



Quality Enhancement Plan

**Foundations of Science:
Improving Scientific Reasoning Among Non-Science Majors**

Submitted By
Sam Houston State University
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A Member of The Texas State University System

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I. Executive Summary

The goal of the Quality Enhancement Plan (QEP) at Sam Houston State University (SHSU) is to improve critical thinking and scientific reasoning in our non-science major students. The plan calls for the development of a new General Education science course called *Foundations of Science*. This course will emphasize the practice of critical thinking, as embodied in the scientific method, and introduce basic scientific facts from a variety of scientific disciplines. This focus on critical thinking is consistent with the universally recognized goal of higher education to enable students to critically evaluate information and make informed decisions on the basis of that reasoned evaluation. The focus on scientific literacy serves the societal need for an informed citizenry capable of dealing with the many scientific and technological issues society faces. Both foci promote the mission and goal of Sam Houston State University to “provide excellence by continually improving quality education,” and to “[p]romote students’ intellectual, social, ethical, and leadership growth.”

The selection of the QEP topic was inspired by institutional research showing that many of the students in introductory non-science courses have not been performing at an appropriate level in their science courses. The selection of the topic was further supported by consensus among faculty that students have not been developing the ability to think scientifically, nor do they have a solid grasp of the nature of science. This was subsequently confirmed by data from a standardized test and by a locally developed instrument. Additional data indicated that many of our students lack interest in science, which contributes to their unsatisfactory level of performance in science classes.

The rationale for the selection of the topic is supported by external research indicating that a majority of college graduates in the U.S. are scientifically illiterate. By implication, this is true of SHSU graduates as well because the university has been teaching science using the same pedagogical approaches commonly used throughout the country. These data, coupled with the recognition by the scientific community that scientific literacy encompasses both scientific reasoning and factual knowledge of science, led to the selection of the Quality Enhancement Plan titled: *Foundations of Science: Improving Scientific Reasoning among Non-Science Majors*.

The specific student learning outcomes for the QEP are to 1) demonstrate the ability to apply scientific terminology; 2) use scientific reasoning when evaluating claims; 3) avoid common logical fallacies; 4) demonstrate understanding of key concepts and theories from science; 5) apply scientific knowledge to an evaluation of claims; 6) distinguish science from pseudoscience; and 7) develop greater interest in science and an appreciation of the need for scientific literacy and critical thinking.

II. Process Used to Develop the QEP

The process of selecting a QEP began with campus-wide conversations in the fall of 2007. Members of the University community were encouraged to submit ideas to the Leadership Committee, the Compliance Committee, or the QEP Committee, and/or to provide input by attending Town Hall Meetings and/or responding to a web-based survey soliciting ideas. Town Hall meetings were conducted for faculty and staff to solicit ideas on October 5, October 9, October 17, October 27 and November 1, 2007. The University Faculty Senate and Staff Council encouraged participation. Input was solicited from the University Faculty Senate and the Staff Council. Throughout this process, the Academic Policy Council (APC) was informed about the QEP and encouraged to help publicize the QEP process.

To reach as broad an audience as possible, the Associate Vice Presidents of Academic Affairs met with various groups to discuss the QEP and request input. The Associate Vice Presidents for Academic Affairs met with the Academic Policy Council, the Alumni Board, Staff Council, and the Council of Academic Deans to discuss the QEP, to solicit ideas, and to inform the committees about the QEP process. A request for additional faculty input on student learning outcomes was made through the academic deans. Specifically, members of the faculty were asked by e-mail, "If there is one thing you could do to improve student learning on the SHSU campus, what would it be?" Subsequently, a website was created to encourage faculty and staff to submit ideas.

After collecting the suggestions, the Provost established the QEP Committee, consisting of 12 representatives from across campus, to review the suggested initiatives. The QEP Committee consisted of the following members:

Richard Eglsaer, Chair	Associate Provost
Rita Caso	Director of Institutional Research
Frank Fair	Professor of Philosophy
Mark Frank	Associate Professor of Economics
Marcus Gillespie	Associate Professor of Geography
Marsha Harman	Professor of Psychology
Joan Maier	Associate Professor of Education
Carroll Nardone	Associate Professor of English
Daughn Pruitt	Associate Dean of Students
Mary Robbins	Professor of Education
Keri Rogers	Associate Dean, Arts and Sciences
Mike Vaughn	Professor of Criminal Justice

The committee initially narrowed the list to six potential QEP topics. Six individual members of the QEP Committee volunteered to serve as a "champion" of one of the topics. These "champions" developed a proposal for their respective topic. Their task

was to outline the basic strategy for implementing the idea and identify potential sources of data to substantiate the educational need. The criteria for consideration of the proposed learning initiatives were as follows:

- There must be a perceived need for the initiative with supporting institutional data to demonstrate that need.
- The initiative must be perceived to adequately address the need.
- The objectives/outcomes of the initiative must be measurable.
- There would be broad-based support for the initiative.

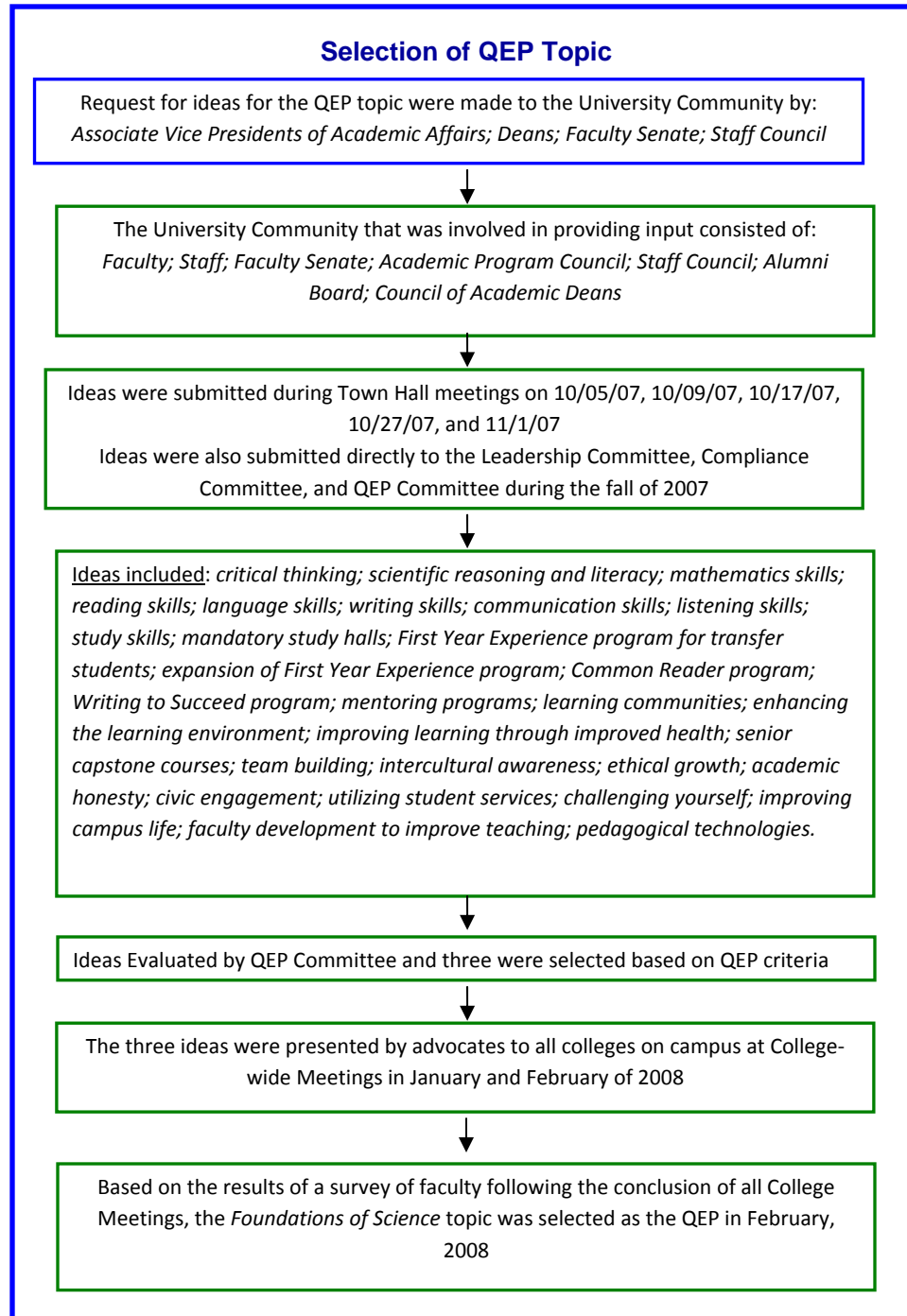
Based on the presentations of each initiative's "champion" and a review of the data supporting each of the ideas, the QEP Committee narrowed the list to three prospective QEP topics: Common Reader, Writing to Succeed, and Improving Scientific Reasoning.

For each of these three topics, a one-page synopsis was developed and distributed to all members of the faculty by e-mail. The three proposals were then presented at college-wide meetings in January, 2008. All members of the faculty were asked to attend the meetings of their respective colleges. Faculty members had a chance to ask questions and provide feedback about each of the suggested QEP proposals. Following the presentations, the members of the faculty expressed their opinions of the proposals by electronically submitting an evaluation of each proposed initiative. The faculty members were asked to use a Likert-style rating scale to appraise the following four statements for each proposal:

- 1) I think the project is aimed at a legitimate student need.
- 2) I think there is sufficient data to demonstrate student need in this area.
- 3) I think the project represents a reasonable effort to address the student need.
- 4) I think this is a project the campus community will support.

A total of 336 faculty members (60%) expressed their opinion on the initiative, out of approximately 559 full-time faculty members. The Improving Scientific Reasoning proposal, *Foundations of Science*, received the greatest support on three of the four questions. Based on the results of this survey (see Table 1 in Appendix I) and subsequent discussion by the QEP Committee, the science course was selected by the QEP Committee as the QEP Learning Initiative that would be adopted by the university.

The QEP selection process is summarized in the following flow chart:



Development of the QEP Topic and the QEP Science Committee

Upon selection of the final QEP topic, the original committee was disbanded and replaced with a committee charged with the task of fully developing the QEP to include designing the new course which addresses the student-learning outcomes for the scientific reasoning initiative, developing an assessment process, and coordinating

efforts between university faculty and administrators regarding the development of the QEP.

Dr. Marcus Gillespie, the original champion of this proposal, was selected to chair this committee. In consultation with the Provost, Dr. Gillespie initially selected eleven faculty members to serve on the committee. The members of the committee initially included individuals from the Departments of Biology (2), Geography and Geology (2), Chemistry (2), Physics (1), Agricultural Science (1); Computer Science (1), Mathematics and Statistics (1), and Sociology (1). Two of these individuals were acting chairs of their departments, and four were former chairs. The committee's first meeting was held in February, 2008.

During the first few meetings held in the spring semester of 2008, philosophical differences regarding the nature of the course developed among certain members of the committee. As a result of these differences, the Chairs of the Departments of Chemistry and Physics requested that their departments be allowed to develop either new or modified introductory science courses that would address some, but not all, of the objectives of the *Foundations of Science* course (see Appendix II). Although two of the departments opted to try a different strategy to improve scientific reasoning, the discussion was productive insofar as current science classes were evaluated and revised.

Following the changes discussed above, the committee was reconstituted to include additional faculty and staff from the College of Education, the Department of Computer Science, the Department of Biology and the Director of Institutional Research. The diverse membership of the committee ensured that the learning initiative would be designed to meet the needs of the targeted students.

III. Identification of the Topic

The following data supported and inspired the selection of the *Foundations of Science* course as the university's QEP Learning Initiative:

- 1) Poor performance by students in the introductory science courses: Examination of the grade distributions in introductory science courses have illustrated that a large portion of Sam Houston State students are failing to master the material. As shown in Table 2A in Appendix I, during the period 2003 to 2007, between 29.3% and 33.1% of our students earned either a D or F in these courses, or dropped (Q) the courses. In short, slightly less than one-third of the students in the introductory science courses have historically done very poorly in these courses. Table 2B in Appendix I provides comparative data for grade distributions in Introductory General Education Core classes (100-level) and General Education Science Classes. This data shows that students perform worse in science courses.

- 2) Students' lack of interest in science as reflected on IDEA evaluations: The IDEA instrument is a nationally standardized, 47-question survey instrument which is completed by students at the end of the fall and spring semesters in all courses at Sam Houston State University. The IDEA gathers information regarding student perceptions of a course. The results from the Fall 2005 semester through the Spring 2008 semester, for all introductory classes in Biology, Geography, Geology, Physics and Chemistry are summarized in Table 3 in Appendix I. These results indicate a consistently weak interest in science courses across semesters, suggesting a need for a new approach to the teaching of introductory science.

- 3) Perception that students lack knowledge of basic science facts: Based on experience in the classroom, it was apparent to science faculty that many students were entering their science courses with limited knowledge of basic scientific facts; i.e., that many could be considered scientifically illiterate. Science faculty were surveyed as to their perception of students' basic scientific literacy. Thirty-four of the thirty-five surveyed introductory science faculty members (97.1%) responded. Only 23.6% of the responding faculty members agreed with the statement, "Most students in my core curriculum classes recognized scientific concepts with little difficulty," while 44.1% of faculty disagreed. Faculty also agreed that students were unable to transfer information from one class to another with only 23.6% of the faculty agreeing with the statement, "Most students in my core curriculum classes often recognized the same scientific facts from one class session to another if they were presented in different contexts." (See Table 4 in Appendix I)

A similar picture emerged from the results of the Foundations of Science Exam. This exam, containing 14 questions related to basic scientific concepts (See Table 5 in Appendix I), was given to students in selected sections of Introductory Biology, Introduction to Computer Science, and Introduction to Geography (total n = 411). The average score on this section of the exam was only 42%. The percent of correct responses on individual questions ranged from a high of 68.6% to a low of 17.3%.

- 4) Faculty perception that students lacked knowledge of the nature of science: Another commonly held faculty belief was that students did not fully understand the nature of science. Although the students understood some elements of the scientific method, few possessed the broad picture as to what constituted the rationale for the scientific method, i.e., an understanding that the method is designed to eliminate bias and sources of error through proper research design and the use of critical thinking. The faculty's perception was strongly supported by the results of the Foundations of Science Exam, which contained seven questions dealing with the nature of science and scientific terminology (See Table 6 in Appendix I). Again, 411 students completed the exam, and the average score on this section of the test was 44.9%. The percent of correct responses on individual questions ranged from a high of 59.9% to a low of 6.6%. The results are presented in Table 6.

- 5) Evidence that indicated students were lacking in critical thinking skills: Many science faculty members felt that a significant percentage of their students lacked the ability to critically evaluate information and to logically relate information and concepts covered in class. In short, the students were perceived to lack critical thinking skills. This perception is reflected in the results of the *Science Faculty Survey* (See Table 7 in Appendix I). The majority of the faculty (52.9%) disagreed with the statement, “Most students in my core curriculum classes successfully explained connections between related principles learned in the course.” Only 32.3% endorsed this item. A similar pattern was noted concerning the belief that “Most students in my core curriculum classes successfully analyzed and drew conclusions about simple science problems, if they had learned about pertinent principles and had access to pertinent evidence.” Again the majority of the faculty (55.9%) disagreed with this statement compared to 23.5% of the faculty who agreed.

These perceptions were also supported by the results of both the *Foundations of Science Exam* and the *Critical Thinking Assessment Test* (CAT) (See Tables 8 and 9 in Appendix I). The CAT is an externally developed, nationally recognized test that was developed with the support of the National Science Foundation. The *Foundations of Science Exam* contained nine questions regarding critical thinking/scientific reasoning. The average score on this section of the exam was 56.2% (n = 411). These results indicate that many of our students have difficulty utilizing critical thinking and/or scientific reasoning.

The CAT was administered to selected core science sections of Geology and Geography classes. The test was given to 204 students toward the end of the Fall 2008 semester. Students were offered extra credit to encourage them to do their best. To ensure that all students received extra credit, all of the tests were scored using a locally-developed rubric which allowed the test to be scored much faster than is possible using the formal grading process. Of the 204 tests, a randomly selected subset of 76 tests was formally graded using the official rubric for the test. The “speed version” of the rubric was more generous in the allocation of points than the official rubric, which requires that more criteria be met in order to receive full credit for a multi-point response. Five people graded the tests using the “speed version” of the rubric, and each was instructed in the procedures for using the modified rubric prior to grading the tests. Fifteen people formally scored the subset of 76 CAT tests using the rubric and procedures developed by Tennessee Technological University. Using the informal, “speed version” of the rubric, the average score was 62.1%. Using the formal rubric, the average score was 39.6%.

- 6) Lack of Instruction on the nature of science and critical thinking: Based on conversations among science faculty members, it appeared that the nature of science and the rules of critical thinking used by scientists were not being stressed in the introductory science courses. This perception was consistent with the idea that the introductory courses are designed to convey the facts of a discipline, not to teach

the nature of science. Interestingly, the results of the *Science Faculty Survey* suggested that the faculty felt that they *were* covering these topics. However, the results of the IDEA Survey indicate that the students either do not think these topics are being stressed or the students are not learning them (See Tables 10 and 11, in Appendix I).

The results of the surveys and tests conducted by the University clearly suggest that students are lacking in critical thinking and scientific reasoning skills, an understanding of the nature of science, and knowledge of basic scientific facts. These data support preliminary observations and faculty intuition that the University's core science curriculum is not adequately addressing the development of scientific literacy and critical thinking. In addition to institutional data, a definitive body of research, conducted over decades, suggests that the majority of Americans, including college graduates, are scientifically illiterate. The selection of the Foundations of Science as SHSU's QEP addresses this national and institutional concern. The implementation of this QEP is intended to produce greater competence in critical thinking and improved knowledge of basic science and a more positive attitude towards science.

The problem of scientific illiteracy and lack of critical thinking skills, in conjunction with the general lack of student motivation to learn science, suggests several possible reasons why SHSU students may experience difficulty in learning science material:

- 1) The students are not learning to think logically and scientifically. Students are often good at memorizing facts, but not at understanding abstract concepts that require them to "connect the facts" to draw a larger picture that constitutes a scientific topic. In a related manner, they seem to have trouble understanding processes based on a chain of causation, i.e. causal reasoning.¹
- 2) Students may not be motivated to study and learn science because they consider it to be either "too hard" for them based on previous experiences with science classes or that it is irrelevant to them.² Students do not grasp the value of scientific reasoning in their daily lives because they do not understand that the methods of reasoning used by scientists are also used in non-scientific settings.
- 3) The inability to fully recognize and appreciate the similarities and differences between science, non-science, and pseudoscience may hinder students' ability to understand the natural world as understood by scientists.³
- 4) The standard approach to teaching science courses may result in a lack of engagement on the part of students, thereby resulting in poorer performance by many of the students at SHSU.⁴

The groundwork for the design of the Foundations of Science initiative as Sam Houston State University's QEP was based on institutional data and national research literature.

The course content and instructional pedagogy address the aforementioned difficulties in learning science material. The course was designed to encourage critical thinking and the use of specific rules of logic embedded in the scientific method. While not a specific goal of the QEP, the ability to apply scientific reasoning to other coursework should enhance students' overall academic performance. These critical thinking skills, coupled with a broader understanding of the nature of science and scientific information gained from this course, will help students grow intellectually. It is also hoped that these skills will also enhance their ability to make better, more informed decisions as adult members and citizens of our society.

The addition of this course to the core curriculum is consistent with the mission of the university to “provide excellence by continually improving quality education.” It is also consistent with the university’s goal to “[p]romote students’ intellectual, social, ethical, and leadership growth.”

To achieve the student learning outcomes, delineated in Section IV, the *Foundations of Science* course must address both critical thinking and scientific literacy. Thus critical thinking and scientific literacy served as the foundation for the QEP’s course objectives and pedagogical approaches.

Critical Thinking Skills

The QEP Committee recognizes that scientific reasoning is a form of critical thinking. To this end, the Committee adopted Bernstein’s definition of critical thinking:

Critical thinking is the process of evaluating propositions/claims or hypotheses and making judgments about their validity on the basis of well-supported evidence. It includes asking the following five questions: (a) What am I being asked to believe or accept? What is the hypothesis? (b) What evidence is available to support the assertion? Is it reliable and valid? (c) Are there alternative ways of interpreting the evidence? (d) What additional evidence would help to evaluate the alternatives? (e) What conclusions are most reasonable based on the evidence and the number of alternative explanations?⁵

This definition of critical thinking is reflected in the acronym TiLCHeRS that will be taught in this course. TiLCHeRS requires students be able to apply rules of logic when interpreting evidence and arguments. The TiLCHeRS acronym stands for

Testable (an idea must be testable for it to be studied scientifically);
Logic (arguments presented in support of a conclusion or theory must be logical; i.e., they must not contain logical fallacies such as those which will be discussed in the course);
Comprehensiveness of evidence (all pertinent evidence must be evaluated before drawing a conclusion);

- Honesty of evaluation (scientists must objectively and fairly evaluate the evidence, even if it contradicts their favored hypothesis or theory);
- Replicability (experiments and studies must be replicated by others before their conclusions can be considered probable or definitive); and
- Sufficiency (the evidence must be sufficient to warrant a conclusion and, the more extraordinary the claim, the greater the amount of evidence needed to support it).

The above definition of critical thinking is also consistent with a position paper of the American Philosophical Association. Developed by a panel of 46 experts from several disciplines throughout the United States and Canada, the American Philosophical Association published the following statement regarding the nature of critical thinking:

We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. Critical thinking is essential as a tool of inquiry.⁶

This statement on the nature of critical thinking embodies the key concepts of scientific reasoning that will be taught in the course, as well as the rationale and need for critical thinking. In the *Foundations of Science* course, students will be required to demonstrate their ability to think critically on a standardized test, course exams, written assignments, and in group discussions.

Scientific Literacy

National research indicating high levels of scientific illiteracy supported institutional data for the selection of this QEP topic. Furthermore, the national research influenced the creation of the learning objectives and pedagogical approaches. This level of scientific illiteracy indicates that the standard approach to teaching science, which is used throughout the country⁷, including Sam Houston State University, does not work well.

Traditional pedagogy stresses the vocabulary and facts of a scientific discipline, but not the significance of those facts or the nature of the scientific endeavor. In essence, students learn seemingly disconnected facts, not a coherent body of knowledge, and so they become bored with science, do not understand its relevance, and forget much of what they have learned in their science courses. Even more important, they leave their science classes without having significantly enhanced their critical thinking skills.

Because methods of teaching science at SHSU are essentially identical to those at other universities, national data on science literacy and critical thinking problems may serve as proxy data for the lack of controlled research findings on deficiencies observed in students at SHSU in their introductory science courses. Because this data is serving as proxy data, a detailed discussion of this data is warranted to provide further support,

beyond the aforementioned institutional data, for the selection of Sam Houston State University's QEP topic.

High incidences of scientific illiteracy among students are supported by a variety of National Science Foundation (NSF) studies. The NSF supports the biennial publication of a report titled, *Science and Engineering Indicators* (SEI). The latest report, published in 2008, shows that, as of 2006:

- 1) 44% of Americans do not know that it takes the earth one year to go around the sun;
- 2) 66.5% of Americans reject the scientific theory that the universe began with an explosion; i.e., the Big Bang. This number has remained unchanged since 1996;
- 3) 45.5% do not know that electrons are smaller than atoms;
- 4) 36.5% do not know that the father's gene determines the gender of a baby;
- 5) 56.5% do not believe that humans developed from earlier species of life. Interestingly, the number of Americans that do not accept evolution has actually increased by 10% since 1996;
- 6) 54% believe that Creationism should be taught in public school science classes, and 43% believe the Intelligent Design should be taught;
- 7) 44.5% do not know that antibiotics will not kill viruses;
- 8) 58.5% do not know that control groups are needed when evaluating the efficacy of a drug treatment; and
- 9) 60% of Americans do not know that they have eaten genetically modified foods.⁸

In the SEI 2001 assessment, respondents were asked to explain what it means to do something scientifically. The survey found that two-thirds of Americans did not have a firm grasp of the scientific method. According to authors of the report, this lack of understanding may explain why a substantial portion of Americans believe in various forms of pseudoscience, which has been defined by Shermer⁹ as "claims presented so that they appear [to be] scientific even though they lack supporting evidence and plausibility."

Research conducted at the Carnegie Institution of Washington's Geophysical Laboratory, and Clarence Robinson Professor of Earth Science, reported that less than 10% of seniors at Harvard University could explain why it's hotter in summer than in winter and only half could identify the difference between an atom and a molecule.¹⁰ This same study reported that less than 7% of adults were scientifically literate and, of

particular importance to universities and Sam Houston State University's proposed QEP, less than 22% of college graduates were scientifically literate. In other words, 78% of college graduates are scientifically illiterate. Equally telling, only 26% of those with graduate degrees are scientifically literate. This information suggests that traditional methods of teaching science in universities are largely unsuccessful in producing scientifically literate graduates.

In developing the *Foundations of Science* course objectives and pedagogical approaches, the QEP Committee adopted the definition of scientific literacy espoused by Dr. Jon Miller of Northwestern University. According to Dr. Miller, "scientific literacy" means three things:

- 1) an understanding of basic scientific concepts and facts,
- 2) an understanding of the nature and process of scientific inquiry and the ability to distinguish science from pseudoscience,
- 3) the ability to read and understand the science section of a major newspaper.

Dr. Miller, in the Summer 2003 newsletter of the American Physics Society, *Forum on Education*, concluded that in 1999, only 17% of Americans were scientifically literate.¹¹ Thus, according to a nationally recognized expert that has been studying scientific literacy for more than 20 years, 83% of Americans are scientifically illiterate. Dr. Miller's conclusions, which are based on his work with the NSF, further support the need for a new type of science course. Furthermore, his inclusion of both the methodology of science and the ability to distinguish science from pseudoscience in his definition of scientific literacy provides specific support for the type of science course that is being developed for the university's QEP, which emphasizes the methods of science and the analysis of pseudoscientific and extraordinary claims.

In the UK, the lack of interest in the physical sciences had a profoundly negative impact on college-level science education because it led to the closure of 80 university science departments between 2000 and 2007, though some reopened under a new name. These results, reported in a *New Scientist* article, noted that teenagers criticize science courses for not allowing students to engage in debate and discussion of issues they find interesting.¹² This conclusion supports the pedagogic approach that will be used in the *Foundations of Science* course, which will require students to discuss and analyze popular topics of interest to them.

Further evidence of a general lack of engagement with science relates to the newspaper reading habits of Americans. Although Americans express support for science and technology (87%), the percentage of Americans who say they closely follow science and technology news declined from 20% in 1996 to 15% in 2006. By this measure science and technology now ranks tenth out of fourteen news categories.¹³

The information cited thus far regarding the lack of scientific literacy and enthusiasm for science has focused on the national level. Unfortunately for Sam Houston State University, and Texas in general, the status of science education is at least as bad, if not worse, than that of the United States as a whole. In a report prepared by the Thomas B. Fordham Institute titled the *State of State Science Standards 2005*, Texas earned a score of F on the science standards it prepared for K-12th grade students.¹⁴ Students that enter Sam Houston State University from Texas high schools are coming from one of the lowest ranked states in terms of science standards. This contributes to the problems that the university faces with low levels of interest in science and poor academic performance. Realizing the skills of incoming students, the QEP Committee recognized the need for improving science instruction.

One of the co-authors of the State of State Science Standards report, Dr. Ursula Goodenough, wrote in the American Society for Cell Biology (ASCB) Newsletter, January 2006 that,

science education...basically fails to convey to students what can be called the scientific worldview – a narrative account, with supporting empirical evidence, of our current understandings of the origins and evolution of the universe, the planet, and life (including humans) – a worldview based on the findings of the historical sciences.¹⁵

She went on to say that, in her view, “a presentation of such a comprehensive scientific framework could help ameliorate the epidemic of scientific illiteracy in our society.” She also reiterated the theme just discussed; namely, that most students find science classes boring and tedious. Based on these concerns, she and two other professors from her university developed a team-taught course that attempts to teach this worldview.¹⁶

Many other scientists have advocated this ‘broader view’, Foundations of Science approach. For example, the late physicist, Dr. Carl Sagan, one of the pre-eminent popularizers of science, tried to convey to the public not only the importance of science, but the beauty and wonder of the universe revealed by science. He understood that knowledge of scientific facts was important in helping people accomplish this, but he also emphasized the greater need for understanding the nature of science as well. He wrote in his book, *The Demon Haunted World* that,

If we teach only the findings and products of science – no matter how useful and even inspiring they may be – without communicating its critical method, how can the average person possibly distinguish science from pseudoscience?...The method of science...is far more important than the findings of science.

More recently, Dr. Dudley Herschbach, winner of the 1986 Nobel Prize in Chemistry, also emphasized the importance of the nature of science when he wrote that, “Genuine science literacy requires understanding how scientific knowledge is attained, its nature and limitations.” “Ironically,” he said, “such large epistemological questions are seldom addressed in science courses.”¹⁷

In summary, overwhelming evidence indicates that the majority of Americans, including college graduates, are scientifically illiterate. Not only do they not know many of the basic facts of science, they do not understand the nature of science itself, its methods and its emphasis on the use of reason and evidence to draw conclusions. This is not because they have not taken science courses; rather, it is largely because the science courses that they have taken focused primarily on the details of a specific discipline and on the memorization of vocabulary terms, rather than on the nature of science and critical thinking.

The goal of the *Foundations of Science* course is to address the problems of critical thinking and scientific literacy by providing an in-depth understanding of the nature of the scientific endeavor as it pertains to scientific reasoning, while simultaneously providing a broad overview of key scientific concepts from a variety of scientific disciplines. This will enable students to critically evaluate claims. As regards the key facts of science, the emphasis is on breadth of coverage, rather than a discipline-specific depth of coverage. This will enable students to become broadly scientifically literate and to understand the strands of scientific knowledge and methodology that weave the fabric of our understanding of the natural world.

Conversations with Experts and Peers

While working on the development of this course, the members of the QEP Science Committee had the opportunity to meet with Dr. Louise Mead, an evolutionary biologist who is a member of the staff at the National Center for Scientific Education in Oakland, California. She met with the QEP Science Committee on October 3, 2008, to discuss best practices in teaching scientific literacy in the college classroom.

The committee also had contact with Dr. Greg Mayer, a biologist at the University of Wisconsin, Parkside. Dr. Mayer teaches a course titled *Science and Pseudoscience*, and the syllabus content of his course is very similar to that proposed for this course. Through contact with him, the committee members were introduced to a book that will be used as a supplemental reader for the *Foundations of Science* course. The committee also had e-mail contact with Dr. Jon Mueller at North Central College in Naperville, Illinois. Dr. Mueller teaches a course titled *Developing Scientific Thinking Skills* that has many parallels with the *Foundations of Science* course. It was through a conversation with Dr. Mueller (and an unpublished article written by him) that the committee decided to use a modified, simplified rubric for grading ALL of the CAT exams for purposes of providing extra credit.

The committee also had e-mail contact with Dr. James Trefil, who offered support for the course (See Appendix III). Dr. Trefil is a physicist (Ph.D. from Stanford University) and the author of more than thirty books, including college textbooks, on integrated science. Much of his published work is focused on science for the general public. Dr. Trefil teaches at George Mason University as Clarence J Robinson Professor of Physics.

The QEP Science Committee's decision to adopt the *Critical Thinking Achievement Test* (CAT) (discussed below) was the result of a presentation by, and follow-up conversation with, Dr. Barry Stein at the Institute on Quality Enhancement and Accreditation in Orlando, Florida, in July of 2008. Prior to this conference, the members of the committee had been unaware of the CAT instrument.

The decision to incorporate case studies into the course was the result of the information initially provided by Dr. Joan Maier, from the College of Education at Sam Houston State University. Upon learning of this approach, two members of the QEP Science Committee attended a conference at SUNY in Buffalo, New York in September, 2008 to learn more about the case study approach. Because of their enthusiastic response to the information they learned, the QEP Science Committee contacted the University's Center for Academic Excellence (PACE Program) and made plans to host a seminar on the case study approach in the spring of 2009 that will be open to all faculty members and graduate students. This seminar will introduce a much larger number of instructors to the benefits of the case study approach to pedagogy, thereby enhancing the potential benefits of the method and of the QEP initiative. As is evident, the committee's contacts with several experts and peers have played a significant role in shaping the development of the QEP and should have a positive effect far beyond the *Foundations of Science* course.

IV. Desired Student Learning Outcomes

In accordance with the specific student learning outcomes for the QEP, the students will

1. demonstrate that they understand and can apply scientific terminology pertaining to the nature and conduct of science, such as hypothesis, law, theory, control group, operational definition, placebo effect, and double-blind study;
2. apply methods of reasoning used by scientists: i.e., the scientific method based on the requirements of testability/falsifiability, logical consistency, comprehensiveness of evidence, intellectual honesty (objectivity), replication of research, and sufficiency of evidence;
3. analyze and evaluate common logical fallacies and perceptual biases that interfere with the ability to draw reasonable and/or correct conclusions, as well as the difference between facts, informed opinions, and uninformed opinions;

4. demonstrate understanding of key concepts and theories from a variety of scientific disciplines, especially biology, geology and geography/earth science;
5. demonstrate an understanding of the nature of science by applying their knowledge to an evaluation of extraordinary claims;
6. demonstrate how to distinguish science from pseudoscience by scientifically evaluating a wide variety of extraordinary claims that are common in our culture today;
7. appreciate the role of science in their lives and the need for scientific literacy and critical thinking to help make informed decisions about issues currently facing society.

These learning objectives will be assessed using the methods described in the Assessment section of this document.

V. Literature Review and Best Practices

The proposed *Foundations of Science* course follows a 'Best Practices' approach to the teaching of critical thinking and scientific literacy in terms of course content, objectives, and pedagogical techniques.

Best Practices: American Association for the Advancement of Science - Project 2061

The course content and objectives are in complete accord with guidelines established by the American Association for the Advancement of Science (AAAS), which is an international, non-profit organization founded in 1885, whose mission is to "advance science and serve society" through initiatives in science policy, international programs, science education, and more.¹⁸ The AAAS serves 262 affiliated societies and academies of science, and it publishes the journal *Science*.

In 1985, the AAAS began a long-term initiative, Project 2061, aimed at improving scientific, mathematical and technological literacy. Project 2061 set forth 12 benchmarks for K-12th grade education. The benchmarks are equally applicable to higher education to the extent that they emphasize an understanding of the nature of science and the integrated nature of both the scientific endeavor and the scientific understanding of the universe.

One of the underlying themes of the initiative, termed "Habits of the Mind," emphasizes the use of evidence, logic, intellectual honesty, curiosity, and skepticism in the thought process. This focus is consistent with the aims of SHSU's QEP, *Foundations of Science*. Project 2061 and the QEP recognize that even though most students will not become scientists, they nonetheless can use these habits of mind, coupled with scientific knowledge, in their everyday lives to evaluate information.

The “Nature of Science” section, within Project 2061, aligns with the specific rationale for our QEP and the *Foundations of Science* course:

Acquiring scientific knowledge about how the world works does not necessarily lead to an understanding of how science itself works, and neither does knowledge of the philosophy and sociology of science alone lead to a scientific understanding of the world. The challenge for educators is to weave these different aspects of science together so that they reinforce one another.¹⁹

In short, according to the AAAS, scientific literacy requires that students learn both the nature of science and scientific facts; one without the other is not sufficient. The *Foundations of Science* course weaves these aspects of science together. The *Foundations of Science* course specifies the objective of teaching scientific facts from a variety of scientific disciplines and teaching scientific methods and reasoning. The objectives of the QEP are consistent with the objectives of Project 2061 as shown by the following selected objectives and comments listed in Project 2061. The parenthetical comments in italics provide the QEP learning objective and/or assumptions.

1. Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere and can be discovered by careful, systematic study. (*The QEP’s corresponding aspect is that the universe operates according to universally applicable rules that we can understand and use to enhance our knowledge of the universe.*)
2. From time to time, major shifts occur in the scientific view of how the world works. Change and continuity are persistent features of science.... No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth. (*This pertains to the QEP objective of teaching students the nature of scientific theories and the progressive nature of science.*)
3. Scientific inquiry is more complex than popular conceptions would have it. It is far more flexible than the rigid sequence of steps commonly depicted in textbooks as "the scientific method." It is much more than just "doing experiments," and it is not confined to laboratories. More imagination and inventiveness are involved in scientific inquiry than many people realize, yet sooner or later strict logic and empirical evidence must have their day. (*This also pertains to the objective of teaching students the nature of science and its reliance on the laws of nature, logic, and imagination.*)

4. Students should not be allowed to conclude, however, that the mutability of science permits any belief about the world to be considered as good as any other belief. Theories compete for acceptance, but the only serious competitors are those theories that are backed by valid evidence and logical arguments. (In the QEP, *this pertains to teaching students the difference between scientific theories and opinions, the difference between facts, informed opinions and uninformed opinions, and the level of certainty that can be ascribed to a claim or conclusion based on available evidence.*)
5. Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories. (*This pertains to the QEP objective of enhancing student understanding of the conduct of science.*)
6. Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. (*This pertains to the distinction between experiments and studies - which will be emphasized in the QEP course.*)
7. There are different traditions in science about what is investigated and how, but they all have in common certain basic beliefs about the value of evidence, logic, and good arguments. (*This is part of the scientific reasoning process that will be taught using the TiLCHeRS acronym; specifically, logic.*)
8. Scientific teams are expected to seek out the possible sources of bias in the design of their investigations and in their data analysis. (*This relates to the Foundations of Science course emphasis on the need to comprehensively evaluate evidence with intellectual honesty, and on the need for peer review. It also relates to the course material concerning memory, perceptual errors, and biases. These are subsumed under the TiLCHeRS acronym.*)
9. Scientific theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings. (*This pertains to the course goal of teaching students the difference between scientific theories and nonscientific theories.*)
10. No matter how the curriculum is organized, it should provide students with opportunities to become aware of the great range of scientific disciplines that exist. (*The Foundations of Science course is specifically designed to provide students with a multi-disciplinary, broad overview of key ideas in the biological and earth sciences, with an emphasis on being able to apply this knowledge from several science fields to an evaluation of claims using the case study approach.*)

11. Science disciplines differ from one another in what is studied, techniques used, and outcomes sought, but they share a common purpose and philosophy, and all are part of the same scientific enterprise. Disciplines do not have fixed boundaries. *(The multi-disciplinary nature of this course is specifically intended to emphasize the fact that disciplinary boundaries are not fixed and that a coherent understanding of the universe requires knowledge from several disciplines of science.)*
12. Education has multiple purposes and one of its goals emphasizes the need for education to prepare students to make their way in the real world, a world in which problems abound - in the home, in the workplace, in the community, on the planet. *(The Foundations of Science course requires students to apply what they have learned regarding science and critical thinking to an evaluation of real-world claims with which they are familiar.)*
13. Quantitative, communication, and critical-thinking skills are essential for problem solving, but they are also part of what constitutes science literacy. Students should be able not only to acquire certain skills but also to use them in new situations. *(These habits of mind, which will enable students to read and evaluate claims presented in the media are one of the goals of the course. Students will develop their ability to do this using a case study approach in class involving group discussions, as well as in written assignments, which require reflection and analysis.)*
14. Honesty is a desirable habit highly prized in the scientific community and essential to the scientific way of thinking and doing. *(This is one of the TiLCHeRS concepts.)*
15. Students will internalize the scientific critical attitude so they can apply it in everyday life, particularly in relation to the health, political, commercial, and technological claims they encounter. *(This is one of the key goals of the course as evident in emphasizing the evaluation of claims.)*
16. View science and technology thoughtfully, being neither categorically antagonistic nor uncritically positive. *(Students must understand the limits of scientific knowledge in terms of what is and is not scientifically testable or knowable, and both the benefits and risks that the application of scientific knowledge entails. Scientific theories are always subject to modification if necessitated by new data. In short, the scientific method does not constitute the totality of human experience and cannot address all issues of importance to people. It cannot discover 'absolute truth'. Aesthetics and issues that fall within the realm of morality and ethics lie outside the scope of science.)*
17. Use and correctly interpret relational terms such as if . . . then . . . , and, or, sufficient, necessary, some, every, not, correlates with, and causes. *(This pertains to logical reasoning, the difference between correlation and causation, and the nature of experiments and studies.)*

18. The use or misuse of supporting evidence, the language used, and the logic of the argument presented are important considerations in judging how seriously to take some claim or proposition. These critical response skills can be learned. (*This is the primary goal of the course, and it is why the course will involve an analysis of a variety of claims.*)

The objectives of the *Foundations of Science* course align with those identified by the American Association for the Advancement of Science in its Project 2061 as being fundamentally important in promoting scientific literacy and critical thinking.

Best Practices: Texas Higher Education Coordinating Board

The Texas Higher Education Coordinating Board (THECB) mandates that science courses in the core curriculum of Texas universities and community colleges meet one or more designated Perspectives and Exemplary Objectives. These perspectives and objectives, which are considered 'Best Practices' in the State of Texas, are listed below along with the corresponding student learning objective (SLO) from the QEP as provided in Section IV:

Perspective 4 - Develop a capacity to use knowledge of how technology and science affect their lives. (Corresponds with SLO 3, 5, 6, 7)

Perspective 7 - Use logical reasoning in problem solving. (Corresponds with SLO 2, 3, 5, 6)

Perspective 8 - Integrate knowledge and understand the interrelationships of the scholarly disciplines. (Corresponds with SLO 4, 5)

Objective 1: To understand and apply method and appropriate technology to the study of natural sciences. (Corresponds with SLO 1, 2, 3)

Objective 2: To recognize scientific quantitative methods and the differences between these approaches and other methods of inquiry and to communicate findings, analyses, and interpretation both orally and in writing. (Corresponds with SLO 1, 2, 3, 6)

Objective 3: To identify and recognize the differences among competing scientific theories. (Corresponds with SLO 4)

Objective 4: To demonstrate knowledge of major issues and problems facing modern science, including issues that touch upon ethics, values, and public policies. (Corresponds with SLO 5, 6, 7)

Objective 5: To demonstrate knowledge of the interdependence of science and technology and their influence on, and contribution to, modern culture. (Corresponds with SLO 5, 6, 7)

Best Practices: Pedagogies of Engagement

Both the lecture and lab components of the course will incorporate 'pedagogies of engagement' to enhance student learning of the objectives outlined for the *Foundations of Science* course. The term 'pedagogies of engagement' was introduced by Russ Edgerton in his 2001 *Education White Paper*²⁰ which assessed the implications of projects in Higher Education which were funded by the Pew Charitable Trusts. In this paper Edgerton wrote,

Learning 'about' things does not enable students to acquire the abilities and understanding they will need for the twenty-first century. We need new pedagogies of engagement that will turn out the kinds of resourceful, engaged workers and citizens that America now requires.²¹

According to Allen and Tanner²², this approach is consistent with that advocated by the National Research Council and the National Science Foundation, both of which are encouraging science educators,

to adopt active learning strategies, and other alternatives to uninterrupted lecture to model the methods and mindsets at the heart of scientific inquiry, and to provide opportunities for students to connect abstract ideas to their real-world applications and acquire useful skills, and in doing so gain knowledge that persists beyond the course experience in which it was acquired.

In a comprehensive review of the literature concerning pedagogies of engagement, Smith et al. (2005) summarized the findings regarding this approach.²³ Their summation shows that this approach enhances student learning and higher order thinking and that it should constitute an essential component for the type of course represented by the *Foundations of Science* course. For example, Pascarella and Terenzini (1991) reported that the greater the student's involvement or engagement in academic work or in the experience of college, the greater his or her level of knowledge acquisition and general cognitive development.²⁴

Particularly important is that the 'learn-by-doing' approach is normally *not* used in the lecture portion of the classroom, which is traditionally relegated to the conveyance of facts and information. Accordingly, students sit passively as the instructor proffers information from his notes to theirs. Under this approach, the students rarely, if ever, have the opportunity to either apply the information they are learning through discussion and analyses *during* the lecture period, or to receive immediate feedback concerning their thoughts. As a result, much of the information that the instructor wanted to convey

is inadequately conveyed, or is lost shortly after the lecture ends. The 'pedagogies of engagement' approach seeks to overcome these deficiencies by continually engaging students in higher-order thinking and application of course content while they are in the classroom. And, because students must prepare for the course discussions, the engagement continues outside of the classroom as well.

There are several approaches encompassed by the 'pedagogies of engagement' model and several terms have been used to express similar concepts. For example, because a 'pedagogy of engagement' necessarily entails interaction among students, and between students and faculty, the terms 'cooperative learning' and 'collaborative learning' are used in the literature. One of the pioneers of the use of these methods in science classes, Dr. Clyde Herreid, uses the term 'case study' as a close synonym for 'pedagogies of engagement', cooperative learning, and collaborative learning. A case study can be broadly defined as a story, either real or fictional, which is used to enhance student understanding of a topic or issue by having them discuss the topic using relevant information and critical thinking skills. The use of case studies which require students to work together to answer a question or solve a problem constitutes a form of collaborative learning or cooperative learning, depending upon how the exercise is structured. This broad definition allows for the use of several approaches in the classroom including the following:

- 1) *Decision or dilemma cases*, which require students to reach a decision based on the information provided about a problem;
- 2) *Appraisal cases*, which require students to analyze and assess an issue;
- 3) *Case histories*, which are largely finished stories that serve students as illustrative models of science in action;²⁵

This approach allows for the use of a variety of interactive formats which include the discussion, debate, public hearing, trial, problem-based learning, scientific research team, team-learning, and jigsaw.²⁶ The learning by doing approach embodied by the case study approach helps students develop their analytical and decision-making skills, internalize learning, grapple with messy real-life problems, and enhance their communication and team work skills.²⁷ Some of the pseudoscientific issues that Herreid cites as illustrative of the need for this type of approach to teaching science are precisely those that will be covered in the *Foundations of Science* course; such as occult experiences and/or extraterrestrial landings on earth. He also notes that the case study approach is better at engaging students who are turned off by traditional lecture approaches, as indicated by the fact that attendance increased significantly when he incorporated case studies.

A 2006 *Journal of College Science Teaching* article supports the case study approach: "Case studies challenge students to think, to process ideas at a higher and more complex cognitive level, and to experience science as a process rather than as a collection of facts."²⁸ The article further states that "it is vital that [...] students are

challenged to think about science and its relevance to their lives, not just memorization of information.” In addition, given the ‘information explosion’ that is occurring and accelerating, it is essential that students learn how to evaluate the quality of information and sources, and make decisions based on evidence. Thus, the literature does provide support for the adoption of a case study approach in the *Foundation of Science* course.

The University of Delaware has largely implemented a case-study approach across the sciences.²⁹ Fully 25% of the faculty members have used the approach. The initial work at the University of Delaware was supported by the NSF and the Fund for Improvement of Post-Secondary Education, which is further evidence of it being considered a ‘best practice’. Another indicator of the growing use and significance of the case study approach is the fact that the *Journal of College Science Teaching* regularly includes articles on this approach, and it also has devoted entire issues of the journal to an examination of case studies. For example, the October, 2006 issue was devoted entirely to articles concerning this approach and funding for that issue was provided by the National Science Foundation (NSF Grant #031279).

The growing acceptance of problem-based learning is indicated by the success of the National Center for Case Study Teaching in Science at the State University of New York, Buffalo. According to an editorial by Dr. Nancy Schiller, co-director of the Center, their web site receives more than 360,000 hits per month, with approximately 2000 people entering the site every day. In the summer of 2006, they received twice as many applications to attend their summer workshop on the teaching of case studies as they had openings.³⁰

The rapidly growing acceptance for this approach as a “best practice” in education is based on the results of a very large number of studies that clearly show its effectiveness. According to Smith et. al., 2005, from 1897 to 1989, almost 600 experimental and more than 100 correlational studies were conducted comparing the effectiveness of cooperative, competitive, and individualistic efforts on learning.³¹ These studies, and the meta-analyses of subsets of these studies, showed that the cooperative learning approach resulted in significant and substantial increases in learning relative to either the individualistic or competitive approaches. The measures used to gage the amount of learning included knowledge acquisition, accuracy, creativity in problem solving, and higher-level reasoning. Analysis of subsets of the studies showed that other positive results accrued from working cooperatively; such as a greater willingness to take on difficult tasks, persistence in working to achieve a goal, greater intrinsic motivation, greater transfer of learning, and greater time spent on task. In short, the research supports that, “discussions are superior to lectures in improving thinking and problem solving”.³²

In summary, the evidence supporting the efficacy of pedagogies of engagement is clear and unambiguous.

VI. Actions to be Implemented

As has been made clear in the preceding discussion, the QEP for Sam Houston State University is centered upon the *Foundations of Science* course. Accordingly, the implementation of the QEP requires the creation of this new course, faculty development for those involved with the course, and the allocation of resources to teach it and evaluate it. The goals of the course have been discussed at length in the material presented earlier; therefore, in the sections that follow, the issues of course design and implementation, staffing, faculty development, student impact, resources, and costs are discussed.

Scope of the QEP

The *Foundations of Science* course will be offered as an optional course in the Natural Science component area of the General Education (Gen-Ed) core curriculum. Accordingly, it will help to fulfill the science requirements for non-science majors seeking a baccalaureate degree. The Student Advising and Mentoring Center at SHSU (SAM Center) will encourage students to take the course as their first college-level science course. Additionally, the course will be promoted at the mandatory orientation sessions for incoming freshmen. Initially, sufficient sections will be offered to enable approximately 500-600 students to take the course during the academic year. This estimate of initial demand is supported by a survey of prospective students. A student survey was conducted in the fall of 2008 (See Table 12 in Appendix I). In that survey, which described the course, 923 students were asked how likely it was that they would take the *Foundations of Science* course. The modal response on a 5-point, Likert-type scale was 4. Overall, 31.2% said that they were “very likely to take the course,” and 34.5% said that they were “somewhat likely to take the course.” As the success of the course increases, the number of sections will be increased. Pending the assessment of the course’s effectiveness in achieving its student learning outcomes, the university will consider requiring the course for all non-science majors, excluding those students whose degree plans have fixed science requirements that would preclude them from taking the course. Although the course is intended for non-science majors, it may serve as an elective for science majors. Therefore, a substantial percentage of students at the university will benefit from an enhanced understanding of critical thinking and the scientific method and will be better prepared for subsequent coursework. They also will be able to make more informed decisions at both a personal and societal level and will be better prepared for the job market.

Course Design and Implementation

This course will be a 4-credit hour lecture/lab course in which the lab grade will count as part of the overall course grade. Accordingly, students will be required to enroll in the lab concurrently with the lecture. The lecture and lab material will be developed jointly by the faculty who will teach the course, and the lecture material will be presented in PowerPoint format. Based on an agreement between participating departments, a minimum of 70% of the course content must be common between sections of the

course. Some variation in topic selection and/or depth of coverage on particular topics will be allowed to enable instructors to have ownership of the course and emphasize topics that are of particular interest to them.

As discussed above, significant portions of class time will be devoted to the case study approach, which is based on group discussions and group analyses of claims by the students. The purpose is to maintain students' interest and reinforce their understanding of scientific and critical thinking concepts by applying these concepts in a group-discussion setting. In-class discussions also will serve to provide immediate feedback to the students, further enhancing their learning.

The lecture sections eventually will range in size from approximately 35 students to 150 students per section. During the first semester, the class sizes will range from 35-65 students. Using this approach, approximately 300 students will be able to take the course during the first semester. During the 2nd semester, some of the class sizes will be increased to 100 or more students. In the ensuing years, the number of sections and class size will be increased to accommodate demand.

Weekly Topics

The specific topics to be covered in the course include the following, which are organized by weekly topic.

Week 1: Why Evidence and Reason Matter: The Nature of Science

Topics include: TiLCHeRS, Multiple Working Hypotheses, Degrees of Confidence, and How Good Science Differs from Pseudoscience and Bad Science

This section lays the foundation for the remainder of the course by emphasizing the need for evidence when drawing conclusions, as well as the nature of the scientific method – which is based on empiricism and skepticism. It also emphasizes the point that science progresses incrementally toward a better model of reality and that some conclusions are tentative in nature, whereas others are firmly established. The progressive nature of science is nicely illustrated by the replacement of discarded ideas that are more accurate and which better describe the facts. In short, the scientific method allows for progress in our understanding of the world.

Week 2: Why Things Aren't Always What They Seem to Be: Errors in Reasoning and the Limits to Perception and Memory

This and Week 3 material further detail the need for the scientific method which attempts to limit both emotional and perceptual biases through rigorous evaluation of information and by peer review. It also addresses the reliability (or lack thereof) of claims made by honest people who may have misperceived what they experienced (e.g., many instances of UFO sightings have been shown to have been natural or manmade objects that were misperceived by honest, credible witnesses). Given that the course will evaluate extraordinary claims, this section helps students understand why a skeptical approach to

the evaluation of such claims is warranted. The principles of correct and incorrect reasoning that will be discussed in this section include the following:

- a) Anecdotes do not make a science
- b) Scientific language does not make a science (the sections on pseudoscience will give examples of this)
- c) Bold statements do not make claims true
- d) Honesty does not equal correctness
- e) The burden of proof is on the claimant
- f) Extraordinary claims require extraordinary proof
- g) Rumors do not equal reality
- h) The unexplained is not inexplicable
- i) Failures are often rationalized
- j) Correlation doesn't prove causation
- k) When looking for the truth, we can't selectively ignore information that conflicts with our views
- l) Emotive words sometimes obscure rationality
- m) An appeal to ignorance does not constitute evidence of a claim
- n) Ad hominem arguments are inappropriate
- o) Avoid hasty generalizations
- p) Overreliance on authority can compromise the objective evaluation of information
- q) Either-Or thinking
- r) Circular reasoning
- s) Reductio ad Absurdum
- t) The slippery slope
- u) The psychological need for certainty, control, or simplicity may hinder the quest for a correct answer. Be aware that reality is complex, not simple
- v) Beware of falling in love with your first answer and the need for multiple working hypotheses
- w) Beware of your assumptions
- x) Concede ignorance when you are ignorant
- y) Beware of the difference between consistent evidence and conclusive evidence
- z) Be aware that just because something appears in a book or news story doesn't make it true

Week 3: Why Things Aren't Always What They Seem to Be: Errors in Reasoning and the Limits to Perception and Memory

This section is designed to illustrate that failure to follow the rules of thinking can lead to negative consequences. It also emphasizes that memories are not always reliable. Again, this relates to the possible unreliability of extraordinary claims made by honest people, the deficiencies of anecdotal evidence, and the need for the scientific method and peer review.

Week 4: Astronomy and Astrology: Stars, Planets, Galaxies, The Big Bang and Your Sign

This section begins the introduction of scientific information for purposes of evaluating extraordinary claims related to astrology by contrasting the geocentric view of the universe, upon which astrology is based, with the facts of modern astronomy. Students will learn about gravity, stars, galaxies, the recession of galaxies, and the Big Bang Theory. In the course of this discussion, they will learn about scientific laws and theories. In particular, students will learn about information that was predicted by the Big Bang theory and subsequently verified by observation; i.e., that predictive ability is one of the hallmarks of a strong scientific theory.

Week 5: UFO's and Einstein: The Size of the Universe and Cosmic Speed Limits

Topics will include some or all of the following: UFOs and Einstein's Theory of Relativity; Area 51 and the Roswell UFO Crash; Crop Circles; Alien Abductions; Mass Hysterias and the Power of Suggestion.

During this week of class, the claim that UFOs are possible alien spacecraft will be addressed, as well as claims regarding alien abductions. Issues of memory distortion and the need for verifiable evidence will be addressed. Discussion will entail a very general overview of the Theory of Relativity and the contrasting theories of gravity based on Einstein's General Theory of Relativity and the Quantum Theory of Gravity. This allows for an exploration of a case study in which two theories yield predictions that are consistent with the observed facts, but are, at present, mutually exclusive (barring unification by String theorists or others).

Week 6: Energy and Heat: Perpetual Motion Machines, Firewalking and the Laws of Nature

This section allows for a continuation of a general discussion of physical laws as they relate to heat, temperature, entropy and extraordinary claims. This section will help lay part of the foundation for the discussion of evolution and creationists' claims that entropy precludes the evolution of life.

Weeks 7-8: Science and the Paranormal: Problems with Controls, Replication, Sufficiency and Honesty

This section will address problems with controls, replication, sufficiency, and honesty. Potential case studies include some or all of the following: Psychic Energy, Psychic Powers, Psychic Detectives, Psychic Healers, Nostradamus, Mediums, A Brief History of Psychic Research, 'Sheep-Goat Effects', Flaws in Paranormal Studies).

These case studies allow for a discussion of serious, scientifically-conducted parapsychological research which has, so far at least, been unable to provide replicable experimental results supporting the claim for psychic powers. This section includes a discussion of alleged hauntings and allows for a discussion of Newton's laws as they pertain to claims made regarding ghosts.

As in all extraordinary claims discussed in this course, students will not be told what they must believe, rather, will be required to look at the evidence and critically examine it from a scientific perspective that includes information relevant to the topic.

Week 9: Number Sense: Probability, Risk Assessment, and the Lottery

This section entails a discussion of several issues related to the misuse of numbers. Numerical information is often used to support extraordinary claims. Students need to know how to make sense of information by understanding the limits to studies and the limits to conclusions that can be drawn from data. In this section of the course, students will learn how to think about numerical information from an informed perspective.

Week 10: Geology Meets Extraordinary Claims: Plate Tectonics, the Bermuda Triangle and Atlantis

During this week of class, several topics will be discussed, such as reporting of information in books about the Bermuda Triangle and how facts can be manipulated to create the impression of a mystery when none exists. The story of Atlantis may have some basis in fact as regards the possible destruction of an island by a volcanic eruption; however, the claim that Atlantis is a sunken continent is scientifically incorrect because continents cannot sink and no evidence of such a sunken continent has ever been found. In the process of discussing these topics, we introduce geological concepts related to the structure of the earth, the formation of the earth, plate tectonics, and radiometric dating.

Week 11: The Grand Canyon and Crystal Power: What Rocks and Minerals Can and Can't Tell Us

This section is a continuation of the discussion of geologic concepts begun the previous week and includes information pertaining to relative dating, radiometric dating, the formation of sedimentary rock, and principles of superposition. This information is intended to help students understand how geologists reconstruct the earth's history through the application of physical laws and the evidence provided by the stratigraphic record. It also provides a basis for understanding how scientists determined that earth is billions of years old. Finally, there are innumerable claims regarding the alleged power of crystals to enhance energy, cure diseases, and divine the future. Students will learn what minerals and crystals are and the fact that no evidence exists to show that they have "special powers."

Week 12: Alternative Medicines and Diets: The Need for Control Groups, Placebos and Double Blind Studies

This section allows for a detailed application of the principles discussed in the first part of the course regarding the scientific method, possible bias, and peer review. Specifically, students are taught the difference between an experiment and a study and the value of control groups when conducting studies. We will also explain the concept of a placebo effect and the way in which it can confound studies. In the process, we will discuss the

ways in which alleged 'treatments' that lack efficacy can be harmful – either directly, through an adverse effect that they may have, or indirectly, by leading a patient to take the ineffective treatment in lieu of one that works, or by mixing treatments, the combination of which can be harmful. We will also discuss why many ineffective treatments seem to work and why studies often yield inconsistent results. In addition, students will learn how scientific-sounding jargon is often misleadingly used by advocates of many untested or unproven alternative medicines, such as the 'Law of Similars' and the 'Law of Infinitesimals.'

Week 13: Legendary Creatures Meet Biological Constraints: Food Chains, Energy and the Evidence

Everyone has heard of Big Foot and the Loch Ness Monster, as well as many other extraordinary creatures. While these claims cannot be dismissed *a priori*, and some claims seem more tenable than others, there are several reasons for doubting the existence of these creatures – ranging from limits to the accuracy of eyewitness testimony (as discussed earlier in the course), to biological facts and principles regarding ecology, population size as related to viable breeding populations, food webs, etc. This topic also allows for the examination of alternative explanations ranging from outright fraud, to the misidentification of animals, and the misperception of natural phenomenon. In short, this section of the course emphasizes the need for 'multiple working hypotheses' and the fact that anecdotal evidence is not sufficient to establish the truth of a claim.

Weeks 14-15: Evolutionary Theory, Creationism and Intelligent Design: More on the Nature of Scientific Theories

This section introduces students to genetics, genetic change and the evidence for evolution. Information from geology and paleontology, observed instances of speciation (such as the cichlid fish in Lake Victoria), and the principles of natural selection operating on genetic variation will be discussed to help students understand the scientific basis of evolution. Students will be asked to evaluate the claim that Creationism and Intelligent Design meet the criteria for a scientific theory. In addition, the instructors will emphasize that evolution and religion are not necessarily incompatible.

Staffing of the Course

It will not be necessary to hire new faculty members to teach the course because existing sections of our introductory science courses, which are currently taught by the designated instructors, will be converted to the new course. Using this approach to staffing the class sections, there should be no issues related to staffing the course. At present, the instructors for the course include Dr. Chris Baldwin (Geologist, Department Chair and former Associate Provost and Dean), Dr. Marcus Gillespie (Geographer/Geomorphologist and former Chair), Dr. Joe Hill (Geologist), Dr. Matt Rowe (Biologist and former Chair), and Dr. Todd Primm (Biologist and Chair). Dr. Brian Lowe, from the Department of Mathematics and Statistics, and Mr. Solomon Schneider, from

the Department of Computer Science (and who has an extensive background in the natural sciences), will assist in preparation of the course material. The lab coordinator for the course will be Mrs. Lori Rose, who has served as the Biology Lab Coordinator for 17 years. She has substantial experience in the development of lab activities and is familiar with the case study approach. As the course grows, additional faculty members will be recruited to teach the course.

The course will be implemented in the fall of 2009. During this and the subsequent spring semester, the university will offer five sections of the course: two in biology, two in geography, and one in geology. One of the sections will be team taught.

Each of the lectures will be linked to labs composed of a maximum of 30 students. During the first semester in which a lab assistant is involved in the program, the assistant will attend lectures so that they will have a better grasp of the nature, goals, and methods of the course. As enrollment grows and the number of lab sections increases a faculty lab coordinator will be hired to support the course. The coordinator's responsibilities will include training the lab assistants, handling supplies and materials, and coordinating the grade information.

Faculty Development

The nature of this QEP with its incorporation of new pedagogical strategies serves as a catalyst for faculty development that is specifically designed to enhance student engagement and learning. Faculty development began with the initial development of the QEP and has continued throughout its implementation. As part of the preparation for writing this document and for developing assessment strategies, the university sent two members of the QEP Science Committee to the Institute on Quality Enhancement and Accreditation in Orlando, Florida in July of 2008. While at this conference, Dr. Gillespie and Dr. Rowe learned about the recently developed *Critical Thinking Assessment Test* (CAT) that will be used to evaluate the critical thinking component of the QEP. To use the CAT, which requires the use of a rubric to grade written responses by students, Dr. Gillespie, Dr. Li-Jen Shannon, and Mr. Solomon Schneider attended a "Train-the-Trainer" workshop sponsored by the NSF and Tennessee Tech University in Chicago in October of 2008. After administering the test for baseline data purposes in the fall of 2008, they taught their colleagues how to score the CAT responses at a grading session held on December 12, 2008. This training session enhanced the faculty's understanding of the process of evaluation and the use of rubrics. In addition, the student responses to the questions on the CAT provided, and will continue to provide, information to the faculty that can be used to enhance their understanding of student strengths and weaknesses in critical thinking, and thereby help the instructors to improve the quality of instruction in the *Foundations of Science* course. As faculty members learn about the potential benefits of directly incorporating and reinforcing critical thinking skills in their courses, they will be able to incorporate this knowledge into other courses they teach. Indeed, members of the group that graded the CAT exam voiced ideas for improving their own courses during the grading session, and one English professor stated that she

was going to change her entire course to a case study/critical thinking approach as a direct result of having been involved in the grading session. Training sessions at Sam Houston State University will be repeated each semester, as needed, for new members of the scoring team.

Two of the most important aspects of this course are its interdisciplinary nature and its use of case studies and student discussions to engage students in active learning. This requires approaches to teaching the course that are new to most of the designated instructors. As part of the QEP development process, Dr. Matt Rowe and Mrs. Lori Rose attended the Case Study Teaching Conference at the University at Buffalo, State University of New York in September of 2008. Dr. Rowe and Mrs. Rose conveyed what they learned to other members of the QEP Science Committee and to members of their departments. The other faculty members that will teach the course also will attend training sessions. In addition, the discussion on case studies led to the suggestion to host a Case Study seminar on campus. The one-day seminar will be held in February, 2009 and will be open to all faculty members on campus. In short, the QEP is fostering training in the use of alternative pedagogical approaches that have the potential to enhance learning across campus, not just in the *Foundations of Science* course.

To ensure quality of instruction regarding the content of the course, the instructors will work together to develop common lecture materials and labs. This has the specific benefit of promoting substantial collaboration across disciplines and cross-fertilization of ideas. Indeed, during the development of the course, several members of the QEP Science Committee were motivated to read relevant books to prepare them to design and teach the course. The faculty members recommended books to one another as a result of their enthusiasm for the material they were learning.

Faculty development also will be promoted by co-authoring articles concerning the QEP, and presenting at professional conferences about the impact of the course on student learning. As is evident from this discussion, the extensive faculty collaboration that is intrinsic to the development of the QEP, and which is not normally done for science classes, is already driving faculty development and will continue to do so.

Student Impact

The largest and most positive impact of this QEP will be on students and their enhanced understanding of critical thinking and the nature of science, as well as basic scientific literacy. This enhanced understanding is the goal of the QEP, and the actions that the university is taking to accomplish this goal are direct and specific. As discussed above, a significant proportion of non-science majors will be directly impacted by this course. The long-term goal is to increase the number of students benefiting from this course.

The *Foundations of Science* course will count as a General-Education (Texas Core Curriculum) science course. As such, it will count as one of the two science courses required for the non-BS degrees and one of four required for the BS degree. Thus, the

addition of this course to the science core curriculum serves to increase the number of options available to students. Because it is a course that uses content from many scientific disciplines in promoting scientific reasoning, students who take this course will graduate with a broader knowledge and understanding of science and critical thinking. The remaining science courses that students will take to fulfill their degree requirements will add to their depth of understanding of specific scientific disciplines. As discussed earlier, one of the hypotheses regarding this QEP is that the *Foundations of Science* course will help to improve grades in subsequent science classes because: 1) students will be better prepared for those courses in terms of scientific knowledge and scientific reasoning; 2) students will have a more positive attitude toward science in general; and 3) students will choose subsequent science courses based on a more informed understanding of course content, which should translate into a stronger interest in the course and into better grades.

The members of the QEP Science Committees believe that the critical thinking skills learned in this course will carry over into other non-science courses as well. Students will ask more questions, evaluate arguments and evidence more critically, and write papers that are based on better evidence and sound arguments. Coupled with the scientific knowledge that they will gain, students will graduate with enhanced abilities to make more informed decisions as citizens of a democracy dependent upon an informed electorate. In summary, the predicted impact on student learning is uniformly positive, with no perceived negative impacts or difficulties associated with the addition of this course as an option in the General-Education science core curriculum.

VII. Timeline

The timeline for development and implementation of the QEP is outlined below.

- 1) Fall 2007 – Town Hall meetings to solicit ideas for the QEP and formation of the QEP Committee.
- 2) Spring 2008 – QEP selected and QEP Science Committee formed. Initial work on the QEP document, development of course design, curriculum proposals for the course, assessment design, and marketing plan.
- 3) Fall 2008 – Continued development of QEP document; submission of course proposals to the College Curriculum Committee, the University Curriculum Committee and the Academic Affairs Council; submission of course proposal to the Texas State System Board of Regents and the Texas Higher Education Coordinating Board; development of the Foundations of Science Exam and the informal CAT grading rubric; assessment of students using both the CAT and Foundations of Science Exam for baseline data purposes; survey of faculty regarding students' level of science literacy and the science faculty's course objectives related to nature of

- science; proposed QEP Evaluator; developed and initiated the marketing plan for the QEP.
- 4) Spring 2009 – Completed and submitted QEP document; QEP website opened to public; primary implementation of marketing plan (See Appendix IV for details). SAM Center begins promoting the QEP to students; host Case Study Conference with Dr. Herreid; develop course lectures and labs; administer CAT and Foundations of Science Exam again to obtain additional baseline data; send QEP Science Committee members to the Case Study Seminar in SUNY.
 - 5) Fall 2009 through Spring 2014 – Offer course and begin implementation of pre- and post-assessment of the QEP and the systematic evaluation of results (See Table 14 in Section X).

VIII. Organizational Structure

Dr. Mitchell Muehsam, Dean of Graduate Studies and Associate Vice President for Academic Affairs, is the SACS liaison for Sam Houston State University. As the QEP is a science initiative, the Provost (Dr. David Payne), the two Associate Vice Presidents for Academic Affairs (Dr. Richard Eglsaer and Dr. Mitchell Muehsam), the Dean of the College of Arts & Sciences (Dr. Jaimie Hebert), the department chairs housing the *Foundations of Science* course (Dr. Todd Primm and Dr. Chris Baldwin), the QEP Science Committee chair (Dr. Marcus Gillespie) and the faculty assigned to teach the course all have some level of responsibility for overseeing the implementation of the QEP initiative at the university, college and/or department level.

While the Provost has general oversight over all academic affairs to include the QEP, the Associate Vice Presidents for Academic Affairs work with the Provost to secure funding for the QEP, to support the marketing plan for the QEP, and to act as liaisons between the QEP Committee and the administration. The Dean of Arts and Sciences is responsible for staffing positions within the college, funding (in conjunction with the Office of Graduate Studies) graduate assistants for the labs, and providing capital expenditures for lab equipment and technology in the classrooms. The department chairs are responsible for faculty teaching assignments and faculty evaluation. Dr. Marcus Gillespie, the Chair of the QEP Science Committee, is responsible for coordinating the development of the *Foundations of Science* course and for preparing the QEP document. Additionally, Dr. Gillespie has signature authority over the QEP budget with Dean Hebert having oversight over Dr. Gillespie's budget authorizations. Dr. Gillespie also is responsible for preparing the SACS-mandated reports regarding these assessments, as well as the final results of the QEP project. The Director of Marketing is responsible for developing a marketing plan for the QEP, subject to the approval of the Chair of the QEP Science Committee and the Associate Vice Presidents for Academic Affairs. The Office of Institutional Research is responsible for implementing the research evaluation design, including comparative analyses of control group, treatment group and

baseline group outcomes observed in data obtained from the IDEA surveys, the CAT instrument, locally-developed assessments used to evaluate concurrent impact, and course grades used to evaluate the downline impact of the QEP initiative. This office also will assess and report treatment versus control differences and value-added change in relation to variations in program implementation. All activities related to the QEP are under the oversight of the Associate Vice Presidents for Academic Affairs and the Provost.

IX. Resources

The budget for the QEP is given below and reflects a realistic assessment of the costs associated with implementing the QEP. The budget was approved by the Provost.

Item	08-09	09-10	10-11	11-12	12-13	13-14	Totals
Lab TAs		20,000	20,000	30,000	30,000	40,000	140,000
Lab Coord.				45,000	45,000	45,000	135,000
Conf.	5,200	5,500	3,400	3,500	4,700	4,700	27,000
CAT Test	32,100	32,100	32,100	32,100	32,100	32,100	192,600
Marketing	1,000	24,000	1,000	1,100	1,100	1,200	29,400
Equipment	6,000	15,000					21,000
Seminar	4,500						4,500
Totals	48,800	96,600	56,500	111,700	112,900	123,000	549,500

X. Assessment

The Evaluation-Research Plan for the Foundations of Science QEP initiative is a recursive five-year strategy for the integrated evaluation of its outcomes, its implementation, and its assessment instruments and processes. The assessment instruments include two nationally-normed instruments, two locally constructed tools, one class-embedded assessment tool and two institutional tracking measures. The content of several instruments is displayed in Appendix I. Descriptions of each instrument are also provided in Appendix V. Figure 1 illustrates the configuration of the Foundations of Science (FS) QEP evaluation-research design. Table 13 summarizes and briefly describes all the assessment instruments and measures in the evaluation plan toolbox.

Figure 1. Evaluation-Research Design

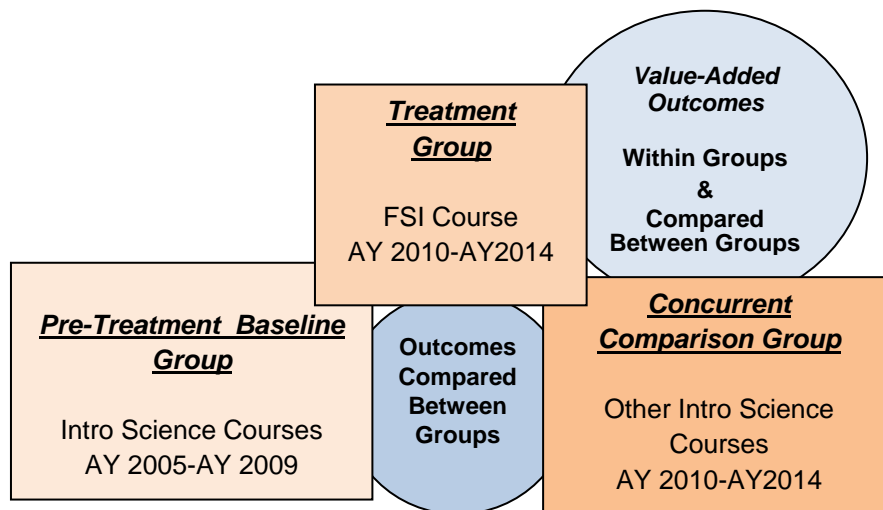


Table 13. Foundations of Science Initiative Assessment Instruments and Measures

CAT	The Critical Thinking Achievement Test (CAT)	Critical thinking Assessment Test (CAT) is a standardized test, externally developed with NSF support, consisting of 15 questions, most of which are short response. These questions involve real-world problems that students find interesting and engaging. The test was designed to measure those components of critical thinking that are considered most important by faculty members across disciplines.
FSE	Locally-developed Foundations of Science Exam (FSE)	The locally developed Foundations of Science Exam (FSE) is a 53-question instrument designed to measure student dispositions toward critical thinking, overall understanding of the scientific method, basic scientific literacy and the nature of science, and critical thinking.

FSCCG	FS/FS-Comparison - Course Grades (FSCCG)	The academic performance of students in the <i>Foundations of Science</i> course will be compared to both baseline data, as well as to the performance of students in comparison groups who did not take the <i>Foundations of Science</i> course within the same time periods. This will help determine if students in the <i>Foundations of Science</i> course master the learning required of their particular science course better, or as well as, <i>comparable</i> students in comparison courses. FS vs non-FS students' course grades will be analyzed for students who have been matched and grouped on background and preparation variables (i.e., SAT/ACT; HS %ile rank; major type; previous science; remediation at SHSU; classification; etc.)
FSSS	Foundations of Science Survey Student Dispositions toward Critical Thinking (FSSS)	The locally developed Foundations of Science Exam contains a subset of 12 questions related to Student Dispositions toward critical thinking. This subset of questions is designated as the FSSS instrument.
NSG	Grade in Next Core Curriculum Science Course (NSG)	Students taking the <i>Foundations of Science</i> course for their first science class will be flagged, and their performance in their next Core Curriculum science course will be tracked. These results will be compared to second science course performance of students in the comparison groups, who did not take the <i>Foundations of Science</i> as their first science class. This will help determine if the <i>Foundations of Science</i> course contributed to better performance in the students' second science course.
IDEA	IDEA Survey (IDEA)	The IDEA System is a commercial assessment product of the IDEA Center of Kansas State University and is used nationally by hundreds of universities each semester. The IDEA system will be used to measure students' motivation and desire to take the courses in which they are enrolled, as well as their perception of their improvement in critical thinking. IDEA responses in these areas will be compared to existing baseline scores for the standard science courses, as well as with concurrent comparison group responses.

TiLCHeRS	TiLCHeRS embedded assignment (TiLCHeRS)	The TiLCHeRS is an embedded classroom homework assignment that will be given on more than one occasion during the semester to students taking the <i>Foundations of Science</i> course. This assignment incorporates five of the six objectives of the course; i.e. all but the objective pertaining to the “appreciation of science.”
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The evaluation-research plan for the Foundations of Science QEP Initiative blends formative and summative assessment tactics and is designed to encourage improvements in both the initiative and in the larger institution by providing for timely reflection upon assessment output on student learning, on initiative implementation, and on the assessment processes through which evidence is generated. The University Director of Institutional Research and Assessment will lead the execution of the evaluation-research plan in close partnership with the Chair of the QEP Science Committee and designated members of the QEP Science Committee. To share the assessment results with the university population and to integrate the QEP assessment process into the university’s ongoing evaluation process, the QEP assessment will be included in the university’s Online Assessment Tracking Database (OATDB). Table 14 below summarizes the recursive five-year plan for the integrated assessment process.

Table 14. Evaluation-Research & Student Outcomes Assessment Plans

Evaluation-Research Plan
<p>Assessment objectives of the Foundations of Science QEP Evaluation Plan:</p> <ul style="list-style-type: none"> • To evaluate the success of the FS Initiative in relation to measured learning outcomes of its participants compared with the measured outcomes of Pre-Treatment Baseline ¹ and Concurrent Comparison Groups ². • To assess expected learning outcomes in relation to the value they have added to the preexisting knowledge and competence of participating students at the time of entry into the course.
<p>Assessment outcome expectations pre-determine the procedural directions that the evaluation research will take:</p> <ul style="list-style-type: none"> • If the measured learning of the FS Treatment Group consistently exceeds measured learning of the Pre-Treatment Baseline and Concurrent Comparison group, & if there is evidence of Value -Added learning, we may conclude that the FS Initiative strategies may be contributing to learning improvement intended by the Initiative. • However, if assessment outcomes do not meet these expectations, assessment results must be closely examined in relation to information about initiative implementation, assessment tools and procedures, and conditions external to the FS initiative to understand deviations from the expected.
<p>To facilitate understanding of both unexpected and expected outcomes, the following iterative steps are integral to the FS Evaluation Plan:</p> <ul style="list-style-type: none"> • Regular documentations and periodic observation of Implementation strategies and conditions to capture inadvertent and intentional strategy and condition changes • Review and evaluation of Assessment tools and procedures at least once each year by their users; by the QEP committee's Student Advisory Committee, and by the Science Committee, for purpose of improving measurement. • Report and Review Assessment results and Initiative updates to Science Committee after Fall and Spring semesters, and comprehensively in an Annual Review Meeting, after which summations of progress will be shared with the university community for feedback. • Initiate plans for improving the FS Initiative, along with any institutional plans to build upon its strategies, during the Annual Review Meeting. • Synthesize work-in-progress and summative evidence from student outcomes assessment, process evaluation and systemic impact evaluation to develop reports, papers, presentations and web publications for dissemination

Student Outcomes Assessment Plan							
Goal: Improvement of Students' Science Literacy, Critical Thinking Skills & Attitudes Towards Science.							
Targeted Student Learning Outcomes (SLOs)	SLO Assessment Instruments & Indicators ³	Who will be Measured?					
		Pre-Treatment Baseline Comparison Group		Foundations of Science Course Treatment Group		Concurrent Foundations of Science Comparison Course Group	
		Measures Used	When?	Measures Used	When?	Measures Used	When?
1. Apply scientific terminology pertaining to the nature and conduct of science	• Locally-developed Foundations of Science Exam (FSE)	FSE	F08,S09	FSE	F09-F13	FSE	F09-F13
	• The Critical Thinking Achievement Test (CAT)	CAT	F08,S09 Pre-Post	CAT	F09-F13 Pre-Post	CAT	F09-S10 Pre-Post
	• TiLCHeRS embedded assignment (TiLCHeRS)			TiLCHeRS	F09-F13		
2. Apply methods of reasoning used by scientists	• Locally-developed Foundations of Science Exam (FSE)	FSE	F08,S09	FSE	F09-F13	FSE	F09-F13
	• The Critical Thinking Achievement Test (CAT)	CAT	F08,S09 Pre-Post	CAT	F09-F13 Pre-Post	CAT	F09-S10 Pre-Post
	• IDEA Survey (IDEA)	IDEA	F05-S08	IDEA	F09-F13	IDEA	F09-F13
	• TiLCHeRS embedded assignment (TiLCHeRS)			TiLCHeRS	F09-F13		

<p>3. Analyze and evaluate common logical fallacies and perceptual biases that interfere with the ability to draw reasonable and/or correct conclusions</p>	<ul style="list-style-type: none"> Locally-developed Foundations of Science Exam (FSE) The Critical Thinking Achievement Test (CAT) Foundations of Science Survey of Students (FSSS)-<i>Dispositions toward Critical Thinking</i> 	<p>FSE</p> <p>CAT</p> <p>FSSS</p>	<p>F08,S09</p> <p>F08,S09 Pre-Post</p> <p>F08,S09</p>	<p>FSE</p> <p>CAT</p> <p>FSSS</p>	<p>F09-F13</p> <p>F09-F13</p> <p>F09-F13</p>	<p>FSE</p> <p>CAT</p> <p>FSSS</p>	<p>F09-F13</p> <p>F09-S10 Pre-Post</p> <p>F09-F13</p>
<p>4. Understand key concepts and theories from a variety of scientific disciplines</p>	<ul style="list-style-type: none"> Locally-developed Foundations of Science Exam (FSE) TiLCHeRS embedded assignment (TiLCHeRS) IDEA Survey (IDEA) FS/Comparison Course Grades (FSCCG) Grade in Next Core Curriculum Science Course (NSG) 	<p>FSE</p> <p>IDEA</p> <p>FSCCG</p>	<p>F08,S09</p> <p>F05-S08</p> <p>AY04-08</p>	<p>FSE</p> <p>TiLCHeRS</p> <p>IDEA</p> <p>FSCCG</p> <p>NSG</p>	<p>F09-F13</p> <p>F09-F13</p> <p>F09-F13</p> <p>F09-F13</p> <p>S10-F13</p>	<p>FSE</p> <p>IDEA</p> <p>FSCCG</p> <p>NSG</p>	<p>F09-F13</p> <p>F09-F13</p> <p>F09-F13</p> <p>F09-F13</p>
<p>5. Apply knowledge about science to evaluation of extraordinary claims</p>	<ul style="list-style-type: none"> Locally-developed Foundations of Science Exam (FSE) 	<p>FSE</p>	<p>F08,S09</p>	<p>FSE</p>	<p>F09-F13</p>	<p>FSE</p>	<p>F09-F13</p>

6. Distinguish science from pseudoscience by scientifically evaluating a wide variety of extraordinary claims	• Locally-developed Foundations of Science Exam (FSE)	FSE	F08,S09	FSE	F09-F13	FSE	F09-F13
	• Foundations of Science Survey of Students (FSSS)- <i>Dispositions toward Critical Thinking</i>	FSSS	F08,S09	FSSS	F09-F13	FSSS	F09-F13
7. Appreciate the role of science in our lives and the need for scientific literacy and critical thinking	• IDEA Survey (IDEA)	IDEA	F05-S08	IDEA	F09-F13	IDEA	F09-F13
	• Foundations of Science Survey of Students (FSSS)- <i>Dispositions toward Critical Thinking</i>	FSSS	F05-S08	FSSS	F09-F13	FSSS	F09-F13

¹ Pre-Treatment Baseline measures are assessment results obtained with FS Initiative Instruments from past members of the same population of students who will later participate in the FS Treatment.

² Concurrent Comparison Group measures will be the assessment results from students not participating in the FS Initiative at the time that it is being implemented

³ Detailed descriptions of Assessment Instruments and Indicators are provided in Appendix V

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APPENDIX I: DATA TABLES

Table 1: Responses to Survey for Selection of QEP Topic (n = 336)

The "Count" and % values refer to the number and percent of respondents that selected "Agree" and "Strongly agree"

Question 1: I think the project is aimed at a legitimate student learning need.

<u>Common Reader</u>		<u>Science</u>		<u>Writing to Succeed</u>	
<u>Count</u>	<u>%</u>	<u>Count</u>	<u>%</u>	<u>Count</u>	<u>%</u>
199	59.23	231	68.75	238	70.83

Question 2: I think there is sufficient data to demonstrate student need in this area.

<u>Common Reader</u>		<u>Science</u>		<u>Writing to Succeed</u>	
<u>Count</u>	<u>%</u>	<u>Count</u>	<u>%</u>	<u>Count</u>	<u>%</u>
143	42.56	193	57.44	184	54.76

Question 3: I think the project represents a reasonable effort to address the student need.

<u>Common Reader</u>		<u>Science</u>		<u>Writing to Succeed</u>	
<u>Count</u>	<u>%</u>	<u>Count</u>	<u>%</u>	<u>Count</u>	<u>%</u>
185	55.06	223	66.37	212	63.10

Question 4: I think this is a project the campus community will support.

<u>Common Reader</u>		<u>Science</u>		<u>Writing to Succeed</u>	
<u>Count</u>	<u>%</u>	<u>Count</u>	<u>%</u>	<u>Count</u>	<u>%</u>
140	41.67	203	60.42	155	46.13

**Table 2A: (FSCCG) FS/Comparison Course Grades
2003-07 Grade Distribution in 100-level Science Courses
(Pre-Treatment Baseline)**

Academic Year	D (%)	F (%)	Q (%)	Total D, F, Q (%)
2003 (n = 2869)	15.7	10.8	5.5	31.9
2004 (n = 3087)	15.1	10.9	5.6	31.6
2005 (n = 3303)	13.6	11.3	4.5	29.3
2006 (n = 4933)	15.9	13.0	4.2	33.1
2007 (n = 3956)	14.9	10.8	6.6	32.4

**Table 2B: Grade Distributions in 100-level General Education Classes vs.
100-level Science Classes (Fall 2007 and Spring 2008)**

Note: Difference is actually larger than shown because General Education values include science courses.

Fall 2007 Grade Distribution Comparison			Spring 2008 Grade Distribution Comparison		
Grade	100-level	Science	Grade	100-level	Science
A	24.96%	11.0%	A	23.96%	12.63%
B	26.91%	22.7%	B	28.02%	24.41%
C	22.17%	25.8%	C	21.96%	28.94%
D	10.72%	18.5%	D	9.24%	14.2%
F	11.01%	15.1%	F	8.18%	9.49%
Q	3.26%	6.2%	F	8.41%	10.03%
W	0.87%	0.0%	W	0.14%	0.12%
X	0.11%	0.0%	X	0.05%	0.06%

Table 3: Fall 2005-Spring 2008 IDEA Survey Responses of Students in Introductory Science Courses on Interest in Science Courses

Note: Data is from 66 courses; %s shown are students who selected answers 4 and 5

1 = Definitely False 2 = More False Than True 3 = In Between
 4 = More True Than False 5 = Definitely True

1. I had a strong desire to take this course.
 - a) Percent Range for options 4 and 5: **12% to 76%**
 - b) Percentage of Positive Responses (Responses of 4 and 5): **35.64%**
 - c) Number of sections in which half or more of students indicated a positive desire to take the course: **14 or 21.2%** * Six of the 14 (42.8%) were from the same science course, Astronomy.

2. I really wanted to take this course regardless of who taught it.
 - a) Percent Range for options 4 and 5: **15% to 80%**
 - b) Percentage of Positive Responses (Responses of 4 and 5): **30.90%**
 - c) Number of sections in which half or more of students indicated a positive desire to take the course regardless of who taught it: **4 or 6%** * All four were from the same science course, Astronomy.

Table 4: Faculty Survey Responses Regarding Student Knowledge of Science Facts

n = 34

1. Most students in my core curriculum classes recognized scientific concepts with little difficulty.

Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
14.7%	29.4%	26.5%	11.8%	11.8%

2. Most students in my core curriculum classes often recognized the same scientific facts from one class session to another if they were presented in different contexts.

Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
20.6%	29.4%	23.5%	11.8%	11.8%

**Table 5: Results of Foundations of Science Exam
(FSE - Basic Scientific Literacy)**

n = 411

Note: The number in parentheses indicates the percent correct.
The correct answer is italicized.

1. The seasons are caused by: (34.8%)
 - a. the changing distance of the earth from the sun
 - b. *the tilt of the Earth's axis*
 - c. variations in solar energy output
 - d. All of the above
 - e. A and B only
2. The statement that carbon dioxide in the atmosphere traps heat energy is: (56.9%)
 - a. an opinion
 - b. a theory
 - c. *a fact*
 - d. a hypothesis
3. The basic unit of heredity is the: (65.7%)
 - a. atom
 - b. molecule
 - c. *gene*
 - d. chromosome
 - e. cell
4. The gender of a human baby is determined by: (68.6%)
 - a. *the father*
 - b. the mother
 - c. either the father or mother
5. If a 100 pound cannon ball and a 20 pound bowling ball, of the same diameter, are dropped from the same height, at the same time: (52.8%)
 - a. the cannon ball will hit first
 - b. the bowling ball will hit first
 - c. *the cannon ball and bowling ball will hit at the same time*
 - d. it is impossible to predict what will happen
6. People should wear seatbelts because of what law of physics? (54.7%)
 - a. First Law of Thermodynamics
 - b. Second Law of Thermodynamics
 - c. *Conservation of momentum*
 - d. mass-energy equivalence
 - e. none of the above
7. Which of the following can give rise to genetic change within an organism? (46.6%)
 - a. the behavior of an organism
 - b. chromosomal translocation
 - c. mutations in genes
 - d. all of the above
 - e. *B and C only*

Table 5 - Continued

8. Speed limits for curves on roads are based on: (26.8%)
a. the Coriolis force b. the Bernoulli Principle c. Coloumb's Law
d. *centrifugal force* e. centripetal force
9. The light from stars is generated by: (33.3%)
a. burning of molecules b. nuclear fission
c. *nuclear fusion* d. radioactive decay
10. An antibiotic can be used to kill: (57.7%)
a. viruses b. *bacteria* c. both A and B d. neither A nor B
11. A thick layer of clay (which is made of very small particles) could have been deposited: (20.5%)
a. on a beach
b. *in the deep ocean*
c. in a windy desert
d. on the side of a mountain
e. any of the above are equally likely
12. The presence of ancient layers of rock that are folded indicates that:
a. a landslide occurred (17.3%)
b. a mountain range once existed in the area
c. a plate collision occurred
d. All of the above
e. *B and C only*
13. The rate of radioactive decay (which is used to date rocks and artifacts): (26.8%)
a. can vary with changes in temperature
b. can vary with changes in pressure
c. can vary over time
d. all of the above
e. *never changes*
14. According to the evidence currently available, which of the following best expresses the status of the Big Bang Theory? (38.9%)
a. It is a complete theory that has successfully answered all questions regarding the origin of the universe.
b. *It satisfies all of the requirements of a well-developed scientific theory even though it is not complete.*
c. It has very little theoretical or observational evidence to support it, but it's "the best theory" that we've got at this time.
d. It has not yet been able to generate predictions which can be tested.
e. Both C and D

Table 5 - Continued

15. The claim that Atlantis was a *continent* that sank is: (21.5%)
- plausible given the information provided by Aristotle
 - plausible given our understanding of tectonic processes
 - both a and b
 - impossible given the composition of continents*
 - it is impossible to say at this point whether it is plausible or not
16. The presence of rock layers of different types in the Grand Canyon, many of which are separated by erosional surfaces, indicates that: (53.8%)
- the area was covered by ash from numerous volcanic eruptions
 - the layers were deposited in a single flood event
 - the layers were deposited in different environments, discontinuously, over long periods of time*
 - the layers were deposited continuously in the same environment over long periods of time
 - it is impossible to know how to interpret this information
17. Which of the following is thought to be false according to the Theory of Evolution? (37.5%)
- Genetic change is random
 - Isolation of groups within a species can lead to speciation
 - Homologous structures and vestigial structures are evidence of “descent with modification”.
 - Evolution is goal-directed (purposeful)*
 - All of the above are thought to be false by evolutionary biologists

**Table 6: Results of Foundations of Science Exam
(FSE - *Understanding of the Nature of Science*)**

n = 411

Note: The number in parentheses indicates the percent correct.
The correct answer is italicized.

1. On what basis are scientific theories judged? (58.4%)
 - a. Their ability to make accurate predictions.
 - b. Their ability to explain a range of related observations.
 - c. Their consistency with laws of nature and known facts.
 - d. *All of the above*
 - e. A and B only
2. Which of the following is TRUE? (55%)
 - a. Science can solve any problem or answer any question.
 - b. Science can use supernatural explanations if necessary to account for an observation.
 - c. *Scientific theories are tentative in nature.*
 - d. All of the above are true.
 - e. Only B and C are true.
3. Well supported scientific ideas develop from hypotheses, to theories, and then to laws of nature. (6.6%)
 - A. This is true
 - b. *This is not true*
 - c. Sometimes this is true
4. In spite of decades of scientific research on many topics, such as earthquakes and tornadoes, scientists still cannot predict when and where they are going to happen. This is because: (22.4%)
 - a. phenomena like these do not obey natural laws (i.e. rules).
 - b. phenomena like these sometimes obey natural laws, but not always – and that makes it difficult to predict them.
 - c. *phenomena like these do follow natural laws, but the laws are complicated and difficult to apply.*
5. If a researcher has complete control over the factors/variables that affect the process under study, the researcher can: (For example, a physicist studying the formation of snowflakes under laboratory conditions could...) (54.5%)
 - a. *determine cause-effect relationships among factors*
 - b. determine correlations among variables
 - c. determine neither cause-effect relationships nor correlations

Table 6 - Continued

6. Which of the following is true of the *experimental* approach to research? (57.9%)
- It allows hypotheses to be tested.
 - It allows the scientist to control all relevant variables in the experiment.
 - It allows cause-effect relationships to be determined.
 - All of the above*
 - A and B only.
7. If a researcher CANNOT control the variables related to his topic of research, but can collect information about those factors, he can: (For example, a geographer who is studying the relationship between income level and crime could...) (59.9%)
- determine cause-effect relationships among factors
 - determine correlations among variables*
 - determine neither cause-effect relationships nor correlations

Table 7: Science Faculty Survey Responses Regarding Students' Ability to Use Scientific Concepts

n = 34

1. Most students in my core curriculum classes successfully explained connections between related principles learned in the course.

Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
23.5%	29.4%	14.7%	17.6%	14.7%

2. Most students in my core curriculum classes successfully analyzed and drew conclusions about simple science problems, if they had learned about pertinent principles and had access to pertinent evidence.

Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
23.5%	32.4%	20.6%	8.8%	14.7%

**Table 8: Results of Foundations of Science Exam
(FSE - Critical Thinking Skills)**

n = 411

Note: The number in parentheses indicates the percent correct.
The correct answer is italicized.

1. Melissa, a high school student, found some large footprints in the snow while hiking in a remote area of Washington State. The prints, which were several days old based on the melt pattern, were human-like in appearance, but much bigger. When Melissa returned home, she told her friends that she had found definite proof that Big Foot exists. After all, she said, "What else could have made the prints?" Melissa was absolutely convinced that she was correct. Based on this information, Melissa's conclusion is: (78.3%)
 - a. definitely correct
 - b. almost certainly correct
 - c. either a and b
 - d. *not justified*

2. Matthew listened to a speaker who claimed that he had seen an alien spacecraft (UFO) hover above the ground near his deer stand while he was out alone one night on a hunting trip. Matthew had always thought that people who made such claims were a bit crazy, but he was very impressed by the sincerity of the speaker, who clearly believed what he was saying. Given this information, which of the following is reasonable for Matt to conclude regarding this claim? (81.5%)
 - a. Matthew should conclude that the man really had seen an alien spacecraft because of his sincerity.
 - b. Matthew should conclude that the man is crazy or a liar.
 - c. *Matthew is justified in doubting that the object was an alien spacecraft, but he cannot claim that it definitely wasn't.*
 - d. Matthew should conclude that, whatever the object was, it was not an alien spacecraft.

3. Karen had recently broken up with her boyfriend and was experiencing periods of crying and lethargy, as well as problems with insomnia. She was becoming so depressed that she didn't care if she lived or died. After two weeks of feeling badly, she went to her physician who prescribed a common anti-depressant; however, Karen didn't like the idea of taking drugs and so she stopped taking them after two days. A few days later, a friend of hers suggested she try the natural herb called St John's Wort. After taking it for three weeks, she said that she felt restored to her normal self and so she continues to take two capsules a day because she has become a "firm believer" in the benefits of St. John's Wort. Given this information, which of the following statements is correct? (52.8%)

Table 8 – Continued

- a. Karen’s experience provides strong evidence that St. John’s Wort is beneficial in treating depression.
 - b. Others that suffer from depression should probably take the herb as well.
 - c. Both a and b
 - d. *Nothing can be concluded about the usefulness of St. John’s Wort based on Karen’s experience.*
 - e. St. John’s Wort is definitely not effective at treating depression.
4. A single study of 300 people found that individuals who have a natural crease in their ear lobes are more likely to suffer from heart disease than are individuals that do not have such a crease. Based on these findings, which of the following can be concluded? (62.5%)
- a. Ear lobe creases cause heart disease
 - b. Heart disease causes ear lobe creases
 - c. Either A or B must be true
 - d. *Neither A nor B is true*
5. John claims that spiritual beings are always around him and that they help him make decisions in his daily life about such things as which courses to take each semester and what car to buy. However, he claims that they do not give him specific information, such as yes or no answers to questions, nor do they make predictions about what will occur. Is his claim that these beings help him make personal decisions subject to scientific testing? (61.6%)
- a. Yes
 - b. No
 - c. Possibly
6. Maria did a study in which she found that people who had lived together before they were married were more likely to get divorced than those who did not live together before marriage. Maria concluded that living together before marriage increases the risk of divorce. Maria’s conclusion is an example of a/n: (45.5%)
- a. law
 - b. *hypothesis*
 - c. theory
 - d. fact
 - e. operational definition
7. Consider the following information: An abnormally high number of cancers occurred in an area in Missouri in which people derived their water from a river which received runoff from farm fields sprayed with several herbicides. One of these herbicides is called ‘Weed-be-Gone’. Thinking that Weed-be-Gone causes cancer, the researchers took blood samples of the people who had developed cancer and found that the herbicide was, in fact, in their blood and fat tissues. They therefore concluded that ‘Weed-be-Gone’ was the cause of the cancer. Based on the information provided, this conclusion. (16.3%)
- a. is definitely true
 - b. is strongly supported by the evidence
 - c. both A and B
 - d. *is not justified*
8. A researcher wanted to study the hypothesized benefits of a treatment (pill) designed to help obese people lose weight by curbing their appetites. In the study, 100 people of similar age and weight were given the pill, 100 people were given a placebo pill with no active ingredients (but the subjects thought it was a real pill), and 100 people were given nothing. All 300 people followed the same exercise routine, all were non-smokers, all were of similar age, and

Table 8 – Continued

all had wanted to lose weight. The people were randomly placed in each group and participants stayed in the project for one year. The following data was obtained from the study. (37.7%)

	Treatment Pill	Placebo Pill	No Pill
Average Weight loss	5 pounds	4.8 pounds	3.2 pounds

Based on this data, the researchers stated that their hypothesis had been strongly supported. Is this conclusion warranted?

- a. Yes b. No c. either A or B, it's a matter of opinion

9. A researcher wanted to study the hypothesized benefits of a cancer treatment using a new chemical 'cocktail' developed by a pharmaceutical company. In the study, 200 people were given the new chemotherapy treatment and 200 people were given a traditional chemotherapy treatment. Two hundred additional people were studied but, at their own request, they were not given chemotherapy because of their concerns over potential side effects. The people who were treated completed the prescribed chemotherapy routine, and all participants were non-smokers, were of similar age, and were in similar medical condition at the beginning of the study. The side effects of the new therapy were no different from those of the traditional therapy. The following data was obtained from the study. (69.3%)

	New Therapy	Traditional Therapy	No Therapy
Average survival time after treatment	5 years	3 years	2 years

Based on this data, the researchers stated that they would recommend the new chemotherapy treatment to their future patients. Is this recommendation warranted?

- a. Yes b. No c. either A or B, it's a matter of opinion

Table 9: Results of the Critical Thinking Assessment Test (CAT)

- A. Informally graded version using locally-developed rubric.
(n = 204, max. possible score = 43)

N	High score	Low score	Average score
204	40 (92%)	12 (28%)	26.7 (62.1%)

- B. Formally graded version using the official rubric.
(n = 76, max. possible score = 38)

N	High score	Low score	Average score
76	28 (74%)	1 (2.6%)	15.03 (39.6%)

**Table 10: Results of the Science Faculty Survey Concerning
Science-related Course Content**

n = 34

1 = not at all 2 = very little 3 = a little 4 = moderately 5 = strongly

To what extent did your teaching in core curriculum science courses emphasize...

1. introducing and reinforcing scientific facts?	1 (8.8%)	2 (5.9%)	3 (23.5%)	4 (14.7%)	5 (44.1%)
2. helping students understand relationships between scientific facts?	1 (5.9%)	2 (11.8%)	3 (11.8%)	4 (26.5%)	5 (44.1%)
3. providing examples of scientific principles applied to daily life?	1 (20.6%)	2 (20.6%)	3 (26.5%)	4 (14.7%)	5 (11.8%)
4. emphasize and analyzing scientific phenomena in relation to scientific principles?	1 (29.4%)	2 (8.8%)	3 (35.3%)	4 (8.8%)	5 (14.7%)
5. giving students practice in explaining phenomena in relation to scientific principles?	1 (14.7%)	2 (8.8%)	3 (20.6%)	4 (23.5%)	5 (32.4%)
6. explaining and/(or) demonstrating aspects of the scientific method?	1 (11.8%)	2 (5.9%)	3 (17.6%)	4 (35.3%)	5 (29.4%)
7. the distinction between scientific and nonscientific ways of thinking?	1 (11.8%)	2 (8.8%)	3 (26.5%)	4 (32.4%)	5 (20.6%)
8. the difference between correlation and causation when designing research projects and interpreting data?	1 (2.9%)	2 (8.8%)	3 (11.8%)	4 (32.4%)	5 (44.1%)
9. sources of experimenter bias and the need for research protocols to eliminate bias in research design and data interpretation?	1 (5.9%)	2 (2.9%)	3 (8.8%)	4 (29.4%)	5 (50.0%)
10. scientific reasoning/critical thinking?	(5.9%)	2 (2.9%)	3 (11.8%)	4 (26.5%)	5 (52.9%)
11. the difference between hypotheses, laws and theories?	1 (2.9%)	2 (8.8%)	3 (8.8%)	4 (20.6%)	5 (58.8%)

Table 10 - Continued

12. the need for internal consistency when developing scientific theories (i.e., the requirement that the theory be consistent with observed facts)?

1 (5.9%) 2 (11.8%) 3 (26.5%) 4 (23.5%) 5 (32.4%)

Table 11: Fall 2005-Spring 2008 IDEA Survey Responses re. the Degree to Which Critical Thinking was Emphasized in Introductory Science Courses

Note: Data is from 66 courses; %s shown are students who selected answers 4 and 5

1 = no apparent progress 2 = slight progress 3 = moderate progress
 4 = substantial progress 5 = exceptional progress

1. Learning to apply course material (to improve thinking, problem solving, and decisions).
 - a) Percent Range for options 4 and 5: **18% to 85%**
 - b) Unweighted average of percent values for options 4 and 5: **53.78%**

2. Learning to analyze and critically evaluate ideas, arguments, and points of view.
 - a) Percent Range for options 4 and 5: **17% to 85%**
 - b) Unweighted average of percent values for options 4 and 5: **42.4%**

Table 12: Student Survey of Interest in the Proposed FS Course

n = 923

1. If you had to compare the new course described above to traditional science courses offered to satisfy the core curriculum requirements, how interested would you be in the new course?

Extremely Uninterested	Somewhat Uninterested	Neutral	Somewhat Interested	Extremely Interested
12.7%	10%	18%	33%	26.3%

2. If you were just starting your science coursework, how likely would it be that you would take the new course?

Definitely Not	Probably Not	Don't Know	Somewhat Likely	Very Likely
7.4%	9.3%	17.7%	34.5%	31.2%

APPENDIX II: DESCRIPTION OF THE PROPOSED CHEMISTRY COURSE AND COURSE REVISIONS FOR PHYSICS COURSE

In lieu of participating directly in the QEP, the Department of Chemistry chose to develop a new *Chemistry and Society* course (Chemistry 135) with the goal of providing students with a greater understanding of issues related to the use of chemicals in the modern world. As such, it will focus on enhancing scientific literacy as regards the discipline of chemistry and will enable students to make more informed decisions regarding chemistry-related issues. The new Chemistry course must undergo a 2-year review and approval process (standard for all new courses), and will be implemented in the fall of 2010. The Physics department chose to modify one of its existing courses, Physics 135, to include guest speakers whose presentations are intended to help students better understand the relevance of physics in their daily lives and to engage students in discussions and deliberations regarding a variety of issues related to science and society. The Physics department will implement the changes in the Physics 135 course in the fall of 2009.

Because these courses will not focus upon the development of scientific reasoning and critical thinking, as will the *Foundations of Science* course, the science departments decided that the Physics and Chemistry courses would not be included as part of the formal QEP Learning Initiative.

APPENDIX III: LETTER OF SUPPORT FROM DR. JAMES TREFIL

George Mason University

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Sept. 4, 2008

To members of the Curriculum Committee and members of the SACS Review Committee,

I am writing this letter in support of the proposed "Foundations of Science" course which is the centerpiece for the Quality Enhancement Plan for Sam Houston State University. Having spent most of my professional career attempting to promote science literacy by teaching introductory science courses that emphasize a synthesis of the key ideas in science, as well as authoring both college-level science textbooks and popular science books for the general public, I understand the need to teach science from an integrated standpoint in order for students to develop basic scientific literacy. Most professionals in science education would agree that the traditional approach of teaching science as a set of facts and vocabulary terms, as is often done in many introductory science classes, is ineffective in conveying a coherent, well-rounded view of the nature and conduct of science, and of the universe as understood by scientists. Of equal or greater importance is the fact that this approach fails to teach scientific reasoning and critical thinking and thus fails to prepare students for their future roles as intelligent citizens.

The "Foundations of Science" course that is being proposed by the QEP Committee will, I believe, enhance scientific literacy and increase students' desire to learn science by using scientific information and methods to evaluate extraordinary claims in which students are interested. This approach also will make the material more relevant to the students, and will significantly improve their critical thinking skills. These reasoning skills will benefit students in their undergraduate education, and throughout the rest of their lives.

Hoping that these remarks will be helpful in your deliberations, I remain

Yours Truly,



James Trefil

Clarence J Robinson Professor of Physics

APPENDIX IV: MARKETING PLAN

- December 2008:
- 1) Finalized Marketing Plan.
 - 2) Develop website.
 - 3) Began placing informational decals about QEP on paycheck envelopes. Continued use of decals through end of January, 2009.
- January, 2008
- 4) Provost sent letter to university regarding upcoming QEP visit.
 - 5) Article regarding QEP placed in the *Houstonian* and the *Huntsville Item*, the school newspaper and local newspaper, respectively.
- February, 2009
- 6) Held luncheon with key students and members of the Sam Advising Center, the Reading Center, and the Writing Center to provide information about the QEP/FS course.
 - 7) Sent e-mails to students and faculty regarding QEP and the FS course.
- March 2009
- 8) Placed informational banners; sandwich boards and posters about the QEP at key locations on campus.
 - 9) Set up informational “table tents” at cafeterias on campus.
 - 10) Provide informational brochures to Advising Center.
 - 11) Ran articles in *Houstonian* and *Huntsville Item*.
 - 12) 3000 T-shirts with QEP logos distributed to students at key locations on campus.

The total cost of the marketing plan was approximately \$24,000.

APPENDIX V: ASSESSMENT INSTRUMENTS AND THEIR ADMINISTRATION

1. The Critical Thinking Achievement Test (CAT)

The (CAT) is a standardized test which consisting primarily of 15 short response questions. According to Dr. Barry Stein at the Institute on Quality Enhancement and Accreditation in Orlando, Florida, the questions on the CAT involve real-world problems that students find interesting and engaging, thus contributing to their motivation to do well. While not timed, most students finish the test within 45 minutes. The test was designed to measure those components of critical thinking that are considered most important by faculty members across disciplines. These critical thinking skills are listed below and the QEP Learning Objectives (See Section IV) with which they align are indicated by the number/s in parentheses:

- 1) Separate factual information from inferences that might be used to interpret those facts. (3)
- 2) Identify inappropriate conclusions. (2, 3)
- 3) Understand the limits of correlational data. (1, 2, 3)
- 4) Identify evidence that might support or contradict a hypothesis. (1, 2, 3)
- 5) Identify new information that is needed to draw conclusions. (1, 2, 3)
- 6) Separate relevant from irrelevant information when solving a problem. (1, 2, 3)
- 7) Learn and understand complex relationships in an unfamiliar domain. (1, 2, 3, 6)
- 8) Interpret numerical relationships in graphs and separate those relationships from inferences. (1, 2)
- 9) Use mathematical skills in the context of solving a larger real world problem. (1, 2)
- 10) Analyze and integrate information from separate sources to solve a complex problem. (1, 2, 3, 4, 5)
- 11) Recognize how new information might change the solution to a problem. (1, 2, 3, 4, 5)
- 12) Communicate critical analyses and problem solutions effectively. (6)

Skills 1, 2, 3, 4, 5, 6, 7, 10, 11, and 12 relate either directly or strongly to the goals of the *Foundations of Science* course, and skills 8 and 9 are tangentially related. For this reason, and those discussed below, we believe that this test is the best available standardized test to assess the learning outcomes of the *Foundations of Science* course.

The test can be used in a pre-test/post-test design to evaluate the effects of a single course or to evaluate the effects of many college experiences. The inter-rater reliability for graders is = 0.82 and the test-retest reliability of CAT version 4.0 was > 0.80. The test appears to be culturally fair, as neither gender, race, nor ethnic background are significant predictors of overall performance on the test.

Administering the CAT Exam as Part of the QEP

Students in designated sections of the *Foundations of Science* course will be given the CAT exam at the beginning and end of the semester in the form of a pre-test and post-test. All tests will be graded using the modified rubric, and a subset of these exams will be formally graded using the rubric for the test. Because of the time and cost requirements for grading and administering the exam, it will be given to different sections of the course on an alternating basis, with approximately half of the sections tested in any given semester. This ensures that each section of the *Foundations of Science* course will be tested over the course of a year. The exact number of exams being formally graded will be determined based on the requirements for statistical validity. Because the course content among sections of the *Foundations of Science* course is very similar, tests from all course sections can be combined into a single pool from which a representative sample can be selected for scoring. The tests will be coded in such a way as to allow the data to be disaggregated to analyze individual course differences. Once the tests are scored, they are sent to Tennessee Tech University, which grades the test forms and analyzes the data. The results will then be sent back to the university.

Administering the CAT to Collect Baseline Data Prior to Implementation of the Course

To obtain baseline data prior to the implementation of the course, 204 students in introductory Physical and Historical Geology and Weather and Climate science classes were given the CAT exam in the fall2008 semester, with the process repeating in Spring 2009. Each of these courses is part of the science core curriculum at Sam Houston State University and each is taught by an instructor that will teach the *Foundations of Science* course. This group of students will serve as a pre-test control group for purposes of comparing their ability to think critically and scientifically relative to that of the students that will take the *Foundations of Science* course beginning in the fall of 2009. For purposes of minimizing the confounding effects that could arise by including students that have taken multiple science classes, students were asked to indicate how many college-level science courses they had completed on their scoring forms and only those tests taken by students completing their first or second science class were selected for formal grading.

To encourage students to take the test seriously, they were told that the test was an extra credit assignment and that they would receive 4% of their course grade for their effort on the test. They also were told that the test results reflect on the quality of the university and are used to assess student learning for purposes of accreditation. This information was contained in a prepared statement that was read to the students prior to beginning the exam.

For purposes of awarding extra credit, *all* tests were scored using a locally-developed, simplified rubric in which specific point values were assigned for various types of

responses. This overall approach was deemed necessary to motivate students to do their best, while also avoiding the possibility of penalizing them for doing poorly over material that they had not been taught. The scores were recorded on a form that was separate from the test itself thus ensuring that no markings would appear on those tests scored formally.

Those tests randomly selected to be formally scored as part of the QEP baseline database were scored using the rubric and procedures designed for the CAT test by Tennessee Technological University. Fifteen faculty members graded the tests at a 6.5 hour session on December 12, 2008.

The scores acquired for Fall 2008, and those that will be acquired for Spring 2009 semester will constitute part of the baseline data to which the performance of the students in the *Foundations of Science* course will be compared.

Administering the CAT to Students in the *Foundations of Science* Course

Students enrolled in the *Foundations of Science* course will be given the test at the beginning and end of the semester. This allows for pre-test and post-test comparisons to be made for purposes of assessing the efficacy of the course in enhancing the critical thinking ability of our students. In addition, the scores taken at the end of the course will be compared to the baseline scores from Fall 2008 and Spring 2009. Data regarding the reliability of the CAT exam indicates that if no attempt is made to enhance critical thinking in a course, then there will be no statistically significant difference between the pre-test and post-test scores. Therefore, this exam should clearly identify any changes in critical thinking resulting from having taken the *Foundations of Science* course.

In order to motivate the students in the *Foundations of Science* course to do their best on both the pre-test and post-test, they also will be told that the CAT exam will count as extra credit and that they will receive the higher of the two grades that they earn. The same procedures described previously will be used to score the assessments and only exams from students taking their first or second science course at the college level will be formally graded. This approach ensures the equivalency of the procedures used to acquire and compare the baseline data with the data from the *Foundations of Science* courses, as well as that between the pre-test and post-test scores within the *Foundations of Science* course. If time and budget allow, the Science Committee also may choose to evaluate students who have taken other science courses prior to taking the *Foundations of Science* course to determine if these students show an improvement in their critical thinking skills.

Assuming that the results are as expected; i.e., the students in the *Foundations of Science* course do better than those which did not take the course, then the Science Committee will confine its future assessments to pre-tests and post-tests within the *Foundations of Science* course. If the difference is *not* statistically significant, then the

comparison between traditional science courses and the *Foundations of Science* course will be repeated in subsequent semesters until a difference is established. If the results of the comparisons do not differ significantly, this will indicate that the course is not accomplishing its goal of enhancing critical thinking and will require modification. Consequently, changes will be implemented in course design and the CAT exam will be given to students in both the standard science classes and the *Foundations of Science* classes each semester in order to track the results of the course modifications.

The Results of the Fall 2008 Baseline Assessment Using the CAT Instrument are provided in Table 10.

2. Locally-Developed Assessment - FSE, FSSS

In addition to the assessments based on the CAT instrument, the Science Committee developed its own multiple-choice instrument called the Foundations of Science Exam, a 53-question multiple-choice exam designed to measure student dispositions toward critical thinking, overall understanding of the scientific method, basic scientific literacy, the nature of science, and critical thinking. This test was given to 411 students in the fall 2008 and will be given again in spring 2009, and will serve as baseline data. Students were motivated to do their best by being awarded extra credit based on the percent of correct responses they had on those questions that dealt with factual information.

Once the *Foundations of Science* course is implemented, the exam will be given to students at the beginning and at the end of the semester and will serve as a pre-test/post-test assessment within the course. To encourage the students to do their best, they will be told that the test will count as a test grade, and that the grade they receive will be the highest of the two test scores. For QEP assessment purposes, the pre-test and post-test scores will be compared to determine if there is a significant improvement in student performance.

This test will also be given to students in traditional science courses at the end of each semester. To encourage them to do well, they will be told that they will receive extra credit worth up to 4 percent of their grade based on their performance on the exam. The committee recognizes that there is a difference in the 'motivational factor' in this testing procedure in that the test counts as a *test grade* in the *Foundations of Science* course, but as *extra credit* in the standard classes; however, the committee believes that this will not compromise the ability to compare the performance of the two groups of students. Furthermore, the students in the *Foundations of Science* course will take the test twice, thereby allowing us to do a direct comparison to determine if their performance actually improves as a result of having taken the course. Finally, if their performance does improve, and if the students in the *Foundations of Science* course do better than those in the standard courses on this exam, the results will be mutually reinforcing. The results of the Foundations of Science Exam that was given to 411

students in the fall semester, 2008 are shown in Table 6 (Literacy), Table 7 (Nature of Science), and Table 9 (Critical Thinking).

In addition, the grades on these exams can be compared to those on the CAT to determine their level of correlation. For this purpose, the comparison will be matched; i.e., the scores for students that were formally-graded using the CAT exam will be compared to the scores of the same students after they have taken the Foundations of Science exam.

The Foundations of Science Survey of Students (FSSS) is a distinct scale which is administered with the FSE. The twelve multiple choice items of this survey measure student dispositions toward critical thinking, as well as testing basic scientific literacy, understanding of the nature of science, and critical thinking.

3. Course Embedded Assessment - TiLCHeRS Assignments

As with any course, students in the *Foundations of Science* course will be given a combination of homework assignments and tests during the semester which will serve to indicate their level of learning. These tests and assignments will include both critical thinking components and specific questions concerning the science content of the course. These assignments should enhance student performance on the CAT because the reasoning skills required for many of them will be similar to those required for the CAT instrument.

One of the key assignments given on more than one occasion during the course is the TiLCHeRS assignment. This assignment incorporates all of the courses objectives except the one pertaining to 'appreciation of science'. Accordingly, it is an excellent means of evaluating students' understanding of course material.

Student mastery of the specific science content (i.e., facts and theories) of the course will be assessed on course exams. No attempt will be made to use standardized tests to assess this aspect of the course, as the committee is unaware of any test that would be appropriate for our purposes.

4. Institutional Tracking and Comparing Student Performance in FS and Subsequent Classes

The academic performance of students taking the *Foundations of Science* course as their first science class will be compared to baseline and comparison groups, and will be compared in subsequent science courses to the performance of students that did not take the FS course. This will require a form of 'tracked assessment' in which the grades earned by *Foundations of Science* students in their second science course are compared to those of similar *non-Foundations of Science* students. This will be done to determine if the *Foundations of Science* course resulted in better performance in the second science course. This assessment will require that the *Foundations of Science* students be 'tagged' so that they can be tracked and distinguished from those students

who did not take the course, but who are also completing their second science course. This effort will require assistance from the Office of Institutional Research and the Registrar's Office. At no time will the results of individual student performance be made available.

5. Measuring Attitudes and Self Reported Learning with the IDEA Survey

Finally, as an indicator of enthusiasm for the course, the responses on the IDEA course evaluation system will be employed. IDEA is a set of nationally validated and normed, standard scales. Among other things they measure students' motivation and desire to take the courses in which they are enrolled, as well as their perception of their improvement in critical thinking. IDEA responses in these areas will be compared to the existing baseline scores for the standard science course, as well as with concurrent comparison group responses.