The problem is deciding how schools should evaluate teacher effectiveness and who decides what measurements and attributes to include. Without definitive standards for measuring quality or effectiveness it is difficult to compare teachers and programs. It should also be determined if the same set of standards for measuring teacher effectiveness can be used in every discipline and at every level of education. Teachers in different disciplines employ many strategies and methods that are effective regardless of the content being taught, but certain methods are more effective in some disciplines than others because of the very nature of the disciplines. While effective teachers in different disciplines possess a similar set of core qualities, differing qualities may be necessary for teachers of specific disciplines. An effective art teacher may be described very differently from an effective math teacher.

I contend that there are multiple definitions of teacher effectiveness, depending on who is defining the term and the context in which it is defined, and that there are core qualities embedded in each of those definitions that should be identified and included as an important part of teacher training and professional development programs. The list should also include qualities determined from the student's perspective, including the promotion of student interest and motivation. Both are absent from most discussions of quality or effective teachers. Teacher effectiveness research should evaluate all aspects of the teaching and learning process. James Stronge, in *Qualities of Effective Teachers,* (2007) suggested that while most research indicates that the keys to teacher effectiveness are instructional and management processes (professional qualities); interviews and surveys support teacher affective characteristics over instructional strategies. These affective characteristics include the teacher's social and emotional behaviors, such as caring, fairness and respect, positive interactions with students, a positive attitude toward the teaching profession, being a reflective teacher, and promoting enthusiasm and motivating learning (Rodgers & Raider-Roth, 2006; Stronge, 2007). The purpose of this research was to determine how students rank the different characteristics, including affective characteristics and instructional/professional characteristics, of effective secondary science teachers. The results were used to determine if promoting student interest and motivation are important qualities of science teacher effectiveness as identified by those participating in the actual learning process (the students) and to determine the relationship of student interest with achievement in secondary science courses and future career choices. The literature was used to provide a framework for defining teacher effectiveness and to provide the foundation for survey questions concerning qualities of effective secondary science teachers.

Defining Teacher Effectiveness Using Assessment Results

The present accountability movement that has swept the nation in the past twenty years has grown from holding individual schools accountable to holding individual teachers accountable for student achievement. State mandated test results are supplemented by district-wide benchmark exams in an effort to tie student achievement to specific teachers. Schools in Texas that receive low state ratings are allowed to "clean house" and dismiss every teacher in order to improve academics with the assumption that poor achievement is the direct result of poor teaching. Teacher pay incentives are promoted for teachers whose students show improvement on state assessments. School ratings are dependent upon state assessment scores, therefore resources are poured into schools in an effort to enable every student to pass the state exam. The pressure on students to pass the test and the importance of the test scores in determining teacher effectiveness is driving most, if not all, present education reforms.

Holding teachers accountable for student learning is actually nothing new. A 1920s publication authored by Learned and Bagley suggested that teachers should be judged by the performance of their students, but at that time an effort was made to make sure teachers knew what qualities and practices they should demonstrate as effective teachers in order to improve student performance (Imig & Imig, 2006). What is new to the teacher accountability movement is the level to which teachers are held accountable without regard to outside influences on students and without a clear definition of how and what to measure. Whereas the family and community once shared the responsibility for educating children, the present teacher's role has expanded to include all aspects of a child's education; affective, moral, social, and cognitive (McClellan, 1999; Muijs, Campbell, Kyriakides & Robinson, 2005). Implying cause and effect by equating teacher effectiveness with student achievement is problematic because so many student variables, such as family demographics and learning ability, are out of the teacher's control (Leigh, 2006).

It is hypocritical for national standards in science to state that science literacy and student understanding in science are primary goals while accountability systems measure only student content knowledge (American Association for the Advancement of Science [AAAS], 1998; NRC, 1996; NRC, 2005; NSTA, 2007). The time spent on instruction that promotes the social and emotional development of the student, as well as their ability to function in a democratic society, has been pushed aside in order to prepare all students to excel on the standardized tests (Cochran-Smith, 2005). Instructional components that promote interest and are enjoyed by students, such as practical application and discussion, have been eliminated because of the time required (Osborne & Collins, 2001). Teachers resign themselves to covering content because of national and state mandates, regardless of whether student understanding occurs (Rodgers & Raider-Roth, 2006). The present goal should be to prepare a scientifically literate adult through application and understanding of science and also prepare a student who can pass the state assessment. Both can be achieved in the classroom of a highly effective teacher.

Qualities of Teacher Effectiveness

The literature search revealed many definitions of teacher effectiveness and many lists of effective or exemplary teacher qualities, few of which were subject specific. This information was used to assimilate a list of core qualities for all disciplines with the assumption that good teaching reaches across all disciplines. The assumption was also made that effective learning is dependent up the effectiveness of the teacher. The American public believes that quality education begins with quality teachers and two out of three people support increased teacher quality through hiring more teachers, giving them better working conditions, training, and higher salaries (Educational Testing Service [ETS], 2002). The ETS research revealed that for most adults the definition of a quality teacher is formed from memories of a favorite teacher from their own educational experience and although the definition varied, a consistent theme was that knowing how to teach was more important than knowing what to teach. This creates a disconnect between what the government believes to be important (experience, degrees and content knowledge) and the understanding of the American public that pedagogy and a connection to the student is equally, if not more important (ETS, 2002; Liston, et al., 2008; U.S. Dept. of Ed., 2007).

Qualities of effective teachers compiled from the research can be loosely broken down into three categories; academic, professional qualities, and personal. Teacher academic qualities have been found to be a predictor of teacher effectiveness on student achievement. A study of Texas schools in 1991 found that teacher expertise (based on licensing examination scores, having a master's degree and teaching experience) accounted for more of the difference in inter-district reading and math achievement than socioeconomic status (Darling-Hammond & Sykes, 2003). Darling-Hammond (2000, p. 13) determined that "differences in teacher qualifications (educational degrees, certification status, and experience) accounted for approximately 90% of the total variation in average school-level student achievement in reading and mathematics at all grade levels tested". High teacher quality may be the strongest determinant of student success (Darling-Hammond, 2000; PEN, 2004; Tytler, Waldrip, & Griffiths, 2004). Teacher verbal ability (literacy level) and content-based pedagogy, as well as content majors and experience, were also cited as determinants of teacher quality and effectiveness (ETS, 2004; National Council on Teacher Quality [NCTQ,] 2005; Public Education Network, 2004). These qualities can be considered either academic or professional (or both).

The following consensus of qualities of effective teachers in all disciplines assimilated from the literature includes all three aspects of teacher qualities; personal, academic, and professional.

Summary of Qualities of Effective Teachers in All Disciplines

Personal qualities included:

- communication skills (including listening),
- the ability to identify resilient qualities in students,
- persistence,
- physical and emotional stamina,
- willingness to admit mistakes,
- recognizing and compensating for their own weaknesses,
- not being power-seeking,
- caring relationships with students and peer teachers,
- being respectful of all people,
- viewing themselves as professionals,
- receiving satisfaction and energy from interactions with students,
- a commitment to acknowledging and appreciating student effort,
- a focus on deep learning,
- having a history of success in multiple endeavors,
- taking responsibility for their actions and teachings,
- becoming critical thinkers (linking cause and effect),
- becoming good motivators,
- organizational skills with classroom organization designed for student engagement and learning,
- being non-judgmental (not judging a behavior but trying to understand the motivation behind a behavior),
- being very organized and good at multi-tasking,

- the ability to resolve conflicts,
- the ability to discriminate emotions (both their own and those of others) to inform decisions and actions,
- not moralistic, responding as professionals (not easily shocked), and
- life-long learners (Haberman 2004, Marshall, 2006; Muijs, et. al., 2005; NCTQ, 2005, Weiss, Pasley, Smith, Banilower, & Heck, 2003).

Academic qualities included:

- more content training (especially for secondary teachers),
- pedagogical knowledge,
- higher literacy level, and
- stronger academic credentials (Haberman, 2004; NCTQ, 2005; PEN, 2003).

Professional qualities included:

- commitment to inclusion and supporting accountability for at-risk students,
- commitment to and protection of student learning,
- ability to translate theory and research into practice (including knowledge of child development),
- coping with bureaucracy,
- creating student ownership,
- engaging parents and caregivers as partners in student learning,
- community outreach,
- not identifying themselves as saviors but focusing on students in spite of the system,
- working with colleagues and not in isolation (collaborative skills),
- understanding the imperative of student success,
- sharing the organization's goals,
- attending to student's learning styles and differentiating instruction, and
- leading inside and outside of the classroom (teacher leaders) (Haberman, 2004; Marshall, 2006; Muijs, et. al., 2005; NCTQ, 2005; PEN, 2003; Tomlinson, 2000; Thomson & Mascazine, 2003).

Teacher Effectiveness in Science Education

While most of the teacher effectiveness research has been generic, the differences in structure and content of the varying disciplines suggest that some qualities of effectiveness may be discipline specific (EPIC, 2007; Muijs, et al., 2005). Effective science teachers, because of the very nature of science, should be described differently from teachers in other disciplines. The process of learning science through laws and theories, through learning to do science, and learning about the processes of science are unique to the discipline and require unique instructional methods (Alsop, et al., 2005). Effective science instruction involves identifying preconceptions, introducing content in a way that invites the formulation of questions and conclusions, experimentation and discussion of results, and teacher demonstrations (Bullock, 1998). The presence of the science laboratory and the relevance of science issues and technology set science apart. The uniqueness of science suggests that the qualities of effective science teachers may also be unique.

The National Research Council (2005) defined an effective or successful science teacher as one with science content knowledge, who understands the nature of science and is knowledgeable about how students learn, and who enables students to activate prior knowledge and then build on and organize that knowledge so that it can be used to understand and appreciate their world. This definition implies that teachers possess content knowledge, pedagogical knowledge, and personal characteristics that enable them to relate the information to students. The following lists summarize characteristics of effective science teachers as found in the literature. Many of the characteristics mirror those discussed in the previous section.

Summary of Qualities of Effective Science Teachers

Personal qualities include:

- more enthusiasm for science teaching than when they started,
- a commitment to lifelong learning,
- creating an environment conducive to learning (being respectful of student contributions, yet rigorous),
- feeling well qualified to teach science (efficacy),

- putting in far more than minimal time,
- involvement in extracurricular assignments, and

- having high expectations for themselves and their students (Penick, Yager, & Bonnstetter, 1986; Varella 2000; Weiss, et al., 2003)

Academic preparation includes:

- at least ten years of experience in education and
- more hours and degrees beyond the B.S than teachers in general (Penick, et al. 1986; Varella 2000)

Professional qualities may include:

- staying in the same district for most of their careers,
- attending and make presentations at professional meetings and in-service training,
- actively involved in school improvement and reform efforts,
- lecturing far less than teachers in general,
- stressing a process-approach science,
- using professional journals in their teaching,
- consistency in their philosophy and teaching strategies and that application in the classroom,
- gaining inspiration from other teachers, their students, professional publications professional meetings, and involvement in project development activities,
- aligning content to national, state, and district standards,
- engaging students with the content (purposeful interaction and investigation),
- ensuring access for all students and preventing any students from 'slipping between the cracks',
- monitoring student understanding through the use questioning,
- helping students make sense of the mathematics/science content by providing explanations at appropriate junctures in the lesson,
- making the content relevant and connected to overarching concepts,
- using dialogue to find content meaning, and
- employing critical reflection and scaffolding when determining what instructional strategies will be used (Alsop, et. al 2005; Penick, et al., 1986; Varella 2000: Weiss, et. al. 2003).

The qualities listed for teachers of all disciplines and teachers of science have many similarities as well as a few differences. The lists for science teachers included primarily characteristics a teacher might use to describe themselves and not necessarily characteristics a student might use to describe their teacher. The generic lists included both qualities a teacher would list and also those that could be observable by a student, such as being respectful, non-judgmental, caring, and being a good motivator. The lists can basically be summed up to include a personal, vested interest in students and their educational success, a commitment of both time and professional resources, a commitment to the learning process and to school goals, and experience in the classroom. The importance of relevance in science appeared to be a bigger issue than in the other disciplines. The literature did not address the issue of developing and promoting student interest as being an important quality of teachers of science.

Science Teacher Effectiveness and Student Interest

Content relevance is an important attribute of quality science education. Interest in science is promoted when science is made relevant through the application of everyday events, social issues, the human body, or extraordinary phenomena (Elster, 2007). Television shows, movies, books, and other media applications, which are such a prevalent part of students' lives, offer a plethora of relevant topics yet few of these applications are used to teach science. Promoting student interest by making science relevant does not rank very high on the list of effective science teacher qualities, if it was present at all (Alsop, et. al., 2005; NRC, 2005, Ryder, 2002; Sonmez & Lee, 2003; Tytler, et al., 2004). Science education researchers understand that effective science education encourages student interest by making science relevant and making the connection between what students are learning and their present world knowledge, resulting in higher achievement rates (Stronge, 2007; Tytler, et. al., 2004). Placing the science content in context should precede the teaching of concepts and process skills (Yager, 2002). Contextual science enables the student to "create a relationship" with the concept, enabling “the development of knowledge and competence in new situations” (Elster, 2007, p. 8). The promotion of student interest is important not only in motivating the student while they are involved in a class, but it is also important to “a student’s evolving attitude toward a particular subject or activity” (Stronge, 2007, p. 28). A good teacher is capable of connecting the learner to themselves, the ideas of science, and the world; “good teachers do more than boost achievement, they shape lives” (p, 112, Liston, et al, 2008). Students often choose a career because of the direct influence of a particular teacher. There is a difference between just enjoying a class and in becoming interested in a subject because of teacher influence. A student’s perception of a class using the “happiness index” may not be a good measure of a teacher’s effectiveness or a particular instructional strategy, but a positive classroom experience contributes to a students’ overall learning experience (Kreber, 2005, p. 341; Wilson, 2006). The positive classroom experience is perpetuated by the perception that the teacher cares for the student (Tevin, 2007).

Student interest is multi-faceted and includes motivation as well as addressing beliefs about ability. Perceived ability accounts for “significant proportions of variance in both achievement and effort in science class” (Debacker & Nelson, 2000, p. 246). Despite these facts, there is little research addressing the importance of student interest, efficacy, or motivation as a predictor of achievement or future career choice. Promoting student interest implies getting students involved in actually “doing science” and applying the content to relevant social issues. A personal relevance with science enables students to understand the purpose behind learning science (Elster, 2007). Present research advocating inquiry and student centered activities is in direct opposition to the “heavy emphasis on direct instructional strategies that teachers report in response to standardized testing" (Tretter & Jones, 2003, p. 345-346). Science teaching methods should be employed that enhance student creativity and meaningful learning (Balfakih, 2003). Students in science should be allowed opportunities to personally explore the significance of science, actually participate in "doing science" using inquiry methods, learn core concepts instead of disconnected facts, and uncover misconceptions (Zemelman, Daniels, & Hyde, 1998). Students taught science through the use of inquiry missed school less often, had fewer behavioral problems, had a better attitude toward science, participated more often in class, were more engaged, and saw improved grades (Tretter & Jones, 2003). It is further suggested that teachers not rely on textbooks alone, but study science contextually, linking classroom experiences to student interests and engaging students with current science issues (Ryder, 2002; Varella, 2000, Zemelman, et al., 1998). The gulf between the science content taught in school and the real-world, technological, socially relevant view impedes teaching for understanding in science (Osborne, Simon & Collins, 2003). Many science educators believe that the current educational system does not prepare people for science and its relationship to society and that the emphasis in science education should shift from subject matter knowledge required for state assessments to major themes and concepts that allow people to engage with science as adults (Alsop, et. al., 2005; Ryder, 2002; Sonmez & Lee, 2003; Tytler, et al., 2004). F. J. Rutherford (2005) blamed teacher education for not keeping pace with the requirement for a better understanding of the nature of science, the interdependence of science and mathematics, or the relevance of environmental and public policy issues. Also proposed was the possibility that present science education does not result in an understanding and application of science (Gallagher, 2000). This is problematic in college science classes as well as at the secondary level, further perpetuating the problem. More than 85% of university and engineering students who received high evaluations in their science classes actually had no real understanding of the science concepts taught at the university level and improvement at the secondary level will only occur when college science improves (Yager, 2002). Many secondary science teaching strategies are simply reflections of what science teachers observed in their university science classes. College professors also lament the emphasis of knowledge over skills at the secondary level. Professors instead emphasize the importance of "attitudes, process skills, and study skills" over "topics, concepts, and knowledge" transferred from high school science (Derek, 2003, p. 1154). College chemistry professors believed that it was more important for students to develop an appreciation for the everyday application of chemistry and overcome their fear of that discipline than to master specific facts about chemistry (Derek, 2003). This was especially true in chemistry and physics where students have fewer experiences to make life connections than they have in biology (Osborne & Collins, 2001). The entire science educational system must be examined to determine the real purpose for high school science. The content can be mastered, and it can be mastered using methods that promote interest and understanding. Teachers must break the cycle of planning for what they will do and instead plan for what the student will do, using instructional strategies and applying content so that neither students nor the teacher becomes bored (Alsop, et al, 2005). In order for science students to learn concepts and processes, the science content must be made relevant to the lives of the students (Yager, 2002). Disconnected facts do nothing to further student interest. Teaching science as a relevant subject that relates directly to student lives promotes student interest in the discipline.

What was not determined by the literature review was whether a highly qualified teacher demonstrated effectiveness in areas other than student achievement, nor if being highly qualified inherently included a passion for the subject being taught. There was no discussion of whether a teachers' passion about the students and/or the subject matter contributed to effectiveness as much as professional qualifications. Also absent from the research on teacher effectiveness was the use of student input in informing instructional decisions. The educational systems' ignorance of student perspectives is akin to marketing researchers ignoring consumer feedback. Researchers should get "in the trenches" at the student level in order to discover what student's identify as effective qualities of science teachers (Anderson and Helms, 2001). Students must be included in determining what efforts will improve their learning before science education reform efforts can start to take shape and have a lasting influence (Yager, 2002). Teachers impact student learning and achievement more than any other factor and impacting teaching practices is the most effective strategy for improving student learning (Short, 2006; Tytler, et al., 2004). Research is needed to determine what teaching practices students believe promote interest, understanding, and achievement. The effectiveness of the teacher and measurements of both student interest in science and the teacher's attitude toward their personal educational journey are important to teacher quality and effectiveness (Alsop, et al., 2005; Darling-Hammond & Sykes, 2000; Darling-Hammond, 2003; Holloway, 2006; PEN, 2004; Tytler, et al., 2004). Student interest and motivation may be tied to the teacher's ability to translate their own excitement and interest in a discipline to the students, and a teacher's attitude toward education can strongly influence student attitudes. Research has shown that effective teachers are life-long learners and take a personal interest in their own personal educational pursuits (Haberman, 2004; Varella, 2000). Effective science education should address a student's motivation, beliefs about their abilities, and beliefs concerning the difficulty of a task; therefore, effective science teachers are both purveyors of content and academic cheerleaders (Debacker & Nelson, 2000). Teaching students how and where to find information and instilling a desire to learn are important components of teaching because without student engagement and efficacy learning comes to an abrupt halt. Students "interpret the feedback we give them to decide whether they have hope of future success, whether the learning is worth the energy it will take to attain it, and whether to keep trying" therefore the students are important resources in determining the effectiveness of a teacher (Stiggins, 2007, p. 3). '"High stakes" testing which can cause students to give up hope cannot be viewed as productive. The threat of failure is not a motivation for many students. Finding out what motivates students is the key to promoting interest and understanding.

Summary

Teacher expertise is dependent upon survival in "the intermediate swampy zones of practice where practicalities and demands of daily life in a science classroom collide with teaching expertise and reflection in and on teaching practices" (Schön, 1987, p. 3). My assertion is that there cannot be a single definition of science teacher expertise or effectiveness. The issue becomes one of context. The practices of a teacher are dependent upon both intrinsic and extrinsic teacher qualities and the learning process is dependent upon student engagement. Teacher qualities cannot be divorced from student expectations. My experience as a science educator at the secondary level and as a teacher educator has shown me that teacher effectiveness is a combination of many different academic, professional, personal qualities. Teachers can have an excellent academic background and yet be either completely ignorant of science pedagogy or completely unable to engage students. There is more to teacher quality than content preparation; pedagogy is equally important in promoting student achievement (Holloway, 2006). Student interest is also very important, and both pedagogy and student interest may be even more important to at-risk students than high achievers, who are often motivated more by grades (Stronge, 2007). Student achievement and life-long interest in science are products of student interest in a science classroom.

Advanced secondary level science classes and university science departments face lower enrollments because of the lack of student interest in science (Elster, 2007). Determining the importance of student interest is vital to the promotion of student learning and ongoing interest in science. It may very well be one of the most essential qualities of an effective science teacher. Carl Sagan once commented that every child begins life as a scientist, observing their world with wonder and awe (NRC, 1998). Somewhere in the educational process students lose that sense of wonder and awe and become disinterested in science and how it affects their everyday lives. Science becomes rote memorization of facts, and students are not allowed to question those facts. Teachers must be trained to help students retain that wonder and awe and must teach them to question. Making science relevant and interesting is essential to teaching the discipline and until research can provide evidence of that importance, pre-service and in-service programs cannot be planned and implemented to train teachers to be effective science educators. The implications of this research will contribute to the body of literature and research that drive decisions by universities, teacher education programs, school districts and administrators, and teachers concerning how pre-service teachers should be prepared and then further supported throughout their careers as in-service teachers through professional development and advanced degrees. If students view interest as paramount to their personal success in science, the implication for secondary science education should shift from an emphasis on teaching and learning factual information to an emphasis on content relevance and interest.

CHAPTER THREE

Research Design

Rationale of Mixed Methods Approach

The present trend in public education is to measure teacher effectiveness using student achievement data (Imig & Imig, 2006; NCLB, 2001). Training teachers to become effective is an important tenet of pre-service education programs and in-service professional development, and a thorough understanding of what constitutes teacher effectiveness is necessary to the success of those programs. This study makes the assumption that student achievement is not the only indicator of teacher effectiveness, but a result of many contributing factors that finally culminate in that outcome. Student learning and student achievement are not always synonymous and other factors must be considered when identifying a teacher as being effective.

This study was a mixed methods examination of how secondary science teacher effectiveness is defined by college second semester biology students. The results of the study may or may not contribute to current trends focusing on student achievement as a measure of teacher effectiveness (Imig & Imig, 2006). The results will, however, provide insight into how college second semester biology students view their past secondary science experiences and teacher effectiveness while possibly informing future decisions concerning the training of teachers to best meet the needs of secondary science students. The intent of this research was to provide multiple insights into how students perceive that their own learning was advanced through the influence of their high school science teachers. The initial survey (Appendix A) results that provided a rank-order list of core qualities of effective secondary science teachers may have statistical generalizability because of the large sample size (>100). The resulting analysis of information concerning the relationship between student interest and grade point average or career choice may only provide information from an identified group of students that has analytical generalizability if at least two of the students support the theory that higher achievement and career choice are influenced by teachers who promote student interest (Yin, 2005). The intent of this research was to provide accurate, detailed, transferable data in place of the traditional generalizability found in quantitative research. This research contributed to an existing body of knowledge concerning effective secondary science teacher qualities and may expose some existing misconceptions concerning what qualities of teaching actually promote student achievement and career choice. Making sense of the phenomena through the eyes of the participants is a basic tenet of qualitative research and this study is an attempt to understand how qualities of effective science teachers are understood by students participating in the educational process (Creswell, 1998; Patton, 2006).

The questions researched for this study included:

- What are the common qualities of effective high school science teachers, as described by college second semester biology students?
- Where does the promotion of student interest rank in the list of qualities of effective high school science teachers, as described by college second semester biology students?
- What is the relationship between student interest in secondary science and student achievement in secondary science?

- What is the relationship between student interest in secondary science and the choice of a science major in college?

Site Selection

Baylor University, located in Waco, Texas, was purposefully selected for the location of this study because it has a strong science program that attracts diverse students from all over the nation and the world. Access to a diverse student body allowed the researcher to obtain information about effective secondary science teachers that would not be possible by surveying students in a small number of secondary schools. The purposeful selection of the participating university also allowed for a more thorough understanding and comparison of data (Merriam, 1998). Students were introduced to the purpose of the research through a short presentation (5-10 minutes) in their Biology 1306 class. They were encouraged to participate after listening to an explanation of the importance of student input into educational research. The presentation included advising students that they would receive an email that had the survey address attached and that the survey would be completed electronically. The results of the survey were made available electronically at the end of the research to all students who provided their email addresses as part of the initial survey.

Data Collection and Analysis

The subjects of this research were college second semester biology students enrolled in Biology 1306, a class required of all biology majors. There were multiple sections of biology offered, and more than six hundred students were enrolled for the spring 2008 semester. Permission to survey and interview students was obtained through the

Institutional Review Board at Baylor. The survey was administered electronically in order to simplify data collection and analysis, as well as enable the quick generation of follow-up surveys if needed (Skulmoski, Hartman, & Krahn, 2007). The survey was sent to Baylor University biology professors, who then forwarded the survey and consent information to all Biology 1306 students via campus email. This provided total anonymity if the students so desired. While the majority of the students were eighteen and nineteen year old freshmen, there was also a mix of older students and upper classmen. Freshmen students who were not yet eighteen years old were eliminated from the study using the demographic information provided by the survey. Informed consent was indicated by the student's choice to participate in the electronic survey (Appendix B). Students could opt to submit the survey through regular mail service instead of electronically, although none chose that option. The initial question on the survey gave the students the opportunity to choose whether they would participate anonymously. They were given the choice to provide their name and/or email address so that they could be contacted for further information, if needed, and/or so that they could be provided a summary of the research results. No names were used in the written research and the identity of the students was protected through the use of response data numbering. A pilot study of the surveys was conducted with high school Advanced Placement biology students at Midway High School, Waco, Texas, to help identify problematic questions.

A mixed methods approach to this research was chosen because of the need for different types of data. The initial instrument was a survey that combined both quantitative and qualitative data collection (Appendix A) using direct and open-ended questions formulated specifically for the targeted group, college second semester biology students. Collecting both types of data allowed for triangulation with the information obtained in the literature (Patton, 2002). The survey questions were formulated from other surveys, literature, and personal experience (The University of Texas, 1999; McBer, 2000).

The demographic questions included information identifying the undergraduate degree program chosen, gender, age, marital status, racial/ethnic background, high school graduation year, high school name, location, and whether the school was classified as urban, suburban, or rural. This information did not contribute to answering the research questions but provided information for possible future analysis and allowed a comparison to the overall demographics at Baylor University. Respondents were also asked to provide information concerning what high school science classes were taken and the grade obtained so that the relationship of grade point average (GPA) and the importance of student interest could be analyzed. The results of the initial survey were first analyzed quantitatively to compile a student generated list of core qualities of effective secondary science teachers and to determine the ranking of the promotion of student interest on that list. The objective questions provided demographic information and allowed for ranking of the most commonly cited attributes. The Likert-scale questions on the survey, questions 13-15 (Appendix A), provided the data for the first two research questions: determining the common qualities of effective high school science teachers and determining where the promotion of student interest ranked in the list of qualities of effective high school science teachers.

The teacher qualities listed on the survey for questions 13-15 were grouped into three categories: personal, professional, and classroom management (Appendix A). The answer choices were a priori worded to be favorable responses. Respondents chose from a Likert-scale with answers ranging from "strongly agree" (5) to "strongly disagree" (1). The assignment of numerical values to the answer choices allowed for a mean to be calculated for each response and the responses ranked numerically.

The open-ended questions provided qualitative information to supplement the quantitative information in answering each of the four research questions and were used to further direct the research. The survey responses to questions 16-18 and 20 were used to explain the ranking of student interest obtained quantitatively from the initial survey as well as explain why the different groups of students may have ranked student interest differently (Mason, 2006). It was anticipated that a second survey might be required because of the acquisition of unanticipated data. The Delphi method was chosen for this portion of the research because "it is an iterative process to collect and distill the anonymous judgments of experts using a series of data collection and analysis techniques interspersed with feedback" (Skulmoski, et al., 2007, p. 1; Bryman, 2006). The Delphi method was also chosen because of its flexibility in designing the surveys and deciding how many subsequent surveys would be required. Although this method is usually used in quantitative studies it is also "well suited to rigorously capture qualitative data" and helps structure the transition from quantitative to qualitative methods, as well as forcing the simultaneous analysis and collection of data (Skulmoski, et al., 2007, p. 9). This allowed for immediate analysis before the next round of data collection.

Survey questions for the ensuing survey were open-ended and semi-structured because inherent differences could be present in the individuals surveyed (Merriam, 1998). A grounded theory approach was taken in the qualitative portion of this study in an effort to determine relationships between information gleaned from the core qualities of effective science teachers as identified by the surveys and the core qualities identified in the literature. The constant comparative method was used to continually compare, formulate, and analyze categories of commonalities, emerging trends, and qualities (Creswell, 1998; Glaser & Strauss, 1967; Merriam, 1998; Patton, 2002). There was no a priori decision of sample size for either the initial survey or additional surveys. The initial survey involved more than 100 students therefore the results may be generalizable to other populations. The students identified as subjects to be subsequently surveyed after the initial survey constituted a much smaller sample size, therefore the results may be transferable only. The use of both quantitative and qualitative survey questions allowed insights into the analysis of teacher qualities and provided information that can be generalized to inform further research. The use of multiple sources of data (quantitative and qualitative) and triangulation between these sources and the literature was important to the credibility of the research (Creswell, 1998; Merriam, 1998). Using an inductive design allowed patterns to emerge from the initial survey without specifying in advance what those patterns might be, constantly comparing the emerging patterns to each other and to the patterns existing in the literature (Patton, 2002; Yin, 2003).

Upon completion of the research a summary of the results of the survey was disseminated to all Biology 1306 professors and the survey participants who provided their email addresses.

Clarification of Biases

Prior experience as an educator has allowed me the opportunity to work with secondary science students, teachers as peers, as an instructor of both pre-service and in-service science teachers, and as an administrator at the high school level. The experience of working with teachers at all stages of development has prepared me to be both sympathetic and empathetic to the inherent problems in secondary science education. My experience as a parent of two children who experienced different routes through public education has also contributed to my understanding of science education and the importance of student interest as a predictor of future interest. Any biases present in this research would arise from identifying too closely with teachers and students within the educational system. Clarification of biases is important at the outset of any qualitative analysis and biases may occur in this research because of my background in the education of high school students, college students, pre-service teachers, and in-service teachers (Creswell, 1998; Merriam, 1998). These biases, if controlled, could actually benefit the study in that they allowed me to have multiple perspectives and understandings of the issue of teacher quality and teacher effectiveness.

Conclusion

Determination of the teacher qualities that promote student interest and therefore student achievement and a life-long interest in science is paramount in the field of science education today. Simply stating that science should be made relevant to students is no guarantee that the implemented curriculum will include relevance. Student input must be garnered that sheds light on what is most effective in promoting science relevance in the classroom. The purpose of this research was to determine if in fact student interest in secondary science is important to the promotion of student achievement and life-long interest in science for Baylor University second semester biology students and to determine what qualities of effective science teachers those students deemed important.

The identification of the role of student interest in promoting student achievement and the choice of a career may contribute to a different approach to the preparation of effective science teachers. The student role in producing the results of this investigation is an approach not often taken by educational researchers. The significance of using student contributors to science education research has been overlooked in the past. This research specifically targeted second semester college freshmen biology students in compiling a list of attributes of effective secondary science teachers, particularly as the primary source of information for determining if effective secondary science teachers used the promotion of student interest to drive student achievement in their classrooms and if that subsequent interest influenced the choice of science as a major in college. The importance of student contributions at the secondary level of science education cannot continue to be ignored. The students are the ultimate investors in the educational system and their input is vital to promoting understanding and application in science. Without student interest and engagement it really does not matter what dog and pony show is used, little student learning will occur.

CHAPTER FOUR

Analysis of Data

Research Rationale

This study emerged from the researcher's concern for secondary science education and the basis from which decisions were being made concerning present secondary science pedagogy. While everyone has an opinion as how to best teach secondary science, lacking from the research was the student perspective. This research is an attempt to begin to fill that void.

Data Collection

This research was conducted during the 2008 spring semester using an electronic survey of Baylor biology students (Appendix A). The participating biology professors either sent the survey to students through Blackboard email or supplied the student email addresses to the researcher. The researcher personally spoke to each of the seven sections of Biology 1306 in the spring of 2008 prior to the survey being administered. The purpose of this was so the students would understand the importance of responding to the survey and would have a face and name to link to the research being conducted. The initial survey was emailed to 645 students enrolled in Biology 1306 via Blackboard by the professors during the week of February 11, 2008. The follow-up requests for participation in the initial survey occurred during the weeks of February 18 and February 25. A total of 128 students responded to the survey. Two of the respondents were under eighteen years old and had to be eliminated from the study, and one respondent was eliminated because of an incomplete survey. The overall response rate was 19.8%. There were 77 students, 60%, who provided their names and email addresses so that they could be contacted for further information or subsequent surveys and be provided a summary of the research results.

Analyses of Demographics

The research instrument provided demographic information about the 125 responders and this information is displayed in Table 1. As would be expected of a freshman level course, the majority of respondents were classified as freshmen and over 90% were 18-20 years old. The number of female to male respondents was almost 3 to 1 (74.4% to 25.6%). A profile of Baylor undergraduate students for the fall of 2007 revealed that the student body ratio of female to male students was 58.5% to 41.5% and 18-20 year olds comprised 67% of those students (Baylor University, 2008). The larger percentage of female science students at Baylor is indicative of a nationwide trend of more female graduates in the sciences which began in 1985. Information provided by the National Science Board's "Science and Engineering Indicators" (S&EI) indicates that fewer young American males are entering the science field, an area that has always been dominated by men (Heylin, 2008). According to Heylin (2008) the number of women earning bachelor's degrees in science rose to 56% in 2005. The number of female students in this survey was closer to 75%. Participation in the survey was optional, therefore the number of freshmen biology students who responded to the survey may reflect a larger percentage of females because a larger number of women chose to complete this survey.

Table 1

Demographics of Responders

Demographics	Number	Survey Percentage	Baylor Percentage
Gender			
Male	32	25.6	41.5
Female	93	74.4	58.5
Ethnicity			
African-American	10	8.0	7.8
American Indian	1	0.8	0.6
Anglo	74	59.2	71.3
Asian	23	18.4	7.8
Hispanic	17	13.6	10.4
State/Country			
No response/Unknown	6	4.8	0.3
International	3	2.4	1.8
Texas	91	72.8	81.2
Other US	25	20.0	16.3
Enrollment Year Status			
Freshman	77	61.6	-
Sophomore/Junior	48	38.4	-
Age			
18-20	113	90.4	-
21-24	12	9.6	-
School District Location			
No answer	2	1.6	-
Urban	31	24.8	-
Suburban	75	60.0	-
Rural	17	13.6	-

The ethnic breakdown, state of residency, and classification as international students of Baylor University undergraduates also closely mirrored that of the survey responders. The decreased percentage of Anglo biology students responding to the survey (59.2 %

compared to 71.3% of undergraduates at Baylor) is offset by the increase in the percentage of Asian students (18.4% responders to 7.8% overall at Baylor).

Data Analysis for Common Qualities and Ranking of Interest

Data answering research questions one and two was collected using survey questions 13, 14, and 15, as well as questions 16-18 and 20 (Appendix A). Research questions one and two are listed below:

> What are the common qualities of effective high school science teachers as described by college second semester biology students?
>
> Where does the promotion of student interest rank in the list of qualities of effective high school science teachers as described by college second semester biology students?

The survey questions were compiled from survey instruments used by other institutions and from the researcher's experience in secondary schools concerning how students rate effective teachers and teaching (The University of Texas, 1999; McBer, 2000). Many of the qualities cited in the literature were obtained from either surveys of teachers or from educational researchers studying effective teaching and teachers. The lists cited from the literature also included many qualities students would probably be unaware or uninformed of. The survey questions used in this research included only information that would be observable or known by the student. The lists were not quantifiable for this research because few were quantified in the literature. This research was concerned only with the student perspective, therefore a direct comparison of lists provided by the literature and generated from the survey was not possible. The literature did provide information that guided the formulation of questions for the survey, therefore a qualitative comparison was made between the research results and the literature.

There was an overlap and interconnection between many of the qualities found in the literature categorized as personal, professional, and academic. The survey instrument used in this research divided effective teacher qualities into three core categories: personal, professional, and classroom management. The researcher acknowledges that there was an overlap of qualities in each of the three categories, and this was discussed in the analysis and subsequent discussion of results.

Common Qualities of Effective Secondary Science Teachers

Responses to the survey were discussed by question, beginning with questions 13, 14, and 15 (Appendix A). The initial analysis of the objective questions concerning qualities of effective teachers was a simple ranking of means. Tables 2, 3 and 4 present the resulting ranking of qualities of effective science teachers analyzed from questions 13, 14, and 15 in the survey (Appendix A). These questions asked students to rank the qualities of effective science teachers using a Likert-type scale of 1-5 where 5 equaled "strongly agree" and 1 equaled "strongly disagree". The mean for this type of scale can be viewed as 3.0, answering the question as "neutral". None of the characteristics listed for student analysis in questions 13, 14, and 15 received a below means score. A consensus of qualities was obtained from the initial survey so a second survey was not used to gain further information concerning teacher qualities. The data from question 13 was compiled in Table 2 which shows student responses ranking personal characteristics of effective science teachers. Question 14 provided the data from student responses ranking professional characteristics of effective science teachers in Table 3. The data from question 15 was compiled in Table 4 which shows student responses ranking classroom management characteristics of effective science teachers.

Table 2

Means Ranking of Personal Characteristics of Effective Secondary Science Teachers

Survey Question #13: Use the following scale to rate the characteristics/qualities listed as being important personal characteristics of effective science teachers (in your opinion).
Strongly Agree---Agree---Neutral---Disagree---Strongly Disagree
5 4 3 2 1

4.74	Enjoys teaching
4.69	Good communication skills (including listening)
4.68	Respectful of all students
4.64	Enthusiastic about the subject
4.63	Shows concern for student progress
4.57	Ability to motivate students
4.51	Friendly
4.47	Willingness to admit mistakes
4.45	Caring relationships with students
4.44	Interested in students
4.36	Sense of humor
4.35	Non-judgmental
4.35	Flexible
4.35	Invites constructive criticism
4.33	Tolerant of other viewpoints
4.28	Self-confident
4.27	Not egotistical
4.21	Ability to resolve conflicts
4.18	Advanced degrees (master, doctorate, etc.)
3.70	A life-long learner

Table 3

Ranking of Professional Characteristics of Effective Secondary Science Teachers

Survey Question # 14: Use the following scale to rate the characteristics/qualities listed as being important professional characteristics of effective science teachers (in your opinion).

Strongly Agree---Agree---Neutral---Disagree---Strongly Disagree
5 4 3 2 1

4.71	Explains clearly
4.47	Ability to make the material interesting
4.41	Engages students with the content
4.36	Summarizes major points
4.35	Ability to make the material relevant/related to life
4.31	Good questioning techniques
4.29	Good lecturer
4.24	High expectations for students
4.17	Uses a variety of teaching methods
4.16	Emphasizes learning of concepts over facts
4.09	Presents recent developments
3.97	Allows students to share their knowledge and experiences
3.97	Presents origins of concepts and ideas
3.85	Less lecture/more hands-on activities
3.82	Encourages class discussion
3.67	Emphasis on lab activities

Table 4

Ranking of Classroom Management Characteristics of Effective Secondary Science Teachers

Survey Question # 15: Use the following scale to rate the characteristics/qualities listed as being important classroom management characteristics of effective science teachers (in your opinion).

Strongly Agree---Agree---Neutral---Disagree---Strongly Disagree
5 4 3 2 1

4.78	Grades student work fairly
4.70	Available for help outside of class
4.59	Provides feedback on assignments
4.54	Effective use of class time
4.45	Good classroom organization
4.38	Holds students accountable
4.28	Keeps students on-task
4.26	Recognizes and greets students outside of class
4.18	Few discipline problems

Responses to Open Ended Questions

Questions #16-18 and 20 were open ended questions requiring free responses. Students were asked to limit responses to 50 words or less for each question. Three of the open-ended questions were asked on the survey to elucidate additional, less-restricted information from the students concerning what they felt were important qualities of effective high school science teachers. The questions included:

Question 16: What characteristic of an effective science teacher do you feel is the most important from a student perspective (may be chosen from the listings above or your own description)?

Questions 17 and 18: Name your most effective high school science teacher. Why did you choose that particular teacher?

Question 20: What is your description of an effective science teacher? (Appendix A)

The responses to the open-ended questions were coded and analyzed separately. Each question was analyzed for emerging themes and converging categories by identifying and categorizing repeated words and phrases, what Strauss and Corbin refer to as "microanalysis" (Patton, 2002). The words and phrases were color-coded for easy recognition during category coding. Portions of the initial comments were separated into different categories if they contained references to multiple qualities of teacher effectiveness. For example, in response to question 16 "What characteristic of an effective science teacher do you feel is the most important from a student perspective", one student responded:

> A good science teacher needs to be in love with the area of science selected to teach and excited to teach it. They need to be fair and unbiased in grading and in how they treat their students. Coursework should be difficult and challenging but not impossible and the teacher should be available for students to contact outside the classroom.

Instead of listing one most important quality, the student above listed multiple qualities. Each of the qualities mentioned in the quote is an important contribution, therefore the qualities were coded and categorized separately. This procedure was followed for every response to each open-ended question on the survey. The following categories emerged from the initial coding of data:

1. Relevance
2. Interest
3. Teaching methods
4. Demonstration/Hands-on activities
5. Passion for the subject

6. Motivation/Encouragement
7. High expectations
8. Content knowledge
9. Personal qualities
10. Classroom management

The categories of teaching methods, interest, motivation, and classroom management had variations within the categories, therefore they were further divided into sub-categories (Creswell, 1998; Patton 2002). The personal qualities category originally was very large so separate categories were formed for the qualities instead of subcategories. There were very few negative comments in the free-response questions, therefore those comments were placed into a separate category. There were a total of 620 phrases that were separated and categorized for analysis. The division headings were determined from the order they were first encountered in the questions. For instance, "relevance" was determined from the first response analyzed, therefore it is listed first in Table 5. New divisions were formed as each question was analyzed. The divisions and subsequent coding of the phrases obtained from the free-response questions were listed in Table 5.

Table 6 is the result of the analysis of categories and subdivisions determined from the open-ended responses. The words and phrases were re-categorized to fit into the same divisions used in survey questions #13-15, personal, professional, and classroom management qualities of effective secondary science teachers. This allowed a comparison of the quantitative and qualitative information. Table 6 lists a hierarchy of divisions by number of responses containing specific words or phrases of each category

Table 5

Coding for Free Response Questions #16, 17, 18 & 20

1.00	Relevance
2.00	Interest
	2.00a Interest in students/class
	2.00b Interest in the subject
3.00	Teaching methods
	3.00a Explains clearly
	3.00b Use of different teaching methods
	3.00c Use of lecture
4.00	Demonstration/Hands-on activities
5.00	Passion for the subject
6.00	Motivation
7.00	Encouragement
8.00	High expectations
9.00	Content knowledge
10.00	Enthusiastic
11.00	Fun
12.00	Friendly/Engaging
13.00	Humorous
14.00	Interest in student/love, respect & concern for students
15.00	Available/Approachable/Helpful
16.00	Willing to admit mistakes
17.00	Fair
18.00	Good communicator
19.00	Energetic
20.00	Shares personal experiences
21.00	Not egotistical
22.00	Life-long learner
23.00	Patient
24.00	Classroom management
	24.00a Organization
	24.00b Classroom control
25.00	Advanced degrees
26.00	General negative comments

established. The manipulation of the categories of words and phrases was strictly the decision of the researcher, and that decision was driven by how closely the free response comments related to the initial core categories of effective teacher characteristics. For example, "available, approachable, helpful, and patient" were categorized together for final analysis as classroom management qualities instead of personal qualities. The reasoning for this decision was because "available for help outside of class" was listed as a classroom management quality of effective science teachers on question 15 (a Likert-scale question), and several student comments in the free response questions equated a teacher being available outside of class with being helpful and patient. Table 6 shows the number of times each term or phrase was used in the student responses for those questions.

Comparison of Quantitative and Qualitative Data

Questions 13-15, which listed the most effective personal, professional, and classroom management skills, preceded the free response questions on the survey and therefore may have influenced the student responses to questions 16-18 and 20. Question 16 stated, "What characteristic of an effective science teacher do you feel is the most important from a student perspective (may be chosen from the listings above or your own description)?" therefore many students used much of the same wording as that listed in the answer choices of questions 13-15.

The data was collected in different forms, therefore neither a complete word-to-word analysis, nor a statistical analysis comparing the types of data was possible. However, a comparison and analysis for substantive significance of the data was possible (Patton, 2002). The quantitative and qualitative results from the different sets of questions on the survey yielded similar results. The results from Likert-scale questions 13-15 concerning

Table 6

Number of References to Personal/Professional/Classroom Management Qualities of Effective Secondary Science Teachers

	What characteristic of an effective science teacher do you feel is the most important from a student perspective?	Reason for choosing a particular teacher as most effective.	What is your description of an effective science teacher?	Total Number of Responses
Personal				
Interest in/Passion for subject matter	30	14	29	73
Enthusiastic/Fun/Humorous	9	27	19	55
Interest in students/ Love/Respect/Concern for students	16	10	14	40
Friendly/Good communicator/	11	8	4	23
Encourager/Motivator	8	9	5	22
Not egotistical/Willing to admit mistakes	3	2	0	5
Life-long learner/Advanced degrees/Qualifications	2	0	0	2
Professional				
Explains clearly	28	20	25	73
Makes the class interesting	19	18	22	59
Makes the class relevant	19	10	15	44
Uses different teaching methods	13	11	9	33
Content Knowledge	13	8	11	32
Interesting lecturer	13	3	16	32
High Expectations	5	13	9	27
Uses demos/hands-on activities	10	12	3	25
Negative Comments	0	0	6	6
Classroom Management				
Available/Approachable/Helpful/ Patient	8	13	16	37
Organized	6	3	3	12
Fair	2	3	5	10
Classroom Control	2	3	0	5

qualities of effective high school science teachers compiled for Tables 2, 3, and 4 were compared to the results from the open-ended questions, 16- 18, and 20, asking for student opinion as to the important qualities of effective high school science teachers (Table 6). Quotations obtained from student responses to questions 16-18 and 20 were used in the discussion of those free-response questions. The resulting analysis compared the results from both sets of questions within the core categories listed for questions 13-15, which were personal, professional, and classroom management qualities of effective secondary science teachers. The analysis and discussion for each category began with the sub-categories that were either ranked highest on the means analysis or received the most references in the free response questions. The analysis compared the data from the two sets of questions and discussed how the quantitative and qualitative data either supported or did not support the placement and ranking of the data in each table.

Personal qualities. In the quantitative data determined from question 13, "enjoys teaching" and "enthusiastic about the subject" ranked as the first and fourth categories, means 4.74 and 4.64 respectively, on the list of personal characteristics of effective secondary science teachers. In the free response questions, 16-18 and 20, the comparable phrase "interest in and passion for the subject matter" ranked first in the list of personal qualities with a total of 73 responses that included words or phrases alluding to that sub-category. The following student quotes from the free response questions illustrated the importance of a teacher having passion and interest for the subject matter:

> Student #74: I think the most important characteristic [of an effective science teacher] is an enthusiasm for the subject material, but the teacher should also be able to share that enthusiasm with students and help them to feel it too.

Student #87: Effective science teachers are people who have a passion for what they do and have a desire to share with others. They don't teach just to give tests, but they want their students to learn the material and love it as much as they do. I believe that a teacher who is interested in both the material he or she is teaching and the student's desire to learn it is very important.

Student #23: An effective science teacher should also be interested in what he is teaching in order to pass that interest on to the students.

Student #80: It is most important to me that they be interested in the subject and able to make it interesting to students.

The students indicated that a teacher's enthusiasm for the discipline was an important component of student interest in the class. They believed that teacher enthusiasm was contagious and necessary in order for students to become interested in the material.

A difference was observed in how students responded to questions 16 and 20 versus questions 17 and 18 in discussing a teacher's passion for the discipline. Responses to questions 16 and 20 indicated that students most often cited that "having an interest in the subject matter" and "passion for teaching" the discipline were very important characteristics of effective secondary science teachers, with 30 and 29 responses, respectively. When asked to cite the reason for choosing a particular teacher as their most effective secondary science teacher in questions 17 and 18, students chose the second category "enthusiastic/ fun/humorous" more often, with 27 responses. However, "having a sense of humor" ranked further down the list on the means ranking (11^{th} in Table 2) with a mean score of 4.36, indicating that students chose "agree" more often than "strongly agree." Responses to question 13 used to rank effective teacher qualities and free response questions 16-18 and 20 appear to show discrepant results between the quantitative and qualitative data, yet the difference is in which question is being answered. While students placed the greatest importance on a teacher being interested in and enjoying the subject matter when describing important qualities of an effective secondary science teacher, when asked to explain why they chose a particular teacher as their most effective high school science teacher, this particular group of students chose the teacher most often because the teacher was humorous and fun. One student responded that the most important characteristic of an effective science teacher was one "with a sense of humor that you can joke around with. It will make the environment less intense and make it easier to learn and remember things". Students also remarked that a good sense of humor was essential and that having a fun teacher "made class very enjoyable. I actually looked forward to going to his class every day." Overall there were a total of 55 responses to the sub-category "enthusiastic/fun /humorous" assimilated from the comments to questions 16-18, and 20 for personal qualities of effective secondary science teachers, which placed this sub-category second in Table 6.

Although "good communication skills" ranked second as a personal quality of effective science teachers with a mean of 4.69 (question 13, Table 2), there were only two references to actual communication skills in free response questions 16-18, and 20. Students described the need for teachers to be personable and friendly in the free response questions but there was no direct mention of "good communication skills". Being a "good communicator" was combined with "friendly" for the analysis of questions 16-18, and 20 because the student references to communication included both attributes. There were 23 references to “friendly/good communicator” in the free response questions. Being friendly ranked seventh with a mean of 4.51. One student responded that an effective science teacher “can relate to students and isn't afraid to come down to their level to help them”. Another student indicated that good communication consists of more than speaking and listening skills, “a good science teacher has to be able to interact with the students in a way that they are actually willing to participate in the lesson”. Student #114 summed up the communication connection with the learning process, “If the teacher is available and friendly, any problem understanding information or assignments can be discussed and a solution found.”

In the means ranking for question 13 concerning personal qualities of effective secondary science teachers, sub-categories which referred to the student/teacher relationship ranked between third and tenth. Being “respectful of students” ranked third on the list (mean = 4.68), “showing concern for student progress” ranked fifth (mean = 4.63), having “caring relationships with students” ranked ninth (mean = 4.45) and “interested in students” (mean = 4.44) ranked tenth (Table 2). There were 40 references to the student/teacher relationship (“interest in students/ love/ respect/ concern for students”) in questions 16-18, and 20, ranking it as the third most referred to sub-category of important personal characteristics of effective science teachers (Table 6). Once again there appeared to be a difference between the quantitative and qualitative analyses, but closer inspection revealed that there was only a 0.24 point difference in the means of the third ranking and the tenth ranking personal characteristic, indicating that there was little difference in how students ranked those personal qualities. The ranking of qualities in question 13 for “respectful of students”, “showing concern for student progress”, “having caring relationships” and “interest in the students”, was supported by responses to open-ended questions 16-18, and 20 concerning the importance of the student/teacher relationship.

> Student #58: To me, I feel like the teacher's love for the students is the most important characteristic. I believe that love and care for the students is needed in order for a teacher to teach the students to their full potential. Students love teachers who care for them. She [my most effective science teacher] was more than a teacher to me as she was like a family. Her love for her students was overwhelming. She would stay after school nearly every day for a couple hours in order to help students who had trouble understanding the concepts.

> Student #75: Teachers must create a "safe" environment for kids to learn, “safe” in that students do not feel intimidated or stupid asking questions but where each individual is treated with respect.

> Student #6: They must try to have a personal relationship with their students because it affects our learning.

> Student #103: Having a good relationship with students helps students boost confidence in asking for help.

The need for a teacher to be dedicated to the student on a personal level was supported by these comments and included both a time commitment and a relationship commitment. The students indicated that a personal relationship with their teacher was an indicator of that teacher’s love, respect, and commitment to the student, and that the relationship should extend outside of the classroom. As one biology student reflected concerning their most effective high school science teacher, “I struggled in both of his classes, but he talked to me outside of class as a person and not just a student”. Another student indicated that caring for students even helps teachers overcome their own personality quirks, “He was a little strange, but you could tell that he cared and respected his students”.

“Ability to motivate students” ranked sixth on the means table (mean = 4.57) for question 13 (Table 2). The word “encourager” did not appear in that list of qualities, yet was mentioned in free response questions 16-18, and 20. Being an “encourager/ motivator” ranked fifth on the free response table of personal qualities of effective science teachers for questions 16-18 and 20 with 26 responses (Table 6). One student believed that encouragement was “also crucial because positive reinforcement makes students strive harder instead of wanting to quit” and another felt that their most effective high school science teacher was encouraging because he “honestly wanted to see his students succeed in science and in life in general”. Students went beyond suggesting that teachers should be encouraging and motivating and the following quotes suggest specific ways for teachers to be motivating and encouraging:

> Student #27: Showing interest in what they are teaching is important because it motivates students to learn the material.
>
> Student #93: Providing feedback so that students are properly able to keep track of where they are at and what they should be doing to improve themselves.
>
> Student #40: It motivates a student when they know their teacher cares about their grade and their understanding of the subject.

The students indicated that keeping students motivated included the teacher being interested in what was being taught, providing feedback to students so that they could track their own improvement, and the teacher caring about the student’s grades, progress, and understanding.

The sub-categories “willing to admit mistakes” (mean = 4.47) and “not egotistical” (mean = 4.27) ranked 8th and 17th, respectively, on the means ranking for personal qualities from question 13 (Table 2). The combined sub-category “not egotistical/willing to admit mistakes” ranked sixth for questions 16-18 and 20 with only 5 references to those phrases (Table 6). Students expressed concern over the teacher/student hierarchy in the classroom in the following quotes, “An effective science teacher is one that does not make the student feel inferior just because the student knows less than him or her” and “He admits his mistakes and is real with the students that he doesn't know everything”. The quotes indicated that these students felt that although there was an inherent hierarchy in the classroom, no person knows everything and teachers should be willing to admit mistakes and absence of knowledge.

The lowest ranking sub-category for questions 16-18, and 20 was “life-long learner/advanced degrees/qualifications”. The categories “advanced degrees (master, doctorate, etc.)” and “a life-long learner” were also the lowest and next to the lowest sub-categories for the means analysis of questions 13-15 (Table 2). Two students discussed that teachers should be qualified to teach and one mentioned that a teacher should be a life-long learner, “An effective science teacher must always be a lifelong learner who is open to new theories and information since new discoveries are being made in all of the time.”

Professional qualities. The sub-category that received the greatest number of responses for free response survey questions 16-18 and 20 under the category of professional qualities of effective high school science teachers was “explains clearly” with 73 references. This corresponds closely to the means analyzed in “Ranking of Professional Characteristics of Effective Science Teachers” for question 14 where the sub-category “explains clearly” had the highest mean at 4.71 (Table 4). “Explains clearly” was the students’ choice as the most important quality of an effective secondary science teacher in both the quantitative analysis and means ranking of sub-categories for professional qualities as determined from question 14 as well as the qualitative analysis of questions 16-18, and 20. Student responses to the free-response questions supported the number one ranking of "explains clearly" in both analyses. Students were adamant that an effective science teacher be able to take difficult concepts and present them in a way that all students understand:

> Student #43: Nothing is worse than having a teacher that talks above you and assumes that you understand everything he is saying. He will meet you where you are in science and help explain concepts simply and humorously so I can understand them, and the teacher should meet students at the level that they can understand and in a language they can understand.

> Student #52: I believe that it is important for a teacher to clearly relay all of the material. Teachers need to make absolutely sure that every student understands the material they are covering so that no one is left behind in the class.

> Student #119: It is important that the teacher is willing to work with the students to get the point across and make sure the students understand the concept completely.

> Student #70: [An effective science teacher] is able to put scientific material into terms that all high school students will understand instead of just those who are interested in science.

> Student #50: Since she knew that I am a very mechanically savvy person, she often used analogies involving automobiles.

> Student #99: Someone who is willing to work with a student until they fully understand a concept.

The student responses to "explains clearly" can be summarized to include that teachers must explain concepts at a level that ensures student understanding of the material, they should use analogies that the student can relate to, and that the teachers must work with all students until everyone understands those concepts.

The ability of a teacher to “make the material interesting” ranked second on the list of professional characteristics listed by students on both the means analysis of question 14 (mean = 4.47) and in the free response questions 16-18 and 20. There were 59 responses when students were asked what characteristic of an effective science teacher they felt was most important from a student perspective (question 16, Appendix A). Students felt that teachers who were interested in the subject matter were better able to make it interesting to the students, “if they [the teachers] are interested, then it makes me interested”. One student responded that motivating the student to be “interested in learning the information is the most important characteristic a science teacher could possess. None of my high school teachers did this effectively, and I feel that a lot of the possible interest my fellow students could have had was lost because of this”. Others felt that students were not motivated “to pay attention and learn if they are bored by the topic” and that effective science teachers “made us all excited about whatever we were going to learn, no matter how boring the material was”. Although the number of respondents citing this category as important was large, the answers to the free-response questions were less descriptive than in the other categories. Students did not elaborate necessarily on how teachers made the class interesting; they simply stated that teachers must make the class interesting.

Students also felt that high school science classes should be relevant to real-world issues and experiences. This category ranked third with 44 responses for questions 16-18 and 20 for professional qualities of effective secondary science teachers and fifth in the means analysis (mean = 4.35) for those same qualities in question 14 (Table 3). The survey responders believed that complicated material was much easier to understand when explained with current events and applications to real life. Student quotes concerning relevancy in high school science education included:

> Student #48: Because so much of science is so small or so large, to comprehend certain abstract ideas can be difficult and the ability of a teacher to relate that to something more familiar and tangible is invaluable.

> Student #15: [The teacher should] relate subject material to real world situations, actually gives insight as to why I am learning this topic.

> Student #96: A teacher should have the ability to explain things clearly so that a student in any grade could be able to understand it, make sense of the subject, and apply it to life.

> Student #4: [The teacher should] show the student how it affects their life. They are caring and don't just want the student to learn the facts but also want them to learn why and how to apply the material.

> Student #26: The teacher cares about the students actually knowing the subject and being able to apply it.

> Student #116: [My most effective science teacher] was also open about life experiences and any questions we had about life, recent news, understanding.

> Student #103: He always made sure we were updated with what was going on in the world.

> Student #60: [My most effective science teacher] also took time out to give us science facts of the day, revolving around current events. ...he pointed out the concepts in real life.

The student quotes indicated that the discussion of relevant events and life experiences, as well as the application of the material, was important to the understanding of science and that a teacher's ability to make the material relevant was an important quality of an effective science teacher.

"Content knowledge" was the fifth ranking sub-category of professional qualities for questions 16-28 and 20. There were 32 references to teachers knowing the subject matter (Table 6), indicating that students believe there is a need for effective secondary science teachers to have adequate content knowledge. “Content knowledge” was not mentioned as a quality in any of the three categories proposed in objective questions 13-15 (Tables 2, 3, and 4). “Advanced degrees” was listed as a personal characteristic in question 13 (which ranked next to last on the means analysis) but there was nothing listed that would prompt the students to mention content knowledge or knowledge of subject matter as a response to the questions analyzed for Table 6. Students mentioned “content knowledge” repeatedly in the free-response questions. Students quoted in those responses stated that effective secondary science teachers should be very knowledgeable about the subject they are teaching, as well as knowledgeable in other subject areas. Students believed that teachers should:

> Student #9: Be knowledgeable about a wide variety of subjects, not just the one they teach.
>
> Student #24: Have the ability to explain the concept beyond what the text says. They have to have advanced knowledge about the subject in order to fully explain it to the student.
>
> Student #81: Have a grasp of the concept before trying to explain it to the students as well.
>
> Student #27: Be someone who knows what they are talking about.
>
> Student #100: [Be] knowledgeable about the material.
>
> Student #117: [Be] smart in all fields.

According to the quotes, students perceived “content knowledge” as being important because it enabled a teacher to understand the discipline and then explain that information to the student. One student responded, “If there isn't a good knowledge of the subject then it can't be transmitted to the students”. Students also responded that teachers should have knowledge of many disciplines and be able to interconnect those disciplines.

"Interesting lecturer" ranked as the sixth sub-category of professional qualities of effective science teachers from the free response questions (Table 6). The same sub-category also ranked seventh on the means ranking of professional characteristics in Table 3 (mean = 4.29). The responders were not fond of lecturing as an instructional strategy unless it was an interesting lecture and was combined with other instructional strategies. Student quotes concerning the use of lecture as an instructional strategy include:

> Student #80: I do not think that only lecturing is very effective for any subject. The lecturer would have to be very interesting and have good jokes or something to keep our attention.
>
> Student #32: Her lectures were not really strict and in a typical lecture format. Most students tend to doze off when such lectures take place, but her lectures were instead bringing the students into it without putting them on the spot and embarrassing them by asking them questions randomly when they might not know the answer.
>
> Student #3: I think the most important characteristic is presenting the topic in more than one way because all students learn differently. For example, my teacher in high school would usually have a power point presentation or over head slides, and she would actually give a lecture that wasn't just reading from the slides. Then lastly to pull it all together she would usually show a demonstration over the concept we had just learned.
>
> Student #41: Different approaches and good lectures make the material easier to understand and motivate students more.

The student responses analyzed illustrated that lectures should be integrated with other instructional strategies and if lecture was the strategy chosen by the teacher, then it should be interactive, interesting, and funny.

Students felt that teachers should move beyond the lecture and employ different teaching methods and strategies in order to be effective high school science teachers. The qualities "uses a variety of teaching methods" (mean = 4.17), "less lecture/more hands-on activities" (mean = 3.85), "encourages class discussion" (mean = 3.82), and "emphasis on lab activities" (mean = 3.67) as stated in question 14 (Table 3) and those assimilated from questions 16-18, and 20 (Table 6) as "uses different teaching methods" (ranked fourth), and "uses demos/hands-on activities" (ranked eighth) can be combined for the discussion of teaching methods. Students felt that it was particularly important that a variety of teaching methods be used because of different learning abilities and learning styles:

> Student# 65: An essential characteristic is being able to teach on a level that is conducive to all the learning abilities in the class. The teacher should find out the slowest learners from the quickest learners and be able to mediate lesson plans that all students can effectively learn from.

> Student #35: An effective science teacher should be willing to teach the material in different ways so that everyone in the classroom will be able to understand the concept.

> Student #93: I think that they also need to have various methods of teaching like hands-on, laboratory, and lecture to appeal to all the different ways that students can learn and retain material as well as adapt to the material itself. Finally, an effective teacher has to listen to their students to some degree in order to identify how well they understand the material they are being taught and how they might better retain new material in the future.

Students who referred to instructional methods and strategies in their responses indicated that a teacher should be able to use a variety of instructional methods and strategies to ensure that students of all abilities and learning styles understand the content.

The final category of the professional quality analysis was "high expectations". In the means analysis of question 14 (Table 3) this category ranked eighth (mean = 4.24) while it received the fewest responses of any category in the free response questions (Table 6). Although it ranked lower than many of the other categories, students felt strongly about what was required of them. Students felt that teachers should push students and that the coursework should be "difficult and challenging but not impossible" and preferred teachers who were upfront about the requirements, "I like teachers that will straight up say this material is tough so pay attention it will require lots of work from you but I'm here to help in any way possible." One teacher inspired a student to go beyond basic understanding,

> I feel that the most important characteristic of a science teaching is care for learning and thinking. The best science teacher I ever had taught me to think on deeper levels instead of basic recall of facts. This teacher didn't let you answer a question on the surface. He would keep asking more questions until you got to the level he wanted.

Students expected to be held to high expectations and appreciated teachers who taught them how to meet those challenges. When asked to explain the reason for choosing their most effective science teacher, responses included:

> Student #34: [She] expected us to come to class prepared, didn't baby us by dummying down her expectations. She had high expectations for us and worked with us to help us meet them.

> Student #122: I chose him because he challenged us. He constantly gave us a heavy workload. He expected so much from us and he encouraged us to do better.

> Student #35: [She was an] amazing teacher because she taught me to be responsible for my work.

High expectations translated into student responsibility for their own learning. Students expressed that coursework could be demanding and challenging as long as the teacher provided support and encouragement.

Classroom management qualities. Information analyzed for the category of "classroom management" was assimilated from question 15 and a ranking of means within this category was established (Table 4). This information was compared to references concerning classroom management obtained from free response questions 16-18, and 20 (Table 6). The category that ranked highest in the means analysis of effective teacher qualities for classroom management was "grades students work fairly" with a mean of 4.78 (Table 4). This mean was higher than any response to questions 13-15 concerning personal, professional, and classroom management qualities. When asked to rank the quality, students chose "strongly agree" most often, but when asked to discuss the qualities of effective science teachers in questions 16-18 and 20, students mentioned grading work fairly and treating students fairly in only 10 responses. For this reason "fair" ranked third in the list of five classroom management qualities obtained from the analysis of questions 16-18 and 20 (Table 6). While students "strongly agree" on the importance of this quality, when asked the most important effective teacher quality in question 16, fairness was mentioned only twice. When asked to describe their most effective science teacher in question 18, the students referred to fairness in three responses. The students did not elaborate on aspects of fairness in any of the responses, but referred only to students being treated fairly and graded fairly.

Categorizing the free response that would be comparable to "available for help after class" in the means analysis was difficult because of the similarity to the personal attributes category "friendly/engaging". The decision was made that a friendly and engaging teacher would not necessarily be "available, approachable, helpful, and patient" therefore a separate category was formed. "Available for help outside of class" ranked second in the means analysis for classroom management qualities of effective science teachers with a mean of 4.70 (Table 5). It ranked first in the free response analysis of classroom management qualities in questions 16-18 and 20 with 37 responses to either “available, approachable, helpful, or patient”. The adjectives as analyzed in questions 16-18 and 20 referred primarily to the teacher being available to provide help outside of class, as described in the following quotes:

> Student #40: From a student's perspective, I believe that one of the most important characteristics of an effective science teacher is their willingness to help students outside of class.
>
> Student #82: The most important to me is available to help a student outside of class.
>
> Student #111: Being approachable is probably the most important characteristic, in my opinion, because this allows all other problems to be solved. If the teacher is available and friendly, any problem understanding information or assignments can be discussed and a solution found.
>
> Student #64: [An effective teacher is] able to provide students with extra help, approachable.
>
> Student #31: I also think that the teacher must be willing to spend individualized time with any student who has questions, problems, or interests beyond the class time.

Students concurred that a teacher must not only be available at times other than the scheduled class time, but also that the teacher should be willing to spend time with a student (individually if required) so that any questions, problems, or misunderstandings could be resolved.

“Organizational skills” was listed as a professional quality in the literature but was included in this research as a category of classroom management qualities in question 15 (Table 5) because of its effect on the classroom atmosphere. “Good classroom organization” ranked fifth with a mean of 4.45 in the list of classroom management qualities of effective science teachers (question 15, Table 5). "Effective use of class time" (mean = 4.54) was also included in question 15, as was "keeps students on-task" (mean = 4.28). Although listed separately as classroom management qualities in question 15, the sub-category "organized" was inclusive of these qualities for questions 16-18 and 20. "Organized" ranked second out of five sub-categories determined from the free response questions, with 12 responses to classroom organization analyzed (Table 6). In response to question 16 concerning the most important characteristic of an effective science teacher, one student responded:

> Good classroom organization, in my opinion, is the most important characteristic. If I can't see some kind of order or organization, then it gives the impression that the teacher teaches haphazardly and I feel unprepared.

Students also responded that a teacher should be "on-task", "flexible but structured", and "willing to change the structure of the class to fit the needs of their students".

"Few discipline problems" (mean = 4.18) ranked last in the ranking of means of classroom management qualities of effective science teachers determined from question 15 (Table 5). "Classroom control" also ranked last in the list of five sub-categories of classroom management qualities determined from questions 16-18 and 20 (Table 6). There were five responses that referred to how a teacher controlled the classroom and the overall atmosphere of the classroom. The students appreciated a teacher that was in control of the classroom, one who "didn't tolerate bad behavior in the class" and one who was "able to get along with students while remaining in control".

Negative Comments Concerning Effective Science Teachers

There were very few negative comments in the free response questions. Six students had negative comments concerning their experience in high school science. Four comments specifically addressed the effectiveness of science teachers. When asked to name an effective science teacher, the students had the following comments:

> Student # 51: None of my science teachers caught my attention to be specifically effective, while they just took away our tax money as their monthly salary.

> Student # 73: I do not feel that any of my high school science teachers had an effect on me, and I think that's a shame.

> Student # 108: [I] never really had one (effective teacher).

> Student #71: I did not a have a [science] teacher that I enjoyed or learned from.

While it is disconcerting to hear such comments, it is also heartening to realize that only 6/125 students, approximately five percent, felt that they had never experienced an effective science teacher. A three question electronic survey was sent to the three respondents who each had provided their email address. The survey consisted of the following three questions/statements:

1. Describe the practices of an ineffective high school science teacher. Be as specific as possible.
2. Were you referring to a particular teacher/experience/class when responding to the previous survey concerning the ineffectiveness of high school science teachers? Explain that situation.
3. Additional information?

The purpose of the additional survey was to elicit further information concerning the students' negative experiences. There was no response from the students after three requests for the additional information. The remaining negative comment acknowledged that ineffective science teachers existed and recommended that teachers recognize and compensate for their teaching inadequacies.

Conclusion

The quantitative data obtained from survey questions 13-15 asked students to use a Likert-scale to determine their responses to personal, professional, and classroom management qualities of effective secondary science teachers. The results of the means ranking from this information were supported by the data from the free response questions 16-18 and 20 which asked students to determine the most important quality of an effective science teacher, to explain why they chose a particular teacher as their most effective science teacher, and to describe an effective science teacher. The most important qualities of effective secondary science teachers as determined from both the quantitative and qualitative data from the student perspective were:

1. Be passionate about what is taught,
2. Be enthusiastic, fun and humorous,
3. Explain concepts clearly,
4. Make the class interesting and relevant, and
5. Be available and helpful if needed outside of class.

Relationship of Student Interest in Science and GPA

Data to answer research question three was collected using survey questions 12 and 14 and questions 16-18, and 20 (Appendix A).

Research Question 3: What is the relationship between the promotion of student interest in secondary science and student achievement in secondary science?

Question 12: Check the sciences you took in high school with the corresponding grade.

Question 14: Use the following scale to rate the characteristics/qualities listed as being important professional characteristics of effective science teachers (in your opinion).

Question 16: What characteristic of an effective science teacher do you feel is the most important from a student perspective (may be chosen from the listings above or your own description)?

Questions 17 and 18: Name your most effective high school science teacher. Why did you choose that particular teacher?

Question 20: What is your description of an effective science teacher?

Quantitative Analysis

Students were asked to provide the letter grade received (A, B, C, D, or F) for each science class taken in high school (question 12, Appendix A). All respondents took biology, 98.4% took biology and chemistry, and 77.6% took physics as well. Although the survey differentiated between Pre-Advanced Placement and regular science classes, the grades were not differentiated when grade points were averaged. Regular classes were given the same "weight" as pre-AP classes. Only the core sciences, biology, chemistry, and physics, were used in calculating grade point averages for this analysis. Grades for Advanced Placement classes (which were taken by more than 63% of the students) and additional science elective classes were not included in the analysis because of the inconsistency in the number of students taking those classes. More than 75% of the students took the three core sciences, biology, chemistry, and physics, therefore those classes were chosen as the basis for student grade point averages.

The purposeful sampling of Biology 1306 students predicated that the students would have a high aptitude in biology before pursuing a biology or related degree. Figure 1 reveals that more than half of the respondents had a 4.0 GPA in the three core high school science classes. Only three students had a GPA of 2.5-3.0, therefore a larger division of 2.5-3.5 was created for analysis purposes.

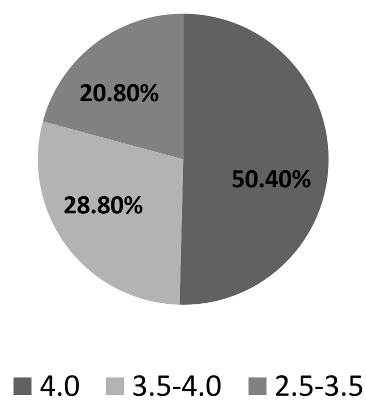
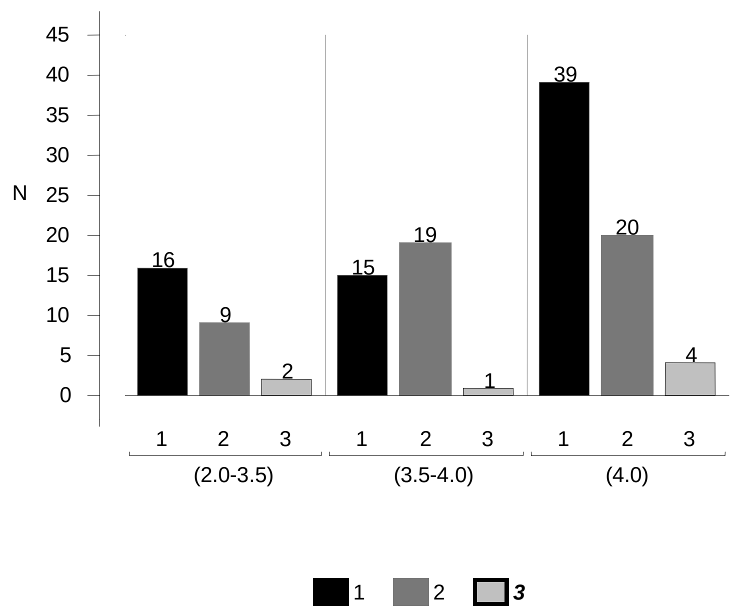


Figure 1. Grade point averages for core high school science classes of all responding students.

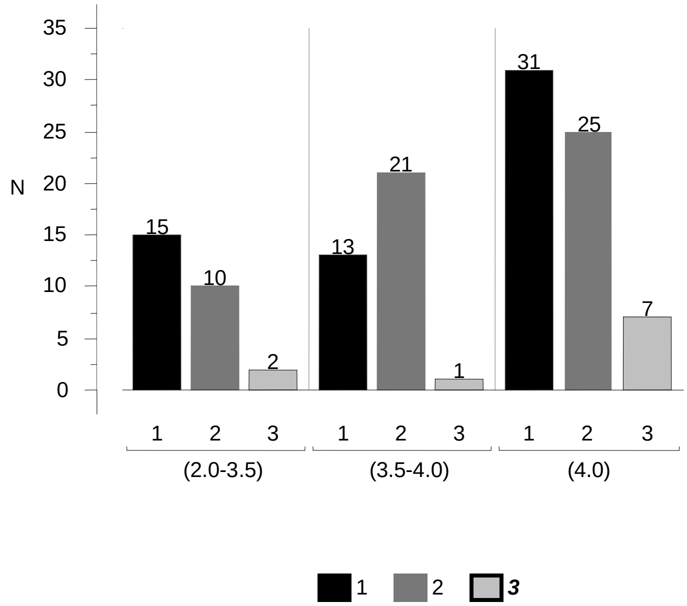
The grade point average information was sampled so that it could be compared to the ranking of "ability to make the material interesting" in survey question 14 concerning how students ranked professional characteristics of effective science teachers (Table 3). The "ability to make the material interesting" ranked second on the list of important characteristics of effective secondary science teachers for all of the students. The information was used in determining if there was a difference in how students with different GPAs ranked that category. A Mantel-Haenszel chi-square was chosen to analyze the data because it is a test for linear association using ordinal variables. It was determined that the sample size (125 students), when divided into GPA groups, was too small to use a statistical analysis for association between interest and GPA. The number of responses to "ability to make the material interesting", divided into three GPA groups, is illustrated in Figure 2. It appears that there is a greater preponderance for students with a 4.0 GPA to choose "strongly agree", yet the figure is based on number of responses and more than 50% of the respondents had a GPA of 4.0 in their core high school science classes.



1-Strongly Agree, 2-Agree, 3-Neutral

Figure 2. Likert-scale rating of "Ability to make the material interesting" for students in each GPA group.

The same comparison was used to examine if "ability to make the material relevant/related to life" was significantly related to GPA (Figure 3). Again, a correlation could not be established because of the difference in number of respondents in the three GPA groups.



1-Strongly Agree, 2-Agree, 3-Neutral

Figure 3. Likert-scale rating of "Ability to make the material relevant/related to life" for students in each GPA group.

Qualitative Analysis

Lack of statistical significance in educational research is never an indication that nothing can be gained from the research, therefore the free-response questions were examined to determine if there was any difference in how students with differing GPAs described the importance of making a class interesting. Fifty-nine responses contained the word "interest" as it related to high school science classes. There was little variation in how the responses were stated for the different GPA groups. As stated in the analysis for the second research question, the responses which discussed the importance of "makes the class interesting" were simple statements and offered very little elaboration on how that might be accomplished. A student in GPA group 3.5-4.0 responded that the teacher "made the material very interesting…she was the one person to whom I may attribute my interest in science. What set her apart from other teachers was undeniably her interest in me". For this student "interest" was a combination of an interesting class and a teacher that took a personal interest in the student.

How a teacher made the class interesting may be dependent on other factors discussed in the free-response questions, including making the class relevant. Students who had a 4.0 GPA in their high school science classes were insightful concerning how teachers could make the classes relevant:

> Student #48: Because so much of science is so small or so large, to comprehend certain abstract ideas can be difficult and the ability of a teacher to relate that to something more familiar and tangible is invaluable.

> Student # 116: He was also open about life experiences and any questions we had about life, recent news, understanding.

> Student #72: Relating the material to other things would help our understanding.

> Student #15: Relating subject material to real world situations actually gives insight as to why I am learning this topic.

A student in the 3.5-4.0 category suggested that "a teacher should have the ability to explain things clearly so that a student in any grade could be able to understand it, make sense of the subject, and apply it to life". In response to the question asking why the student chose a particular teacher as their most effective high school science teacher, a student with a GPA lower than 3.5 suggested that "bringing in current experiences into the class lecture, including things like the current football season leaders, and just managing to apply it to the class" was a good approach to the effective teaching of science.

Although statistical analysis of the different GPA groups was not possible, Figure 2 does illustrate that GPA group 3.5-4.0 chose "agree" more often than "strongly agree" which was different from the GPA groups 2.0-3.5 and 4.0. The latter two groups chose "strongly agree" more often. This same observation of GPA group 3.5-4.0 was true when examining the importance of "makes the class relevant", as this group chose "agree" more often than "strongly agree" concerning relevance as well (Figure 3).

In conclusion, a relationship could not be established between the promotion of student interest in secondary science and student achievement in secondary science. Lack of statistical evidence in the analysis of survey questions 12 and 14 and the similarity of responses from the three different GPA groups to questions 16-18 and 20 prevented any relationship from being established or observed.

Relationship of Student Interest and Career Choice

Data to answer research question four was collected using survey question 14 and questions 16-18, 20, 21, 22a, 22b, and 23 (Appendix A).

Research Question 4: What is the relationship between student interest in secondary science and the choice of a science major in college?

Question 14: Use the following scale to rate the characteristics/qualities listed as being important professional characteristics of effective science teachers (in your opinion). (Table 3)

Question 16: What characteristic of an effective science teacher do you feel is the most important from a student perspective (may be chosen from the listings above or your own description)?

Questions 17 and 18: Name your most effective high school science teacher. Why did you choose that particular teacher?

Question 20: What is your description of an effective science teacher?

Question 21: What career have you chosen to pursue?

Question 22: Did any one of your high school science teachers inspire your current career choice?

___Yes ___No ___Have not decided on a career choice

Question 23a: Name the science teacher who inspired your current career choice.

Question 23b: How did that teacher inspire your current career choice?

Question 24: What/who was your inspiration for your current career choice?

Quantitative Analysis

The purpose of research question four was to determine whether there was a relationship between a student's choice of major and how that student ranked "ability to make the material interesting" as a quality of an effective science teacher. The same sample size problem was encountered with research question four as was addressed in question three concerning interest and GPA. A Mantel-Haenszel chi-square was also chosen to analyze the interest/GPA relationship, but again there was too much variation in sample size between students who chose pre-medical careers and those who chose other science majors, resulting in a very small sample size for those who were not pre-medical. Many students who declare pre-medical majors upon entrance to college decide to pursue other majors after the first semester of the freshman year. For this reason the choice of a second semester biology class was purposeful because of the anticipated decrease in pre-medical majors after that first semester. The number of pre-medical majors remained very high in the second semester as more than 61% of the second semester freshmen biology students were pre-medical majors. Table 7 lists the multitude of career choices cited by students in question 21 and illustrates the large number of pre-medical majors. A relationship could not be established or rejected for the choice of a career and how students ranked “ability to make the material interesting” because of the large variation in sample size for each career group.

Table 7

Biology 1306 Student Career Choice

Career Choice	Number of Respondents
Pre-Medical	77
Pre-Dentistry	8
Physicians Assistant	5
Pre-Veterinary	3
Biology/Research	3
Dietetics	2
Forensic Science	2
Physical Therapy	2
Biochemistry	1
Bioinformatics	1
Biology Education-college	1
Forensic Anthropology	1
Genetics	1
Hospital Administration	1
Law Enforcement	1
Medical Illustration	1
Nursing	1
Pharmacy	1
Sports nutrition/management	1
Undecided	5
No answer	7

Qualitative Analysis

The relationship between student interest in secondary science and the choice of a science major in college could not be established due to the lack of statistical evidence. Statistical analyses could not be used because of the large difference in sample sizes for pre-medical career choices and other career choices. Furthermore, the large number of respondents who chose a pre-medical career prevented comparison of qualitative data using responses concerning the importance of interest in questions 16-18 and 20. This also prevented the comparison of information concerning the inspiration for a student's career obtained from questions 21-24. The analyses therefore focused on whom and/or what influenced the student's interest in science and subsequent career choice.

Survey questions 21-24 asked students to list their chosen career, who or what inspired their current career choice, and if it was a teacher, how or why that teacher influenced the choice (Appendix A). One hundred twenty-five students responded to the questions concerning their career and what or who had influenced their choice of a career. One hundred and two of those responding (81%) listed a medical field (medical, dental, etc.) as the chosen career (Table 7). Almost 62%, 77 students, declared pre-medical as their chosen major. Other career choices that were not medical related included three students pursuing careers in areas of forensics while others were interested in marine biology, law enforcement, bioinformatics, sports management/nutrition, biochemistry and several remained undecided. One student listed pursuing a PhD and teaching at the university level.

Twenty-four of the respondents (less than 20%) listed a teacher as influencing their career choice. Twenty of those students were pre-medical majors and the remaining four consisted of three pursuing other medical related fields and one student who had not decided on a career. One pre-med major listed an elementary teacher as the influence, "My inspiration for wanting to become a doctor came from one of my elementary school teachers introducing the class to the parts of the brain". Another student listed their seventh grade biology teacher as the primary influence, with the remaining students listed secondary science teachers. Twelve of those respondents listed the fact that the class was interesting or fun to be a part of as their reason for listing a particular teacher, the "interest and enthusiasm" of the teacher for the subject matter was influential. Students credited their teachers for not only influencing their interest in science but in exposing their aptitude as well:

> Student #3: [My teacher] was able to show how important chemistry is in our everyday lives and was able to stir up a passion in me for chemistry.

> Student #8: She was like a walking encyclopedia of the human body and its functions. It is a challenge for me to learn that much material and she made it seem like so much fun.

> Student #47: He got me interested in science and if it wasn't for his class I wouldn't have known I was good at science and liked it.

> Student # 50: I had already decided I wanted to pursue a career in medicine, but my field was cemented when I took Biology. [My teacher] was so enthusiastic about every branch of biology that it was a class to look forward to in 10th grade. She made me so interested in the human body that I have decided to attend medical school and study this subject for the rest of my life.

> Student # 38: When I started getting good grades and understanding and enjoying a science class, I began to realize that medicine might actually be something I could do, [my teacher] was so enthusiastic about every branch of biology that it was a class to look forward to in 10th grade. She made me so interested in the human body that I have decided to attend medical school and study this subject for the rest of my life.

> Student #10: I had always wanted to be a doctor like my dad, grandfather, and uncle, but [my teacher] assured me that I would become a great physician someday, further inspiring my decision to pursue a career in medicine. He said I was a gifted individual, and coming from such an intelligent man as he is meant a lot to me.

> Student #11: [My teacher] encouraged me to pursue what I wanted to do and gave me the opportunity to explore my knowledge and skills.

> Student # 60: [My teacher] had a lot of confidence in all his students. He always told us that we could become anything we set our mind to be. He also said that we should have goals in life which we should try to obtain.

Student #61: His anatomy course was one of the hardest classes I've ever taken but I managed an 'A' because he was so good at teaching. I remember we would hold entire class discussions where the class would just ask him questions about anatomy, trying to stump him. We were never successful.

Student # 101: I have always known what I have wanted to do with my life, but he gave me that extra push. He wasn't afraid to say how hard it could be when dealing with the lives of others, but never said it wasn't worth it.

To these students it was important that their teachers recognized and encouraged their aptitudes and abilities. Unanticipated success to meet higher expectations in their science classes was also a factor for several students. While the teacher might not have been the initial inspiration for the student's career choice, the teacher was definitely influential in "cementing" that choice.

Twenty-seven students, 26.5%, listed a family member as influencing their interest in science and choice of a career. Eight respondents listed the influence as either arising from family members already in medicine or family illnesses and genetic conditions.

Student #4: My grandfather. His many maladies and sicknesses combined with the lack of proper health care in the Philippines inspired me to become a physician.

Student # 36: I have had a lot of health problems and would like to help others as I so often have been helped.

Student #40: I've always been interested in food and its effects on the body. My mom told me when I was young that you are what you eat and I took it to heart.

Student #55: My mom, because she always has pushed me to do my best.

Student #83: My younger brother. He is autistic.

Student # 88: The doctors that helped my little sister get well when she was in the hospital as a child.

Students credited experiences with personal or family illnesses as influencing their career choice as well as parents, most often the mother, as inspiring them to pursue the sciences. The desire to provide medical services for others, as they had witnessed being provided for family members, was a determining factor in several students' choice of a career.

Other students suggested that the influence for their career choice came from sources other than family and teachers. Sixteen respondents credited their interest in science to an innate interest or fascination with science and the natural world:

> Student # 120: My inspiration for being a Marine Biologist was my pure love for ocean animals. I love learning about whales, dolphins, sharks, aquatic plants, and how the changing world affects the animals in the oceans. I love watching Blue Planet on the discovery channel.
>
> Student #97: The heart is something I find very interesting. I wanted to learn more so I did and the more I learn the more fascinated I become.
>
> Student # 93: No one really inspired me to do it. It has just always been what I've wanted to do.
>
> Student # 87: I've always loved animals, and I knew that I wanted to help them in some way. My aunt always used to go out and drive along feeding strays, and she would always tell me how one day I would be able to help them too.
>
> Student # 82: The desire to help people, alongside my love of science and human anatomy, is probably one of the biggest reasons why I chose this path.
>
> Student # 44: The idea that I can help people with their problems and I love science and I love learning about the body.
>
> Student # 24: I have always been interested in animals, so veterinary medicine is the logical choice for me.
>
> Student #7: I have always been interested in beauty and medicine, and this way I am able to satisfy both of my passions.
>
> Student #6: It is what I have always been most interested in. It will be fulfilling for me and I will also be helping people.

Students acknowledged that their career choice inspiration originated in an innate love for or interest in science, medicine, animals, nature, and humanity.

Twenty students did not list anyone or anything as influencing their career choice. The remaining responses for the inspiration of a career choice varied greatly with such influences as family physicians and dentists, reasons of faith, and the desire to help people. Perhaps the most revealing quote came from a student who did not receive inspiration or encouragement from a secondary science teacher, but credits the family dentist for the influence. The respondent lamented, “I've always been interested in the medical sciences, and I really do wish that my high school science teachers could have helped develop my love for science even more”. The data does not suggest that the high school science teacher was the primary influence of a career in science for the students participating in the survey. Equally, if not more important, was the influence of the student’s family.

Research Conclusion

The initial research design planned for an evolving study that would scaffold on the information obtained from the initial electronic survey of freshmen biology students. The students who responded to the survey were very verbose and candid in answering the free-response questions, providing extensive contributions to the knowledge base concerning a student’s perception of an effective science teacher. The survey provided ample quantitative and qualitative information for analysis of qualities of effective science teachers, but because of the homogeneity of the student population in Biology 1306, a relationship could not be established between student interest and a student’s GPA or career choice.

Common Qualities of Effective High School Science Teachers

The first research question, "What are the common qualities of effective high school science teachers as described by college second semester biology students?" established a hierarchy of personal, professional, and classroom management qualities of effective secondary science teachers as perceived by students. There were differences in ranking for the sub-categories listed for the quantitative and qualitative data. This is attributable in part to the differences in how the data was collected. The quantitative data was compiled from a pre-determined list of qualities that the students ranked using a Likert-scale, while the qualitative data was assimilated from repeated word and phrases in the free response questions. Similarities and differences were discussed in the analyses, but a conclusion can be drawn from the information concerning what qualities of effective secondary science teachers students deem important. The five highest ranking qualities of effective secondary science teachers determined from examining both quantitative and qualitative data in each category are listed in Table 8 and ranked in order of importance.

Ranking of Promotion of Interest

The second research question, "Where does the promotion of student interest rank in the list of qualities of effective high school science teachers as described by college second semester biology students?" examined the ranking of the importance of student interest within the established hierarchy of qualities of effective science teachers. It was determined from both the quantitative and qualitative data that students believe it is very important for both a science class and a science teacher to be interesting. The ability to make the class/material interesting ranked second on both the qualitative and quantitative lists (Table 8). The only professional quality of effective secondary science teachers that

Table 8

Comparison of Ranking Quantitative and Qualitative Results

Quantitative Ranking	Qualitative Ranking
Personal qualities	
1. Enjoys teaching	1. Interest in/passion for subject
2. Good communication skills	2. Enthusiastic/fun/humorous
3. Respectful of all students	3. Interest in students/love/ respect/ concern for students
4. Enthusiastic about the subject	4. Friendly/good communicator
5. Shows concern for student progress	5. Encourager/motivator
Professional qualities	
1. Explains clearly	1. Explains clearly
2. Ability to make the material interesting	2. Makes the class interesting
3. Engages students with content	3. Makes the class relevant
4. Summarizes major points	4. Uses different teaching methods
5. Ability to make the material relevant/ related to life	5. Content knowledge
Classroom management qualities	
1. Grades student work fairly	1. Available, approachable, helpful, and patient
2. Available for help outside of class	2. Organized
3. Provides feedback on assignments	3. Fair
4. Effective use of class time	4. Good classroom control
5. Good classroom organization	5. No 5th category

ranked higher than “ability to make the material/class interesting” was the teacher’s ability to explain concepts clearly.

GPA and Career Choice

The final two research questions were:

> What is the relationship between the promotion of student interest in secondary science and student achievement in secondary science?
>
> What is the relationship between student interest in secondary science and the choice of a science major in college?

These two questions attempted to establish a relationship between student interest and student achievement, as well as student interest and the student's GPA in secondary science. Neither relationship could be established because of the homogeneity of the Biology 1306 population.

The data was used to examine how the different GPA groups responded to question 14 ranking the professional qualities of effective science teachers. It was determined that GPA group 3.5-4.0 choose "strongly agree" less often than "agree" while GPA groups 2.0-3.5 and 4.0 chose "strongly agree" most often when ranking the sub-category "ability to make the material interesting", although no statistical difference could be established (Figure 2). Students in all GPA groups included references to "makes the class interesting" in questions 16-18 and 20 and there was no perceived difference in the wording or phrasing of the responses for the different GPA groups discussed in this sub-category.

The data provided information that supplemented research question four even though a relationship could not be established between student interest in secondary science and the choice of a science major. The responses to questions 21-23 provided information concerning the influences on the students' choice of a career. It was determined that the greatest influence on a student's career choice came from family members and the role of the teacher was most often to recognize the student's interest and provide encouragement, motivation, and success in support of that career choice.

CHAPTER FIVE

Discussion of Results

Student Perspective

The *No Child Left Behind Act* defines highly qualified teachers through the lens of content knowledge and experience (NCLB, 2002). Legislators, administrators, teachers, and parents each have their own definition of the qualities possessed by a qualified teacher, including many attributes beyond content knowledge and experience. Qualified does not equate with effective and the terms should not be viewed as synonymous. There is the possibility that a teacher could be imminently qualified according to *NCLB* and not be an effective teacher in the classroom. Teaching effectiveness cannot be measured using knowledge and experience alone. Teachers and students know that content knowledge and experience do not guarantee the effectiveness of a teacher and they also know that performance on a standardized test is not a true measure of understanding. Student achievement is often the sole measure of teacher effectiveness and quality and state assessment scores continue to be used to determine both teacher and school effectiveness. While teachers do have input in making instructional decisions, students are rarely asked what they think about the instructional process. This includes how to measure teacher effectiveness. As the consumers and products of the educational system, students are the most important link in the educational chain. They are proof of the effectiveness of the educational system. One of the misconceptions of the educational community is that the instructional decisions of adults “contribute the most to student learning and school effectiveness” (Stiggins, 2004, p. 24). Using student input is a “bottom-up” approach to determining the qualities of an effective secondary science teacher, but to ignore the student voice is to ignore an extremely valuable source of information (Faranda & Clarke, 2004).

This research was an attempt to hear the student voice and to share that voice with those who impact the educational process. It is a snapshot of one group of student opinions at one point in time. The information compiled from this research project was difficult to quantify, therefore the research is primarily descriptive in nature. The participating students were candid in their responses and provided a detailed description of an effective high school science teacher. Many influences, such as family history, educational history, personality, intelligence, culture, and maturity can affect how a student perceives a particular teacher at any given time and the students surveyed for this project were asked to look backward in time. The survey information was based on the students’ experiences in their high school science classes, which for the majority of students was within the past one to four years. Based on the researcher’s experience with both high school and college science students, it was assumed that the students would have definite opinions about their high school science classes and science teachers. This assumption proved to be correct as the students were very open concerning their high school science experiences.

Limited quantifiable results derived from this research did not underscore the significance of student input concerning teacher effectiveness. Each student comment was viewed as contributing valuable information. The differences in student experiences may be few, but they may also be of extreme importance. A carpenter quoted in a college qualitative analysis textbook suggested, “There is very little difference between one man and another; but what little there is, is very important" (Patton, 2002, p. 151). The same is true of students. What motivates and encourages one student may be of little importance to another. Means and modes promote understanding of entire groups of students, but it is the outliers that often provide the greatest insights. This research did examine what the "majority" of students said, but it also looked at individual responses that did not fit the "majority". For this reason the research undertaken has been extremely valuable. It has provided a snapshot of how predominantly high achieving science students in a private university in central Texas perceive secondary science teacher effectiveness based on their experiences in high school. The research also allowed a glimpse into individual student's descriptions of effective secondary science teachers. Perhaps teachers will see their own experiences and students in this research and use the information to become more effective teachers. Self-evaluation is often painful and if we see ourselves as lacking in some of the qualities discussed then we are provided an opportunity to grow as educators in order to better prepare our students.

Limitations of study

The site and participants for this research were purposefully selected because of the potentially large number of participants and access to the research site. The electronic survey provided for the participants was optional, therefore a random sampling of students within the purposeful sample was achieved. The primary characteristic of all respondents was their willingness to participate in the survey and answer the survey questions. While a random sample could allow for generalization beyond the Baylor population of Biology 1306 students, the results of the research must be viewed in the context in which it occurred. Different results may have occurred if the sampling population had been chosen from a different department within Baylor, or if a different university had been sampled. Biology majors may have a different perspective of effective high school science teachers than political science majors, so differences in the sample would dictate that there would be differences in the results. The study would need to be replicated in different universities with students of all majors in order for generalization to be meaningful using the information gathered from this research. This would provide the needed population heterogeneity and sample size uniformity required for statistical analyses to be used to show relationships between student interest and grade point average or career choice and strengthen the results of the means analysis of all qualities of effective secondary science teachers.

The initial intent of the research was to begin with an electronic survey and progress to interviews of purposefully sampled students. The survey provided more information than was anticipated as the students were very honest and open in the free response questions. While interviews would perhaps have provided additional information it is also possible that the students would have been less candid if they were face to face with an interviewer. The electronic survey served as a less threatening way for the students to voice their opinions. A subsequent survey was attempted with students who had negative experiences with a high school science teacher, but the students did not respond to that survey. Although 60% of the students provided email addresses, it is speculated that they did so to receive a copy of the research results and not to because they wanted to be contacted for further surveys or interviews.

Research Summary and Literature Comparisons

The research findings were divided into three core categories of effective secondary science teacher qualities: personal, professional, and classroom management. This is a different division of categories than most often found in the literature. The categories typically used in studies of qualities of effective teachers include: personal, professional, and academic qualities. The categories were changed for this research to better organize the qualities as students might view them. "Classroom management" is not a category identified in the literature, but was chosen by the researcher as a separate category instead of academic qualifications. Academic qualifications were classified under personal qualities assuming that students would view any quality that a teacher possessed before entering the classroom as a personal quality. Professional qualities for this survey included what the student would observe in the classroom. Classroom management qualities included how the teacher managed the class both during and outside of the regular class time. While studies of teacher quality most often cite academic qualifications and experience, it was anticipated that students would put a higher priority on personal and pedagogical skills. The qualities found in the literature were not ranked, therefore a comparison of level of importance with the student responses was not possible. Students' perspectives were obtained through objective, Likert-scale questions and free-response questions which produced information that could be analyzed and compared, as well as compared to the information provided by the literature.

Personal, Professional, and Classroom Management Qualities

Personal Qualities. The highest ranking personal quality of effective secondary science teachers in the Likert-scale questions was that a teacher "enjoys teaching". The highest ranking quality in the free-response questions was "interest in/passion for the subject matter". There were more responses to teachers enjoying the subject matter than for any other personal teacher quality. Being "enthusiastic about the subject" ranked fourth on the Likert-scale questions, but the mean differed from the highest ranking quality by only 0.10. Students know when a teacher is interested in the subject matter and that interest is usually contagious within the classroom. Conversely, students know when a teacher is neither interested in the material, nor interested in teaching and conclude that if the teacher does not value or show interest then the subject really is not important (Catt, Miller, & Schallenkamp, 2007). The need for enthusiasm in teaching secondary science can be summed up by the following quote:

> Student #74: I think the most important characteristic [of an effective science teacher] is an enthusiasm for the subject material, but the teacher should also be able to share that enthusiasm with students and help them to feel it too.

Students also overwhelmingly believed that teachers should be "enthusiastic, fun, and humorous", which ranked second in the free-response questions. It was interesting that "sense of humor" ranked 11th on the means ranking and was mentioned only nine times when students were asked to state the most important quality of an effective science teacher in the free response questions (Tables 2 and 6). Yet when asked why they chose a particular teacher as their most effective, 27 students stated that it was because the teacher was "enthusiastic, fun, and humorous". The qualities of "enthusiastic, fun, and humorous" were chosen for that particular question more than any quality in all of the three core categories. Perhaps students themselves do not consciously understand how these qualities contribute to an overall positive atmosphere in the classroom, but do recognize them in a particular teacher. It is very likely that the students experienced success in the classroom of the teacher chosen as their most effective, not recognizing how a positive classroom atmosphere contributes to the overall learning process, particularly in science (Osborne & Collins, 2001). Enthusiasm in the classroom is contagious and contributes to increased student attention and lesson enjoyment. These are important components in the promotion of interest in science education even though research has not shown if either results in increased student achievement (Polk, 2006).

Students felt strongly about the teacher/student relationship. “Interest in students/love/respect/concern for students” encompassed an overall positive teacher/student relationship in the free response questions and ranked third in that list of qualities (Table 6). “Respectful of all students”, “Shows concern for student progress”, “Caring relationships with students”, and “Interested in students” ranked third, fifth, ninth, and tenth in the means ranking of personal characteristics (Table 2). Students indicated that this positive relationship increased student confidence, affected their learning, and prevented students from feeling intimidated. One student responded that students could not reach their full potential unless they believed the teacher loved, cared and respected them. Rodgers and Raider-Roth (2006) suggest an “alternative paradigm” for the current definition of effective teaching and believe that teaching should be viewed as an “authentic relationship with students where teachers know and respond with intelligence and compassion to students and their learning” (pp. 265-66). This is not the description of teacher effectiveness found in most of the literature. Relational components of education are difficult to measure and are particularly difficult to relate to achievement, although a positive teacher/student relationship has been shown to affect the overall learning process. Teachers who relate well with their students are viewed as credible sources, and students respond more positively to teachers they view as credible (Teven, 2007). Teacher respect for the student is an important contribution to that relationship, and students desire a relationship of "mutual trust and harmony with their instructors" (Faranda & Clarke, 2004, p. 275). Studies of university undergraduates confirm the importance of the teacher/student relationship. A study of students in Georgia confirmed that a students' motivation, projected grades and attitude toward the course could be predicted from how well the instructor communicated genuine concern for the students (Wilson, 2006). Students can enjoy the teacher and the class but respect and trust that teacher enough to be vulnerable and admit when they do not understand the material. The teacher/student relationship therefore also involves communication. This quality ranked second on the means analysis but was mentioned only twice in the free response questions (Tables 2 and 6). Good communication was included with "friendly" when analyzing the free response questions because student references to communication included the teacher being friendly. The quality of "encourager/motivator" was also important to students and was an indicator of teacher caring.

The remaining personal characteristics which were surveyed would not be attributes of the teacher/student relationship and include: teacher self-confidence, inviting constructive criticism, being willing to admit mistakes, not egotistical, ability to resolve conflicts, and flexibility. Also included in the personal category were academic qualifications and being a life-long learner, both of which students rated lowest of all effective teacher qualities in any of the three core categories. Academic qualifications were not as important as relational qualities. The students simply stated that science teachers should be qualified and be open to new theories and new discoveries.

The literature originally surveyed for this research emphasized many of the same qualities important to the students surveyed. The literature included communication skills, the willingness to admit mistakes, being respectful and having caring relationships with students, being a good motivator, creating an environment conducive to learning, and being a life-long learner. What was not emphasized was the need for teachers to be passionate about both the teaching profession and especially the discipline that they teach, qualities rated highest by the students. Creating a positive classroom environment conducive to learning can be accomplished in different ways, but very few studies included teacher qualities such as being fun and humorous as contributors to that positive environment. For the students surveyed it was most important for the teacher to be passionate about their subject and to convey that passion and enthusiasm to the student while also making the class enjoyable.

Professional Qualities. The highest ranking professional qualities in the analyses of both the quantitative and qualitative data included the teachers' ability to explain concepts, engage students and summarize major points, and the ability to make the class interesting and relevant. Students felt very strongly that an effective science teacher should be able to explain the content in a way that all students understand and that this could be accomplished best if the class was interesting and relevant to real-world issues and experiences, which supports past research in science education (Stronge, 2007; Tytler, et al., 2004; Yager, 2002). Combining the free responses to questions 16-18 and

20 which referred to class interest and class relevance accounted for 103 references out of 620 words or phrases analyzed (Appendix A). The student responses implied that the teacher's ability to make the class interesting and relevant was relative to the teacher's content knowledge. Although content knowledge was not listed as a quality of effective secondary science teachers in the Likert-scale questions (questions 13-15), students referenced it 33 times in the free response questions. They felt that teachers should not only know the subject material but also know enough about other subjects to make interdisciplinary connections. Knowing the subject matter in science included not only being academically prepared but also staying current with issues and events in science. Science teachers must invest in professional development that contributes to both science pedagogy and staying current with advances in science education and scientific discoveries. Science teachers do not have to know everything, but they must be able to connect students with the resources that keep them interested and connected.

Students also believed that teachers should use a variety of teaching methods and instructional strategies that addressed the learning abilities and styles of all students without sacrificing high expectations. The students surveyed expected to be challenged and were disappointed when that did not occur. They especially appreciated a science teacher who not only had high expectations but taught the students how to meet those expectations and provided the encouragement to keep the students motivated. This supports the research which shows that students put forth more effort when expectations are higher (Catt, et al, 2007). The teaching methods mentioned by students included the use of lecture as an instructional strategy, as long as the lecture was interesting, informative, and infused with a little humor. It also included demonstrations and hands-on activities, although each of these ranked as the lowest instructional strategies in both analyses. Much of the research in science education emphasizes the importance of inquiry activities and student involvement in "doing science". That was not a priority for the students in this survey. It was more important for this population of students that the teacher know science content, be able to connect the content to what was happening in the students' lives, and provide the structure that enabled the students to learn science. The student responses did not suggest that they preferred one instructional method over another, for example laboratory experiments over lecture. The responses did suggest that it was important for a teacher to use a variety of teaching methods.

The literature search revealed two different approaches to professional qualities which can be categorized as purely professional qualities and pedagogical qualities. The purely professional qualities would not be observable by students (aligning to standards, participation in professional organizations, etc.) therefore these qualities were not addressed. The pedagogical qualities discussed in the literature included a process approach to science, engaging students with the content, ensuring success for all students, monitoring students understanding, and making the content relevant. Students engage in instructional tasks most often when the materials studied are "interesting materials that are culturally relevant and appropriate to the students' instructional level" (Bost & Riccomini, 2006, p. 305). The student survey responses supported the literature on the importance of making the content relevant and using a variety of instructional methods.

Classroom Management. The biology students surveyed believed that it was very important for the high school science teacher to be available outside of the regular class time and be willing to help the student in any way that would promote their success.

Being approachable and helpful implies much more than simply being available for tutorials. Students felt that if the teacher was "available, approachable, helpful, and patient" then solutions could be found to any learning or classroom problem, including problems with inequity. It was very important to the students surveyed that high school teachers treat students fairly and grade fairly. Students easily recognize inequity, and it does not take them very long to discredit a teacher if they feel like they have been unfairly treated. The student responses indicated that if a teacher is approachable then the student feels comfortable confronting the teacher to determine if a conflict or problem was an oversight by that teacher or if it was a student misunderstanding. Perceived unfairness is often simply a product of miscommunication, but the perceived unfairness will be perpetuated if the teacher is viewed as being unapproachable.

The literature classified organization as a personal quality, but because of the contribution to the atmosphere of the classroom it was classified as a classroom management quality for this survey. Students appreciated a classroom atmosphere that was organized and where the teacher was in control of the students. Organization did not imply inflexibility; the students appreciated structure as long as the teacher was willing to change that structure depending on the needs of the student.

Conclusion for Core Category Qualities. The most effective secondary science teacher described by Biology 1306 students would be very knowledgeable and enthusiastic about the subject taught, be able to explain the concepts clearly using a variety of instructional strategies which would scaffold the learning abilities of all students, make the class interesting and relevant, be funny, approachable, and helpful, and have an organized classroom where the teacher is clearly in control.

Student Interest and GPA

The assumption was made at the beginning of the research that a difference would exist in how students with different learning abilities would rank "ability to make the class interesting" and that the responses to the open ended questions would also differ between the GPA groups. It was unanticipated that more than half of the students enrolled in Biology 1306 at Baylor University would have achieved a 4.0 in their core science classes in high school (Figure 1). Almost 80% of the students had a B^+ average or higher. A statistical difference could not be established for the GPA groups because of the large difference in sample size therefore the open ended questions were examined for differences. Again, the majority of students responding had a 4.0 GPA and few differences in the free responses were observed. It was observed that students with a GPA 3.5-4.0 chose "strongly agree" less often than "agree" when asked to rate "ability to make the class interesting" while the other GPA groups chose "strongly agree" most often. The same results were observed with "ability to make the material relevant/related to life". Perhaps student interest and content relevance are less important to B^+ students. Students who achieve a 4.0 GPA are often perfectionists and "higher maintenance" and may need the extra boost of an interesting and relevant class in order to achieve a higher GPA. The same may be true of the average ability student who requires more scaffolding than the B^+ student and the appeal of an interesting and relevant class may provide the connections that allow that student to retain more information.

Student Interest and Career Choice

Understanding how and when students develop an interest in certain academic areas is difficult because of the many influences in their lives. Family, friends, teachers, religion, and the media are all significant influences. Beginning at the age of five, students spend more hours at school than with their families and the influence of the educational system on all aspects of a student's life is immeasurable. School is influential on a student's choice of a career, yet students may change their minds about future careers many times over the course of their education. Career choice is very personal and often age dependent. Some people become aware of their life calling as very young children while others change careers several times before discovering their true passion in life. The survey used in this research focused on the present career choice of Biology 1306 students.

The assumption was also made at the beginning of the research that there would be a difference in how pre-medical students and students pursuing other science careers ranked "ability to make the class interesting". It was again unanticipated that the sample population of second semester freshmen biology students would include almost 62% pre-medical majors and that the remaining students who had decided on a career (36 students) would declare 18 different career choices. Determining a relationship between the career chosen and how a student rated "ability to make the class interesting" was obviously impossible. It was possible, however, to deviate from the research question and examine the influence behind the many diverse career choices. Family members influenced the choice of a career for more than 26% of the respondents. This influence included family members who had experienced specific illnesses and diseases. Teachers were influential in fewer than 20% of the cases. Students saw their teachers not as being influential of the career choice but as providers of inspiration and encouragement for choices already being considered. It is important to note here that teachers are also in the precarious position of sometimes discouraging students from pursuing careers in science. Negative experiences "may remain long after any cognitive achievements. The consequence may be disenchantment with science." (Osborne & Collins, 2001). Negative experiences may include not only disenchantment with science, but the student's perception of an inability to master the material. Not providing students with opportunities to engage in science and not providing opportunities for success will only exacerbate the problem of students choosing other careers over science careers. There were only six students who reported negative experiences out of the 125 students who responded to the survey. In all probability that is not because the majority of students who participated in the survey experienced effective science teachers and learning opportunities at the secondary level, but because the students who had negative experiences pursued careers in areas other than science. The number of students not interested in science careers could very well be a result of students not experiencing interesting and relevant science classes in high school.

Implications for Science Education

High stakes testing is not motivational to all students and learning may not be promoted by the threat of an assessment at the end of a grading period. Students learn best when they have a vested interest in education. This includes being interested in both the material and being able to apply what is learned. If there is no connection to what is happening in their lives then adolescents have little reason to learn. The implications of the absence of interest and relevance in secondary science classes are incalculable. Students may "learn" material long enough to pass an exam, but true understanding and application cannot occur without a vested interest. Test scores in the eyes of a student are no more than evidence of perceived ability. Science students determine their future ability as a scientist based on their success in a science class. While students who are high achievers may be able to overcome ineffective science teaching and the absence of interest and relevance in their science classes, the remaining students are left wondering if they are incapable of learning science or if they are incapable of learning at all. The definition of a high qualified science teacher should be changed from one that relies on academics and experience to a definition that extols content knowledge and “making that content accessible and interesting to students” (Seed, 2008, p. 587). While solid science content preparation and educational experience are very important qualities of effective secondary science teachers, the students surveyed for this indicated that the teacher must also be interesting, make the content relevant, be able to explain the concepts clearly, and care for the student. Implications of those characteristics as they apply to curriculum, teacher education programs, teachers and administrators, and to the students themselves are investigated in the following discussion.

Implications for Curriculum in Secondary Science Education:

The standards movement began with a general set of standards for science, but the science curriculum for most states has been distilled down to prescribed objectives, much like the Texas Essential Knowledge and Skills (NRC, 1996; TEA, 2008). As more and more objectives are added and expanded to these standards there is less time to teach core concepts at a level of true understanding. Promoting interest in high school science classes is time consuming and consists of more than covering content. Defining content in broader terms would allow teachers some degree of choice in teaching the content most appropriate for their population of students. For most high school science students, long-term research projects and time-consuming laboratory investigations are no longer a part of the implemented curriculum. Investigative laboratory experiments that may take several days to complete are often eliminated because of the increased content requirements and the decreased amount of instructional time. Science education research may exalt the merits of such ongoing student research and investigative laboratory experiments, but the reality of teaching high school science today is that instructional time continues to decrease due to days lost to testing while the curriculum continues to expand. The consequences of both are that teaching to promote interest and relevance in secondary science education are not priorities. This research shows that both student interest and relevance should be priorities, and this researcher believes that teaching to promote interest and relevance in science can be accomplished while teaching the prescribed curriculum. This does require a different approach to content delivery and assessment. Effectively teaching the content does not require that every important concept emerge from the teacher's mouth, or that every concept be assessed using pencil and paper tests. Content can be taught using student-centered instructional methods that encourage interest and relevance while content assessment can be ongoing and multi-faceted. Teachers tend to teach as we were taught, and secondary science education continues to be teacher-centered. Changing this will require a paradigm change for both in-service teachers and pre-service teachers.

It is also worth discussing whether the curriculum should be the focus at all. What would secondary science classes look like if students were allowed to structure their own science classes? The adult instructional decision makers assume that students would choose the least difficult material and methods given choices concerning what is studied and how the material is mastered. That is an assumption based on choices we have provided. I have found it very interesting to watch high school students over the past couple of years when they are given choices regarding science projects. Whether the teacher allows the student to choose the research topic or simply allows student choice in how the project is completed, the resulting diversity and depth is amazing. Students choose research topics that are relevant to them, either topics they are interested in (space travel, fast cars, cloning, etc.), or topics which directly affect their lives (diabetes, environmental issues, cancer, etc.). Students will use materials and resources in extremely innovative ways if allowed to choose how to best complete a project. Their ingenuity is boundless, and science teachers do students a great disservice when they are not allowed to tap into this reserve of talent. It is particularly interesting to watch the students labeled as low achievers, whether because of ability or lack of motivation. This is their moment to shine as they will often pour heart and soul into a project they find to be interesting. This researcher recently observed a high school physics class that was instructed to build a house (four rooms, two stories, using cardboard boxes or whatever material was handy) and use Christmas lights to wire several types of circuits. Not only did the students learn the difference between parallel and series circuits, but they built some very creative houses. One particular minority, low-achieving student furnished his structure with his sister's doll house furniture and accessories complete with Pocahontas and Snow White standing on the balcony. He also installed a door bell that sounded like a car alarm. His pride in what he had created was justified. It was a beautiful project and he definitely learned the difference between the types of circuits. Projects such as this can be transforming for students as they achieve success in areas they did not think was possible.

Obviously standardized testing and prescribed curricula will not go away in the near future, but it is imperative that secondary science teachers learn to teach science for understanding within the parameters of both. A careful examination of the Texas high school science curriculum (TEKS) illustrates that there is some “wiggle” room for actually implementing a curriculum that allows for student interest and integration of relevant issues into the classroom, each of which promote understanding in science. The present perception of lack of instructional time may actually be a result of ineffective instructional strategies and wasted instructional time. Both problems can be resolved. As indicated by the respondents to this research survey, teachers who know the material and are passionate about conveying the information to the student will find strategies that are fun, engaging, interesting and relevant and the students will consequently master the material. The students surveyed also emphasized that students will be motivated and encouraged to take control of their own learning if the teacher creates a positive classroom environment where different learning styles and abilities are addressed. Keeping students on task and maximizing classroom time ceases to be problematic. Simply stated: love what you teach, love your students, work within the current educational parameters, and the curriculum will take care of itself. Unfortunately teachers are often placed in classrooms where they are not certified to teach the content or they are weak in the content area, students are not always lovable, and the current educational parameters are sometimes oppressive. Our challenge is to change the system so that the educational imperative for science education is for students to be interested in the material and develop an inherent desire to master that material.

Implications for Science Teacher Education

The survey results indicated that teachers must be personable, caring, good communicators, organized, fair, and good classroom managers. Many of those attributes can be taught in teacher education programs. The challenge for science teacher education programs is not only to prepare teachers to be content certified and be passionate about that content, but to have a solid interdisciplinary background and be able to make science interesting and relevant. Future teachers must have a solid pedagogical foundation to be able to teach students of differing abilities.

Problems with college students choosing the wrong career and not being prepared to teach might be thwarted if every pre-service program had a simple checklist for potential secondary science teachers to fill out before enrolling in the program. It would consist of two simple questions:

> Are you passionate about the subject you intend to teach?
>
> Do you enjoy teenagers?

If the answer to either question is no then the pre-service teacher should probably pursue a different career. Many aspects of teaching can be taught but loving a subject and loving teenagers are usually inherent qualities. Most potential teachers have wanted to be teachers since they were children and many have known what subject they wanted to teach. This is not particularly necessary in order to be an effective teacher but it is definitely a good start. Personality cannot be taught but teachers with very different personalities possess the potential to each be excellent teachers. The goal of teacher pre-service programs should be to take the varied personalities that enter the program and build on the strengths of each of those personalities. The real issues are preparing the future teacher in the content area that will be taught and preparing them to make the material interesting and relevant to the student. Traditional teacher education programs should examine their requirements based on the high school science curriculum and the needs of high school students and alter the program to include content classes that directly address the material taught in high school. Many traditional science teacher education programs do not require as many science credits as required for science majors. This can be problematic as the science teacher may not have the science background preparation that would allow them to make their classes interesting and relevant. It would be very beneficial to all traditional science teacher preparation programs to include some type of real-world science experience. This could take the form of an observational class where the teacher candidate simply spends time in science laboratories, industries, businesses, hospitals, etc. much the same as spending classroom time observing a teacher. Teacher candidates should be exposed to how science is performed in the real world so that they can convey that relevance to their students. Teacher education programs should also examine their programs to see if changes could be made that would attract teachers needed in shortage areas. Texas is facing a science teacher shortage, particularly in the physical sciences. Programs should be developed that recruit teachers in high need areas, either from within other university programs or from industries and businesses. Resources should focus on these shortage areas so that teachers graduating from the programs are highly qualified and effective, regardless of whose definition is used. Grants and scholarships should also be in place allowing quality teacher candidates in the sciences to pursue secondary education in universities that offer exemplary science education programs.

Implications for Administrators and In-Service Science Education Teachers

Administrators should listen to the student voice in deciding personnel issues. It is often difficult for principals to choose the most effective science candidates when the candidates cannot actually be observed in the classroom. According to this research, administrators can look for key phrases as the candidate discusses their experiences and plans. Many candidates arrive for interviews pre-programmed with all of the right things to say during the interview, but a good interviewer will pick up on phrases that allude to the candidates' passion for what they teach and their interest in the students. The candidate can be asked specifically to describe how they make their classes interesting and relevant, as well as how they stay current in their discipline. The candidates can also be asked how a student might describe both their teaching style and classroom atmosphere.

The information gathered from this survey should be used as a mirror for in-service teacher reflection. None of us is a perfect teacher, and we each have room for improvement. Self-reflection is productive, painful, and imperative. Teachers should examine their personal qualities to see if there are areas for improvement, perhaps even asking their students for input. High school students should be given the same opportunity as college students to rate their professors at the end of each semester. The information, if used correctly, would contribute to the teacher's knowledge of themselves and their teaching methods. Teachers can look at how they teach content and determine if it can be presented differently, more interestingly, and more relevantly. Time is such a commodity in the classroom that teachers tend to do the same things the same way in order to save precious time. Administrators should allow teachers time, either during the school day or least periodically, to examine how content is presented, and to assess the effectiveness of those methods. This would allow teachers to look at student expectations such as were revealed in this research to see if they can better meet those expectations.

The information gleaned from this research can also be used in planning professional development. Many of the respondents discussed how important it was for teachers to use different teaching methods to meet the needs of students with different learning abilities. Teachers often understand the principles behind differentiation but do not understand how those principles look in practice, particularly in a high school science classroom. Teachers must be taught how to use grouping, choice, leveled assignments, etc. so that they are comfortable allowing students to use an assortment of strategies to ensure content mastery. Professional development can also be used to provide ongoing content training as well as allow teachers to participate in scientific research with other institutions and industries. Partnerships should be developed with universities and industries that allow teachers to spend time with scientists learning new ways of doing science and participating in new discoveries. The teachers participating in these partnerships would also have access to technology that is often inaccessible to high schools. The students in this research expressed the need for interest and relevance and partnering with other institutions allows the teacher to experience science in ways that can be brought back into the classroom and shared with students.

Implications for Secondary Science Students

Many students enter high school with intrinsic interests in science. High school science teachers have the responsibility to encourage and motivate those students as well as guide the interests of those who may not have decided on a career. The students participating in this research whose career choices were influenced by others looked to their high school science teachers for encouragement and for information that would further their scientific interests. The imperative is for teachers to make their science classes as interesting and relevant as possible so that students will develop and retain an interest in science. An international study of science students, ROSE (the Relevance of Science Education), found that high school students strive for “identity, personal importance, and self-realisation” (Elster, 2007, p. 6). Science classes that tap into that need provide students with opportunities to learn about themselves, where they fit into society, and how they can contribute to society. The ROSE researchers based their research in part on how students become interested in science. Students often are interested because the topic of the moment is interesting (situational interest) which can lead to an individual interest and social involvement with that interest (Elster, 2007). Developing that interest and the subsequent social involvement should be a primary goal of science education.

School districts presently face very serious student dropout problems. Almost one-third of students presently enrolled in U.S. high schools will drop out before graduating (Scherer, 2008). Students either opt to completely drop out of school, or they enroll in an alternative program because the educational system does not meet their present needs. While the dilemma is multi-dimensional and there are as many reasons for dropping out as there are students, the problem can be blamed in part on students not being interested in or recognizing the relevance of school. The development of effective teaching practices which address multiple levels of student ability and disability, and also provide students with opportunities for success can be viewed as a strategy for preventing student dropout (Bost & Riccomini, 2006). The students surveyed for this research identified the need for multiple approaches to teaching and learning. This research also identified the need for teachers to care not only about the student personally but to care about their success in the class. Students who do not feel that their teacher cares about their learning success "act out or tune out" (Rodgers & Raider-Roth, 2006, p. 287).

Implications for Future Research

It is recommended that this study be replicated in different universities with students who are science majors other than biology, and with students who have declared majors outside of the sciences, to determine if the findings of this research can be substantiated. Baylor University is a private institution therefore both private and public university students should also be surveyed.

The most basic dilemma for determining secondary science teacher effectiveness it to determine the most appropriate definition for teacher effectiveness and to determine what qualities contribute to that effectiveness. The authors of *Analyzing Exemplary Science Teaching* suggest that "exemplary teaching might usefully be equated with exemplary learning-presumably increased quality and quantity", therefore learning must occur if teaching is to be considered effective (Alsop, et al., 2005, p. 5). Methods for measuring science teacher effectiveness must be determined that are tied in some way to student learning and achievement. While student achievement can be quantified and measured, it must be determined whether student achievement should be equated with learning and whether this achievement can be used as the primary determinant of teacher/science education effectiveness. If teachers are deemed effective because of student achievement, then the qualities of those teachers of high achieving students should be determined and programs established that train teachers in achieving those qualities. There are reasons students in classrooms of teachers identified as effective achieve at higher levels, the problem is in agreeing on what those reasons are and to what teacher qualities those gains in achievement can be attributed. Continued research is also needed that examines each of the categories studied within this investigation to determine what contributes most to science teacher effectiveness from the student perspective.

While the goals of this research were specifically in response to four research questions, the overarching goal can be stated much more simply and should be the goal of all educational research: promoting educational processes that ensure learning for all students. Reaching that goal involves a general agreement between all parties involved in the educational process and if students are seen as an important party and their voice is allowed to contribute as an integral part of that process then the information provided through this research will contribute to the achievement of that goal.

APPENDICES

APPENDIX A

Baylor University Biology Student Survey: March 2008

Part I. Demographic information.

1. Name and email address or choice to contribute anonymously only.

2. Undergraduate degree program (Choose one or more) (branch to specifics)

Art
Business
Computer Science
Economics
**Education
- Deaf education
- Elementary
- Secondary

English
Foreign Language
Geography
History
**Science
- Biology
- Biochemistry
- Chemistry
- Environmental Science
- Environmental Studies
- Forensic Science
- Geology
- Geophysics
- Neuroscience
- Pre-medical
- Pre-dental
- Pre-physical therapy
- Physics

Journalism
Mathematics
Music
Nutrition sciences
Political Science
Psychology
Telecommunication
Theater Arts

Other (please specify) ___________________

3. What is your gender?
___ male ___female

4. Present classification:
____Freshman
____Sophomore
____Junior
____Senior
____Graduate student

5. What is your age?

<18	30-34
18-20	35-39
21-24	40-44
25-29	45 or older

6. Marital Status
Single Married

7. What is your racial/ethnic background?
African-American
American Indian or Alaska Native
Asian, Pacific Islander, or Hawaiian
Hispanic
White/Anglo/Non-Hispanic
Other________________

8. What year did you graduate from high school?
Before 1980
1980-85
1986-90
1991-95
1995-2000
2001-2005
2006
2007

9. List the name of your high school and school district.

10. List the location of your high school (city, state, and country).

11. Classify your high school according to the following criteria:
Urban
Suburban

Rural

Part II. High School Science

12. Check the sciences you took in high school with the corresponding grade:

Biology	A	B	C	D	F
PreAP Biology	A	B	C	D	F
Integrated Physics & Chemistry	A	B	C	D	F
Chemistry	A	B	C	D	F
PreAP Chemistry	A	B	C	D	F
Physics	A	B	C	D	F
PreAP Physics	A	B	C	D	F
GMO (geology, meteorology, oceanography)	A	B	C	D	F
Environmental Systems	A	B	C	D	F
Anatomy & Physiology	A	B	C	D	F
Aquatic Science	A	B	C	D	F
Astronomy	A	B	C	D	F
AP Biology	A	B	C	D	F
AP Chemistry	A	B	C	D	F
AP Physics	A	B	C	D	F
AP Environmental Systems	A	B	C	D	F
Other_________________	A	B	C	D	F
Other_________________	A	B	C	D	F

Part III. High School Science Teacher

13. Use the following scale to rate the characteristics/qualities listed as being important *personal* characteristics of effective science teachers (in your opinion).

strongly agree---agree---neutral---disagree---strongly disagree
5 4 3 2 1

___Willingness to admit mistakes
___Not egotistical
___Good communication skills (including listening)
___Ability to resolve conflicts
___Ability to motivate students
___Caring relationships with students
___Respectful of all students
___Non-judgmental
___Interested in students
___Enjoys teaching
___Sense of humor
___Enthusiastic about the subject
___Self-confident
___Friendly

___A life-long learner
___Advanced degrees (master, doctorate, etc.)
___Tolerant of other viewpoints
___Flexible
___Shows concern for student progress
___Invites constructive criticism

14. Use the following scale to rate the characteristics/qualities listed as being important *professional* characteristics of effective science teachers (in your opinion).

strongly agree---agree---neutral---disagree---strongly disagree
5 4 3 2 1

___Ability to make the material relevant/related to life
___Ability to make the material interesting
___High expectations for students
___Engages students with the content
___Good questioning techniques
___Good lecturer
___Less lecture/more hands-on activities
___Emphasis on lab activities
___Encourages class discussion
___Presents origins of concepts and ideas
___Emphasizes learning of concepts over facts
___Explains clearly
___Presents recent developments
___Summarizes major points
___Allows students to share their knowledge and experiences
___Uses a variety of teaching methods

15. Use the following scale to rate the characteristics/qualities listed as being important *classroom management* characteristics of effective science teachers (in your opinion).

strongly agree---agree---neutral---disagree---strongly disagree
5 4 3 2 1

___Keeps students on-task
___Effective use of class time
___Good classroom organization
___Recognizes and greets students outside of class
___Holds students accountable
___Few discipline problems
___Provides feedback on assignments
___Available for help outside of class
___Grades student work fairly

Part IV. Please answer the following using 50 words or less per question.

16. What characteristic of an effective science teacher do you feel is the *most important* from a student perspective (may be chosen from the listings above or your own description)?

17. Name your most effective high school science teacher.

18. Why did you choose that particular teacher?

19. Which of your high school science class(es) did your most effective science teacher teach?

20. What is your description of an effective science teacher?

21. What career have you chosen to pursue?

22. Did any one of your high school science teachers inspire your current career choice? (No-Branch to 23, Yes-Branch to 22, Have not decided -end of survey)

___Yes ___No ___Have not decided on a career choice

23a. Name the science teacher who inspired your current career choice.

23b. How did that teacher inspire your current career choice?

23c. What class(es) was/were taught by that teacher?

24. What/who was your inspiration for your current career choice?

APPENDIX B

Email content & Informed Consent Form-all participants

Dear Baylor University biology student,

I am presently conducting research through the Department of Education at Baylor in order to compile a list of qualities of effective secondary science teachers. The purpose of this research is to determine the role of the secondary science teacher in promoting interest and achievement in science, as well as the teacher's influence on a student's choice of a science major in college. The completion of the electronic survey (link to survey) indicates your voluntary agreement to participate in this research. This is an anonymous survey only if you choose. Certain individuals will be identified as contributing additional information to the ongoing study. By submitting your name and email address in the first question, you are agreeing to future contacts from the researcher in which you may be interviewed. Neither your identity, nor that of any teachers discussed, will be identified in any research publications.
Student perspectives in educational research are rare and your contribution is invaluable, so please be thoughtful and completely honest in the evaluation of your past exemplary high school science teachers. The results of the survey will be sent to you after the information has been compiled and analyzed. Your participation is greatly appreciated!

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Any inquiries regarding your rights as a subject, or any other aspect of this research can be directed to:
Dr. Matthew Stanford, One Bear Place #97334, Waco, Texas 76798-7334, phone number 254-710-2236.

APPENDIX C

Electronic Survey Disclaimer-attached to email

"As you may be aware, electronic surveys may be subject to interception, legally illegally by another party, while the information is in transit. Therefore, it is not possible to control whether the information might be viewed by another party. If you are concerned about data security and the discloser of any information contained in the survey, please print the survey and answer the questions by hand and mail the completed survey to the following address: 204 Kingston Drive, Waco, TX 76712.

APPENDIX D

Ineffective Science Teacher Subsequent Survey Questions

1. Describe the practices of an ineffective high school science teacher. Be as specific as possible.
2. Were you referring to a particular teacher/experience/class when responding to the previous survey concerning the ineffectiveness of high school science teachers? Explain that situation.
3. Additional information?

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