Science Education Task Force

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Appendices

Appendix 1

Membership of the Science Education Task Force

Member	Office/Department
Rich Givens, Chair	Assistant Provost/Chemistry
Marylee Southard	Chemical & Petroleum Engineering
Sally Frost Mason	Dean of CLAS/Molecular Biology
Kris Krishtalka	Natural History Museum
Don Steeples	Geology
Jim Woelfel	Western Civilization
Helen Alexander	Ecology & Evolutionary Biology

Thomas Schreiber	Psychology
John Hoopes	Anthropology
Joe Heppert, Vice-Chair	Chemistry
Steve Shawl	Physics & Astronomy
Susan Gay	Teaching & Leadership/Mathematics
Jim Ellis	Teaching & Leadership/Science Education
David Darwin	Civil Engineering
Val Stella	Pharmaceutical Chemistry
Keith Russell	Dean, Libraries

Appendix 2

Charge to the Science Education Task Force

October 22, 1999

To: Task Force Members

From: Robert Hemenway

Re: Science Education Task Force

Thank you for agreeing to serve on the Science Education Task Force. Rich Givens will chair the committee and Joe Heppert will be vice chair.

The recent actions by the State Board of Education provided the impetus for the formation of this task force, but the Board's decision is certainly not the only reason for KU to focus on science education. The national furor over the Board's actions presents KU with a unique opportunity to position itself as a national leader in science education. In my convocation speech to the faculty in September (copy attached), I indicated that the Board's action raises the question of how well we are educating our students in science, both majors and non-majors, and what we can do to promote scientific literacy among the general public. If we believe that these attempts to undermine the teaching of science grow from a misunderstanding of scientific principles, then we have a clear directive. The University of Kansas should be the leader in the state and the nation in science education.

I am committed to KU marshalling the economic means, human resources, and political will to accomplish the following goals:

1. To become a national leader in preparing science students. We are a major American research university. It is our mission to educate scientists who will discover new knowledge, and science teachers who will inspire students to become scientists.
2. To educate all our students, majors and non-majors, to be scientifically literate. Let it be said that every KU graduate will be prepared to contribute to public debate over scientific issues.
3. In so far as we can, educate the public to be scientifically literate. Let KU's continuing scientific education for adult learners be a model for the rest of the country.

4. To seek and obtain extramural funding to assist in accomplishing these goals.

   The charge to the task force is to recommend how we can achieve these goals.

I ask to have your recommendations by May 1, 2000.

The first meeting of the task force will be Thursday, November 11, at 4 p.m. in the Regents Room, 230 Strong Hall. At that meeting, we can discuss the charge further and I will address any questions you may have. Please let Mary Burg in my office, who will staff the committee, know if you cannot attend (mburg@ukans.edu). I look forward to working with you to achieve our goals in science education.

Appendix 3

Bibliography for Science Education Task Force Members

Some Key Resources in Mathematics and Science Education Reform

Boyer Commission (1998) *Reinventing Undergraduate Education: A Blueprint for America's Research Universities.* Stonybrook, NY Carnegie Foundation, http://notes.cc.sunysb.edu/Pres/boyer.nsf

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Additional Resources in Mathematics and Science Education Reform

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Lawson, A.R., Abraham, M.R. & Renner, J.W. (1989). *A theory of instruction: using the learning cycle to teach science concepts and thinking skills.* NARST monograph #1.

The Mathematical Association of America Committee on the Mathematical Education of Teachers. (1991). A Call for Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics. Washington, DC: Mathematical Association of America.

National Research Council. (1989). *Everybody Counts: A Report to the Nation on the Future of Mathematics Education.* Washington, DC: National Academy Press.

National Research Council. (1990). *A Challenge of Numbers: People in the Mathematical Sciences.* Washington, DC: National Academy Press. [Note: this one deals with the numbers of people in the mathematical sciences in high school, college, as majors, and in the workplace. The focus is on higher education in the sciences and mathematics and that we loose people in the pipeline.]

National Research Council. (1991). *Moving Beyond Myths: Revitalizing Undergraduate Mathematics.* Washington, DC: National Academy Press.

National Council of Teachers of Mathematics (1989)*. Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics (1991). *Professional standards for teaching mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics (1995*). Assessment standards for school mathematics.* Reston, VA: Author.

S. Tobias (1992) *Revitalizing Undergraduate Science: Why Some Things Work and Most Things Don't.* Research Corporation. Tuscon, AZ

Appendix 4

Charges for Sub-committees of the Science Education Task Force

January 3, 2000

Each sub-committee of the science education task force is charged with making recommendations within its focus area that will:

1. Enable and increase research and development in science education,
2. Improve and extend science education, including science teacher education, K-12 science education, general education for undergraduates, and education for science majors, and
3. Improve public understanding of science.

Each sub-committee will prepare a written report highlighting its recommendations and issues requiring additional study by April 1, 2000. These reports will be used in drafting a report to the Chancellor by May 1, 2000.

Sub-committee recommendations should be built upon an understanding of the existing nature of science education at KU, current research about most effective methods of science teaching and learning, and existing resources in science education on the KU campus.

Recommendations can focus on improving science education through changes or reforms involving curriculum, teaching methods, staffing, administrative structures, faculty rewards and responsibilities, internal collaborations, and relationships with external institutions and agencies. This list is not intended to be exclusive.

It is important that all recommendations be supported by sound and adequate rationale. Sub-committees should provide some discussion of the potential costs and benefits of each recommendation. Recommendations from different sub-committees may overlap, although communication between sub-committee chairs will help to eliminate serious duplication of effort.

A coordinator has been designated to convene the initial meeting of each sub-committee. At its first meeting, the sub-committee should elect a chair, arrange suitable meeting times and decide on an approach for completing its task. The sub-committee chairs will meet at 4:00 pm the first Monday of each month to discuss the progress of the groups. The full task force will meet as scheduled at 4:00 pm on the third Monday of each month to receive progress reports from the sub-committees and to discuss other business.

Sub-committees will devise their own strategies for completing their assignments. Requests by the sub-committees for information or resources should be channeled through Mary Burg.

The subcommittees are:

Sub-committee #1: Establishing an Institute or Center for Science Education

Sub-committee #2: Presenting the Methods and Processes of Science in Undergraduate Education at KU

Sub-committee #3: Teaching and Learning of Science

Sub-committee #4: Science Teacher Preparation and Professional Enhancement

Questions Posed to Subcommittees as Part of the Charge

Sub-committee #1: Establishing an Institute or Center for Science Education

- What are KU's strengths in teaching, scholarship and outreach related to science education, and how can those strengths be employed to build KU's standing in science education nationally?
- What opportunities exist to compete for grant funding that would support research and outreach in

science education?

- What opportunities exist to develop endowment funding that would support research and outreach in science education?
- What collaborations should be developed within KU to strengthen scholarship in science education?
- What collaborations should be developed with neighboring institutions to strengthen science education scholarship?
- How will these external collaborations influence the nature of science education outreach at KU?
- What resources and personnel are needed to bolster science education scholarship at KU?
- How can an interdisciplinary institute or center work to promote future efforts to build science education scholarship at KU?

Sub-committee #2: Presenting the Methods and Processes of Science in Undergraduate Education at KU

- What are the appropriate venues for presenting the methods and processes of science to students pursuing 1) non-science majors, 2) science, engineering and technology majors, and 3) science education majors?
- What are common issues in science education for these three groups of students? What are the unique needs of each of these groups?
- Do student experiences encompass the philosophy of scientific thought, the social consequences of science and practical experience in applying the methods and process of science? Does some "capstone" experience in the student’s education refocus attention on these experiences near the end of their KU career?
- Are KU’s undergraduate general education courses effective in helping students to develop an understanding of the methods and processes of science?
- What are some courses and programs at KU that exemplify excellence in presenting the methods and processes of science?
- How important are scientific research experiences for science and science education majors? How can KU provide these experiences for more students?

Sub-committee #3: Teaching and Learning of Science

- Who are the student populations served by science and science education courses at KU? What does research tell us about the likely learning styles of these students?
- Are KU’s faculty and graduate teaching assistants using the most effective methods to present the nature and process of science to each of these groups of students?
- What resources exist at KU for implementing needed changes in curriculum and teaching methods?
- Do the proposed reforms imply changes in methods for student/instructor evaluation? What resources exist at KU for implementing needed changes in evaluation?
- What role should the new science teaching facility play in improving science education at KU? How can we accelerate the timeline for this facility?
- Can improving science teaching and learning become a vehicle for increasing the numbers of students in underrepresented and underserved population who choose to enter science and science education careers?

- What programs at KU currently focus on improving the teaching and learning of science in K-12 environments? Are we seeking avenues to improve and extend these programs?
- What programs at KU currently participate in outreach to and informal education with the citizens of Kansas? What current plans exist to extend and improve these efforts?

Sub-committee #4: Science Teacher Preparation and Professional Enhancement

- What is the nature of the current science teacher preparation program at KU?
- What changes in science teacher preparation are envisioned in the School of Education's new Teacher Education Division?
- Is science teacher production a potential target for growth within teacher preparation programs?
- How can science content departments better serve future elementary teachers?
- Can the science teacher preparation curriculum (and science content curricula) benefit from closer collaboration between faculty and departments in the School of Education and the science, mathematics, engineering and technology content disciplines? How can we foster these relationships?
- What is the need for continuing education (professional development) among current science teachers? Should KU develop strategies to increase our involvement in this activity?

Appendix 5

Composition of Subcommittees

Sub-committee #1: Establishing an Institute or Center for Science Education

Joe Heppert, convener

Rich Givens

Jim Ellis

Kris Krishtalka

Sub-committee #2: Presenting the Methods and Processes of Science in Undergraduate Education at KU

Helen Alexander, convener

Marylee Southard

Tom Schreiber

Sally Frost Mason

Val Stella

Steve Shawl

Jim Woelfel

Sub-committee #3: Teaching and Learning of Science

Kris Krishtalka, convener

John Hoopes

Don Steeples

Keith Russell

David Darwin

Sub-committee #4: Science Teacher Preparation and Professional Enhancement

Jim Ellis, convener

Susan Gay

Rich Givens

Sally Frost Mason

Appendix 5.a

Products and Reports from Sub-committee #1

Commentary on CTL Proposal Preparation

The proposal submitted to the NSF Center for Teaching and Learning competition on March 1 is a collaborative effort between researchers from CLAS, the School of Education the KU Museum of Natural History, the Center for Research on Learning, and the School of Engineering. The following collaborators contributed to writing the proposal

Joe Heppert, Chemistry

Jim Ellis, Teaching and Leadership

Jane Bulgren, Center for Research on Learning

Connie Haack, Chemistry

Steve Case, Center for Research on Learning

We acknowledge the support of the Vice Chancellor for Research for a Research Development Fund Grant in support of this effort. We also thank the ITTC for assistance in completing the proposal. Judith Galas was instrumental in editing the proposal. Carole DePew and Barbara Earl were extremely patient and supportive in assembling the final proposal together. Credit is also due to Marigold Linton, who helped establish linkages with Haskell Indian Nations University. Finally, thanks to Dean Gallagher, Associate Dean Weaver, and Associate Provosts Givens and Carlin for shepherding matching support through during the final weeks.

Project Focus. The initial project focus was to approach the problem of "Overcoming Barriers to Inquiry." This focus recognized that in the real world classroom, inquiry often fails to happen. Specific research foci were 1) teacher preparation for inquiry, 2) technology in inquiry, 3) special education and inquiry, 4) minority students and 5) modeling inquiry in science courses at KU. This focus was likely to be replicated by other groups across the country, though unique aspects of the collaborations in this proposal included work with CRL and Haskell.

With only a few weeks left before the proposal deadline, the decision was made to shift to a "unique" focus: special needs students. This group includes minority students (African American and Native American), learning disabled students, handicapped students and underachieving students. There is a danger that scientists will view special needs populations as too narrow a focus for a $15M center. We tried to clearly indicate that this focus was not exclusive: The proposed studies will benefit both special needs students and traditional students. This change in focus is likely to make the proposal stand out from among others nationwide.

Strengths:

1. Strong interdisciplinary collaboration.
2. Partnership with Kansas City Kansas Community College.
3. Partnership with Haskell Indian Nations University.
4. Partnership with Kansas City Kansas School District.
5. Unique focus.

Weaknesses:

1. Need for more tightly focused research questions.
2. Need for more extensive referencing of the project.
3. Need for more science education leadership.
4. Loss of the Topeka School District as a partner.

This latter weakness of the project is troubling. Our scholarly leadership in the area of science education is frankly down to the same few faculty members in science departments and the School of Education. A careful reviewer will look at our current faculty population and identify us as over extended. We need to add further leadership if we are going to take on major new initiatives.

In recent talks with school district mathematics coordinators, it is also clear that we have missed an opportunity among elementary/middle teachers. The need for algebra-readiness content and pedagogical material among these teachers is extreme. School districts are very receptive to training needs in these areas.

Since the submission of the proposal, we have learned that NSF sent very discouraging letters to about 2/3 of the institutions that initially submitted letters of intent. The result was that out of 112 letters of intent, only 38 full proposals were received. NSF was very stringent about page requirements on the full proposals, only 15 pages single spaced, leading me to question how the evaluation of the proposals was going to turn into anything other than a "beauty contest." NSF went through an initial panel evaluation of the full proposals in late March. From this review, they intended to narrow the field to 9 or 10 full proposals. A second reading by a different panel supposedly took place during the third week of April. NSF intends to fund 2-3 proposals from this second group. My understanding of NSF regulations is that a full reverse site visit is required before funds of this magnitude can be committed. NSF must be in the process of contacting investigators to set up these site visits. No one that I am aware of around the country has heard anything about the outcome of the reviews.

Appendix 5.b

Report from Sub-committee #2

Subcommittee 2 Report: Presenting the Methods and Processes of Science in Undergraduate Education at KU

Developed by Helen Alexander (subcommittee chair), Sally Frost-Mason, Thomas Schreiber, Marylee Southard, Steve Shawl, Val Stella, and Jim Woelfel

1. Rationale behind our work

Change is the hallmark of today's society, and it affects all of its parts, including government, business, the educational system, science, and the individuals within each of these realms of human endeavor. Our shared goals, our vision, must be nothing less than providing the means by which each individual is able to function effectively within the ever accelerating pace of technological change.

The rate of change in society is nowhere more exciting, or more rapid, than in the basic sciences, such as astronomy, biology, chemistry, geology, meteorology, and physics. It is within the basic sciences that discoveries are made upon which future technologies will be based. For example, it was through basic science that lasers were first introduced. Basic science produced the transistor. Einstein's work to understand the photoelectric effect, something resulting from basic science, eventually produced the highly sensitive electronic detectors we use in our everyday lives today. The importance of scientific inquiry to our society is not limited to the traditional list of "basic sciences" disciplines noted above. For example, human behavior has a large effect on the spread of certain diseases; psychologists use scientific approaches to understand such processes better. Similarly, patterns of human population growth have important environmental and economic ramifications and is studied by social scientists who have a strong background in population biology and mathematics.

Once, it was possible for the well educated individual to master nearly all human knowledge. Those days are gone forever. Today, the facts of science change too rapidly for anyone except the specialist in a small corner of a narrow field to remain completely aware of all the advances in that field.

Because of rapid change, the facts we teach our students today will be expanded upon and modified tomorrow. Thus, teaching students to understand *how* we know what we know is far more important and long lasting than teaching the facts themselves. We can feel successful in our endeavor if, upon completion of a course, students were to attain the following outcomes:

a) have some knowledge of the history of the science they are studying,

b) understand the nature of the scientific enterprise and inquiry,

c) understand what is science and what is not science,

d) understand some social and personal issues related to the science they are studying,

e) attain the ability to think critically

f) acquire a level of scientific literacy that allows them to understand scientific information they are exposed to in the media

g) understand the basics of scientific approaches so that they can "do science" themselves

h) understand the relationships between science (as a way of knowing) and technology (as a way of doing).

Attainment of these outcomes means that we need to teach the processes of science. The expression *the processes of science* means different things to different people, but we can readily agree that it is an inclusive and broad term. We will take it to include three broad topics:

1) What is science, and what is not science?

* Which topics can be called scientific and which cannot? Why? Why is astronomy a science and astrology is not? Why do we no longer study alchemy?

* What constitutes a fact? A theory? (How do scientists use these terms when they discuss the size of the earth? The value of the speed of light? Evolution? Big Bang?]

* Why is the use f the word "theory" by scientists different than how the term is commonly used in our society?

* One often hears that "a scientific theory can never be proven to be true". What does that mean?

2) How do scientists do their work and form conclusions?

* How can conclusions be formed from imperfect and incomplete data? What is the validity of such conclusions? (Why do scientists support the theory of evolution even though the fossil record is not complete?)

* How can scientists learn about past events that they did not personally experience? (How do scientists study the history of the earth or the history of the universe?)

* What is the nature of measurement? How accurate are measurements, and how do you determine that accuracy?

* In an experimental study, what are controls and why are they needed?

* Is there a single "scientific method" or is there a diversity of approaches taken by different fields of science? [Some sciences, at some times, do experiments; some make observations, while others do computer simulations to check the validity of a given model. Some scientific problems require the use of all possible approaches while others are more limited.]

3) Why is science important enough to our society that we should both teach and support it?

* What would the world be like if we neglected all scientific advances since 1600, the time of the Renaissance?

* What values (such as a quest for knowledge) does science teach us?

* How does the approach to problem solving that is the hallmark of science help us in our everyday living?

* How does science lead to advances in technology?

* How does the use of modern technology lead to the advancement of science?

As our subcommittee approached these issues, we found it necessary to discuss what disciplines are usually considered within the "sciences". We follow the general definitions of science being a study of the physical or material world based on empirical information. Within the College of Liberal Arts and Sciences, courses in biology, chemistry, physics, astronomy, geology, and atmospheric science are clearly "sciences". In addition, there are many courses offered in anthropology, geography, environmental sciences, psychology, and other areas that also are "science" courses. Finally, courses outside of the sciences are important in addressing the philosophy and history of science, and its role in different cultures. We note that mathematics and computer science are essential disciplines that are closely aligned with the sciences. Outside of the College, the Engineering and Pharmacy schools, in particular, have a strong science focus.

We also considered science education within general educational guidelines discussed by national associations. For example, we note that the AAAS, in *The Liberal Art of Science: Agenda for Action* recommends that 50% of instruction in a baccalaureate degree program should be devoted to the liberal arts. Within that, one-fourth should be a liberal education in the natural sciences. At KU, where 124 hours is typical for a degree program, that means that 15-16 hours should be taken in the sciences–two courses more than currently required in the College.

2. Review of how KU is currently teaching students about the "process of science".

. Current emphasis of the importance of teaching the "process of science" with respect to undergraduate education, as revealed by KU’s goals and course requirements

1. Goals of General Education at KU

   The Undergraduate Catalog (1998-2000) lists 11 "Goals of General Education at KU" (p. 14), that were established by the University Assessment Committee (Fall 1989) (see Appendix 1). These include four goals that relate to the issue of teaching "the process of science":

   - No. 6: Gain a better understanding of the role of technology,
   - No. 8: Enhance capacity for critical thinking
   - No. 10: Increase capacity for innovative thinking.
   - No. 11. Increase knowledge of methods used by scholars to explain phenomena in the social sciences, humanities, and the natural, mathematical, and physical sciences

   It is our understanding that a current committee is drafting an updated set of "goals of general education at KU".

2. Principal Course Distribution Requirement

   Within the College of Liberal Arts and Sciences, students must take courses to meet their "principal course distribution requirement" from three broad divisions: humanities, natural sciences and mathematics, and social sciences (see Appendix 2). Three courses are required from each division, with no more than one course from any topical subgroup. In effect, however, students need only take two "science" classes, because of the four topical subgroups under "natural sciences and mathematics", one group is "mathematical sciences", which includes math and computer courses. Using data from 957 BA/BGS students receiving degrees in May 1994, for example, one finds that 10.4% took no biology courses, 29% took no earth science courses, 18.8% took no math/computer science courses, and 43.1% took no physical science courses. These data strongly suggest that most students use math/computer sciences to fulfill one of their science principal courses, and in the process they avoid taking physical science courses.

Within the College, all principal courses should have a strong focus on the "process of science". Specifically, the College has stated: "The purpose of a Principal course should be to acquaint students with the nature of the subject-matter studied in an area, with the types of questions that are asked about that subject-matter, with the knowledge that has been developed and is now basic to the area, and with the methods and standards by which claims to truth are judged." (April 26, 1985, mail ballot to the College Assembly).

b. Review of critical courses within the College of Liberal Arts and Sciences where students should be exposed to "science as a process". We believe it is particularly important that introductory science courses stress "the process of science" since all KU undergraduates will be exposed to some of these courses.

1. Natural Sciences

. Introductory courses for non-majors: We believe that these are courses for which the instructor has a large amount of flexibility. Some departments offer one course for majors and non-majors, however.

ANTH 104/304 Fundamentals of Physical Anthropology (3/4)

ASTR 191 Contemporary Astronomy (3)

ASTR 196 (1) (separate lab to ASTR 191)

ATMO 105 Introductory Meteorology (5)

ATMO 220 Unusual Weather (3)

BIOL 100 Principles of Biology (3)

BIOL 102 (2) (separate lab to BIOL 100)

BIOL 110/MCRB 110 Microorganisms in Your World (3)

BIOL 200/MCRB 200 Basic Microbiology

BIOL 215 Evolution and Diversity in Shaping Our World (3)

CHEM 124 College Chemistry (3)

CHEM 125 College Chemistry (5)

EVRN 148 Principles of Environmental Studies (3)

GEOG 104 Principles of Physical Geography (3)

GEOG 304 Environmental Conservation (3)

GEOL 101 Introduction to Geology (5)

GEOL 105 History of the Earth (3)

GEOL 121 Prehistoric Life (3)

GEOL 302 Oceanography (3) (prerequisite is one science course)

PHSX 111 Introductory Physics (3)

(Note: an additional biology course, *BIOL 120 To know a bug: insects in your world (3)* is in the process of being approved)

b. Introductory courses for majors that are also principal courses, and can technically be also taken by non-science majors. To various degrees, the instructor has less flexibility in content because certain material must be covered to prepare students for other courses, accreditation, or tests such as the MCAT.

BIOL 150 Principles of Molecular and Cellular Biology (4)

BIOL 152 Principles of Organismal Biology (4)

CHEM 184 Foundations of Chemistry I (5)

PHSX 114 College Physics I (4)

PHSX 211 General Physics I (4)

c. Upper-level courses for majors

To some degree, all science courses at least "touch on" the topic of the "process of science". Some, however, probably do more than others. Biology 415 (Field and Laboratory Methods in Ecology) and Environmental Studies 460 (Field Ecology) are examples of upper-level courses that can be taught with a large focus on the "process of science", in that students are collecting their own data on various ecological research questions, analyzing it, and writing up their study in the form of scientific papers. See Appendix 3 for examples of how Biology 415 is being taught in Spring 2000.

2. Social science and behavioral courses

The social sciences, such as Psychology, perhaps because of their focus on humans, have historically had a large focus on methodology in their courses and textbooks. Faculty in Psychology are also introducing a new methods course for their major.

3. Humanities courses

There are numerous courses in History, Philosophy, and Humanities and Western Civilization with relevance to science education for non-science majors. Examples include:

History:

1998-2000 Undergraduate Catalog listings:

HIST 136, Early Science to 1700

HIST 137, History of Modern Science

HIST 305, The Scientific Revolution

HIST 306, Science and Western Culture

HIST 309, History of Chemistry

HIST 311, Great Lives in Science

HIST 404, Technology: its past and future

HIST 407, History of Science in the United States

Actually taught, 1998-2000, (all by Robert Dekosky):

Fall 1998, HIST 136 and HIST 407

Spring 1999, HIST 137 an HIST 309

Fall 1999, HIST 136 and HIST 407

Spring 2000, HIST 137 and HIST 305

Philosophy: general education logic courses and philosophy of science courses

1998-2000 Undergraduate Catalog listings:

PHIL 148, Reason and Argument* (offered every semester)

PHIL 620, Philosophy of Natural Science

PHIL 622, Philosophy of Social Science

PHIL 630, Philosophy of Mathematics

*The instructors for PHIL 148 have been using Robert J. Fogelin and Walter Sinnott-Armstorng, *Understanding Arguments*. The text and course include units on inductive reasoning and on probability, which together make up about 25% of the course.

Philosophy of science courses actually taught, 1998-2000:

Fall 1998, PHIL 620 and PHIL 630

Spring 1999, PHIL 630

Fall 1999, PHIL 622

Spring 2000 ----

Humanities and Western Civilization:

Western Civilization topics or units that are relevant to education about science for non-science students*

HWC 204:

-Hebrew Bible - creation stories in the Book of Genesis

-Early Greek philosophy as birth of science: Socrates, Plato, and Aristotle on reason, argument, and knowledge

-Thomas Aquinas on the spheres of faith and reason

-Galileo's *Starry Messenger* (a pioneer of modern science at work) and *Letter to Grand Duchess Christina (*science and religion)

-Descartes' *Discourse on Method* (foundations for and examples of his approach to scientific method)

HWC 205:

- Darwin, Wallace, and T. H. Huxley on evolution

- Marx, and Engels, Nietzche, and Freud: science vs. philosophy, what science is and is not

*The two Western Civilization courses are general education requirements for all B.A., B.G.S., and almost all B.S. students in the College, and for all Journalism and Social Welfare majors. They are also taken by some Business and Education students to fulfill part of their humanities requirements, and a few students from Fine Arts and Engineering take one or both courses as an elective. CLAS undergraduates make up almost 70% of KU's undergraduate population.

Humanities courses: HWC 510 Science, Technology, and Society*

*This course has been offered for some years, and always enrolls well. It used to be taught by Jack Davidson (Physics), Hal Orel (English), and Jim Carothers (English). It is currently headed up by Phil Baringer (Physics), joined this semester by Barbara Schowen (Chemistry) and Mohammed El-Hodiri (Economics). The course is currently being offered in the spring semester of alternative years. The topic varies from semester to semester, and the faculty in charge make extensive use of guest lecturers, discussion and oral presentation, and written assignments. Spring 1998 topic was "Science and the Burden of Proof"; Spring 2000 topic is "Life in the 20th Century". Current enrollment in HWC 510 is 30.

c. Comments by science faculty on the degree to which they feel that "science as a process" is important and the degree to which they cover this material in their classes (comments were gathered by informal requests for comments)

Appendix 4 provides examples. In brief, faculty agreed that teaching the "process of science" is important. Some felt that they were already doing it, either by introductory comments at the start of the course or by using articles in the news and relating that to the coursework. Many felt that it was a subject that deserved greater attention but that it was difficult to know how to do more. Several felt that it was very difficult to really teach the nature of science in large lectures with little opportunities for interaction.

d. Review of how students in the professional schools learn about the "process of science"

A survey of the curriculum of the professional schools was undertaken. Two of the professional schools, engineering and pharmacy, have obvious science curricula but differ in how students enter the schools. In the case of engineering, students enter the program as freshmen and are expected to have strong high school science and math backgrounds. While in the school of engineering students take many classes; including laboratories, where scientific principles are taught and tested. No course,per se, addresses the issue of "the scientific method" although the introductory courses could be modified to include a "module" on the scientific process which would then be reinforced throughout the curriculum by both didactic course work and laboratory assignments. For the school of pharmacy, students enter this professional school after two years of prepharmacy course work curriculum. However, only about 40% of students entering the KU school of pharmacy perform their prepharmacy course work at KU with the remaining 60% take their prepharmacy requirements at other four-year colleges and community colleges. Within the prepharmacy and pharmacy curricula, the students have a number of courses and laboratories where the "scientific method" is applied, but there is no formal class wherethis is taught as subject matter per se. Within the prepharmacy curricula students are required to take approximately 30 hours of humanities and general studies. Many of the students take courses wherein the "scientific method" is probably discussed. It would not be difficult to have as part of the 30 hour humanities and social studies or basic science requirements, a requirement of at least one course where research and scientific methods are presented and discussed.

Engineering requires only 12 hour of humanities and social sciences, so incorporating a requirement in those 12 hours is more problematic than for pharmacy. The other professional schools: Journalism, Social Welfare, Education, Business, Fine Arts, and Architecture present a greater challenge. In each program the curricular requirements have been examined to find core science courses in which the scientific method is likely to be presented. Each school will be discussed separately.

The School of Architecture requires 68 hours of Liberal Arts & Sciences courses, in which HSS courses must be taken. No explicit courses are given in the catalog to fulfill these hours. There is an introductory course that all majors must take, but that may not be an appropriate course for the subject. Therefore, explicitly requiring a class that would include the scientific method would require a curricular decision at the school level.

The School of Business requires Psyc 104 and a biological science course, one of which must be a laboratory science class. Therefore there is a reasonable probability that each student would be exposed to the scientific method. To increase this probability, a more explicit list of courses having this content would be needed.

In the School of Education, there appears to be a requirement in each of the degree programs for a biological science and/or psychology course. Thus the probability of learning and using the scientific method and its philosophy appears to be high.

The School of Fine Arts has a wide variety of degree programs and as broad a spectrum of general education requirements. However, all programs appear to have explicit biology and western civilization requirements except the following programs: the Bachelor of Music degrees, including Music History and Music Performance. Therefore requiring these majors to take a course that exposes them to the scientific method would appear to require a significant curricular change.

The School of Journalism requires students to take at least three courses in one department of the social sciences and three courses in another department in the College. The catalog lists approved areas of social science from which these courses might be taken, including psychology, geography, and sociology. It does not explicitly require any physical or biological science course. Thus to insure exposure to the scientific method, a more explicit requirement would need to be added. We are particularly concerned that journalism students have little exposure to science, given that future employment may require reporting on the sciences.

The School of Social Welfare has a mathematics requirement to enter the school and appears to have a natural science requirement including a laboratory. To insure exposure to the scientific method, a more explicit requirement may need to be added.

3. Constraints and perceived barriers to improve the teaching of the "process of science" to KU undergraduates

a. Science faculty are trying to cover a certain amount of factual information/content in their courses*; teaching of "process" is likely to lead to reduction in teaching of other material.* This is particularly a problem for majors courses, where faculty need to teach certain material to prepare students for more advanced courses and tests such as the MCAT.

b. *It is often unclear exactly how to increase teaching of "science as a process" in a course.* It is easy for the first lecture of the course to define "what is science", and discuss the scientific method.

However, this lecture material by itself is often perceived by students to be "dry" and unrelated to course content. Instead one needs to figure out ways to incorporate the "process of science" throughout the course, but this is challenging and requires considerable time to develop.

c. *Faculty have limited time to make substantial changes to their courses.* Relatively new faculty have constraints of time spent on teaching because the need for a strong research record for tenure. More established faculty have put years into developing courses and are unlikely to want to make major changes, and feel constraints due to established research programs and service.

d. *Faculty lack a strong incentive to rework their courses to emphasize the "process of science".* The details of a course syllabus or the approach to teaching of science in a particular course is unlikely to be the subject of discussion within a department or with a department chairperson. The faculty who are most likely to change their courses to include more "process" will be ones that are motivated by their own realization that the subject is important… there is little incentive for less motivated faculty to make changes in their course. See comments in "c" above as well.

e. *Teaching the "process of science" will be most effective if faculty members can truly interact with their students.*

1. For many introductory courses, it is typical to have a large lecture of 100's of students and then several laboratory sections. Nearly all faculty find it difficult to teach the large lecture section in a truly interactive fashion - thus most students learn sciences by having someone lecture to them. The laboratories allow interaction, but it is challenging for lab instructors to develop laboratories that focus on "inquiry" instead of being "canned exercises". To be effective, lecture and lab must be tightly coordinated, but this is logistically challenging.

2. Many other science courses are only lecture courses. For example, BIOL 404 (Genetics) is a core course in Biology that is taught to 200+ students in a single lecture without any laboratory or discussion section component. Students would learn "problem-solving material" that illustrates the process of science much better with assigned problem sets and discussion sections, but this is impossible in the current setting. Appendix 5 suggests that KU is unusual in teaching "core" courses without associated laboratories or discussion groups. Large lecture courses and lack of discussion sections can lead to students being passive recipients of information…in turn, lack of student motivation and lack of student -faculty interaction cause faculty to become disenchanted and spend less time on developing/improving their class.

f. *Faculty often feel there is inadequate resources or staff to assist in high quality teaching.* Directors of laboratories have their hands full with the logistics of organizing laboratories and many TA's. Thus, many important activities, such as faculty mentoring graduate TA's on how best to teach, can easily "slip through the cracks".

g. *Many KU students take very few science courses, thus limiting their exposure to any aspect of science, including the "process of science".* As noted earlier, typical KU students need only take 2 actual science courses, given the current choices in the "natural sciences and mathematics" division of the Principals course distribution. Thus for many students, there are only limited opportunities for students to be exposed to science and its methodologies. However, changing Principals course requirements is time-consuming, politically difficult, and reduces the flexibility of student choices.

h. *Increasing the number of individual research experiences for students is difficult given constraints on faculty time.* Although individual research experiences are perhaps the best way for students to appreciate "the process of science", most active faculty already have several undergraduates working in their labs. It is difficult to see how to increase the number of students gaining this experience.

i. *Professional schools often have little flexibility on changing their curriculum because of concerns about accreditation.* Course sequences are defined and it would be difficult to add courses or to greatly change the curriculum within courses. In some profession schools such as Pharmacy, many students do their first years of college at other institutions in the state, and thus KU has little control on their initial curriculum.

4. Recommendations for increasing teaching the "process of science" at KU

a. We recommend that all introductory courses (e.g. principal courses within the College) in the Physical, Natural, Social, and Behavioral sciences (for majors and nonmajors) be taught in such a way that the "process of science" is emphasized, as opposed to primarily emphasizing the "products or facts" of that science. Given that all College students and most Professional School students are required to take several courses in the Physical, Natural, Social, and Behavioral sciences, a focus on the introductory courses is one way to reach a large number of students. Overall, our goal is for students to obtain the outcomes mentioned in the Rationale section of this report. To accomplish this task, we suggest the following steps. The first two steps (1 and 2) are minimal objectives, with 3, 4, and 5 most likely to lead to significant changes in how students perceive the process of science.

1. *Resources and information on teaching the "process of science" must be readily available to all faculty*. As a subcommittee, we have amassed many books, articles, and laboratory exercises that relate to issues of "what is science", "scientific methods", and "social implications of science". Such materials must be easily available to faculty, so that motivated faculty have resources to use to modify their courses. See Appendix 8 for a review of materials our subcommittee has gathered.

2. *We suggest the development of a "module" on this topic that would consist of lecture and laboratory material that faculty could integrate into their courses. We envision that this module would consist of ideas for overheads, power point presentations, and lab exercises*. Our hope is that by actively promoting this information to science departments, faculty teaching science courses would be motivated to include a larger component of this material into their courses. We propose that new funds be obtained to support faculty and GTA's to develop such materials for distribution within the university. To avoid having such materials be "filed away without notice", we would suggest that a team of people might attend departmental meetings or give CTE workshops to demonstrate and emphasize how the module material could be used in classes. It is important to realize that although the CTE is an excellent place for such workshops, most faculty who attend CTE events are teachers who are already likely to be motivated to improve their teaching (i.e. the "preaching to the choir" phenomenon). Thus if efforts were limited to CTE workshops, many science faculty would be unlikely to be involved.

3. The above steps (i.e. having resources available and generic "module" information) are only minimal steps, and we must emphasize that they are not sufficient to obtain the desired student outcomes noted in the Rationale section. To make more systemic changes, *we recommend that all introductory course curriculum be actively examined by departmental or school committees to determine the extent to which the "process of science" is being currently taught, and if insufficient, courses be revised to emphasize this topic*. Thus beyond having an introductory lecture where one addresses "what is science" or talks about different "scientific methods", we envision that the entire course needs to be taught within the framework of how scientists accumulate knowledge and how they make decisions. Appendix 6 provides one example of how a KU faculty member currently actively incorporates the "process of science" in his course, and such examples should be readily available to interested faculty and departments. Appendix 7 provides an example of how faculty are

attempting to modify existing classes to include more "process of science". To make really substantial changes, faculty from within each unit, and ideally those actively involved in particular introductory courses, need to become involved. After review of departmental or school curricula, we propose that funds be available to individuals or departments to help them implement specific changes.

4. We focus on the pre-existing introductory courses because they currently reach the largest number of students. *However, we also encourage the development of new courses or modification of existing courses at all levels to emphasize the process of science*. We particularly encourage "research methods" courses that are tailored for a particular discipline. As a model, the Psychology department recently developed a new course (Psyc 310) required of all majors, which provides an in depth coverage of the methods and processes of science, how such methods are used in the field, scientific writing, and laboratory exercises. We believe that any field that relies on the scientific method as a way of arriving at conclusions should develop such courses.

5. *We encourage increased emphasis on undergraduate research.* The best way for students to learn the "process of science" is to be actively involved with it as an individual, such as doing a research project. We thus encourage increased involvement of undergraduates in independent research. We are well aware of the difficulties of increasing involvement, since most faculty find that having 2 or 3 undergraduates is all that they can handle in addition to their usual responsibilities. *Thus, we also encourage development of group research courses to help undergrads who don't know a mentor to obtain a research experience.* As an example, a biology field ecology course (BIOL 415) is currently being taught this semester by having students carry out complete research projects (i.e. working on one project for several weeks and exposing students to the scientific literature, writing up a scientific paper, etc.; see Appendix 3). In addition, the Psychology department has several upper level courses (Psyc 618, 620, 622) which require the completion of several research projects, including a term project which requires the execution and completion of experimental work that is then written-up in the form of a journal article. Group research experiences can be facilitated by many units within the University. For example, the Experimental and Applied Ecology Program manages the Kansas Ecological Reserves, a 1700 acre area used for ecological and environmental research and education. Specific parts of their program, such as long term study plots on forest composition or the proposed wetland and prairie restoration plots near the Robinson tract, are particularly conducive to group student projects since students can compare data taken in different years.

6. *General comments on how the above curricular change should and should not be implemented.* We are aware that faculty are sensitive about the courses they teach, and do not want to be told by others what they should teach or how they should teach. Further, it is clear that teaching the "process of science" is not an easily defined subject; different instructors and different subjects are likely to address this subject in very different ways. Our goal is thus for individual faculty and departments/schools to focus on this topic and consider the degree to which it is being taught. We do not want to mandate any particular approach to teaching this subject or use of any particular set of materials. We also recognize that critical thinking skills and understanding the process of how knowledge is obtained is central to all disciplines, not just the sciences, and encourage courses across the University to focus on these broad issues.

b. Within the College, we propose that the Principals Course Distribution requirement be changed so that students are required to take three courses in the Physical and Natural Sciences. This would require deletion of the option of taking only two science courses if one takes a mathematics or computer science course. In order to obtain maximum benefit from this recommendation, courses in the Physical and Natural Sciences should be modified to emphasize the methods and processes of science as they are used in that particular field, rather than primarily covering the "facts" of that science. For the Professional Schools, a review should be taken of course distribution requirements to determine if students are obtaining at least some broad background in the sciences (see section 2d for initial review).

c. The above curriculur changes can't be made within the current infrastructure. To make these happen, we recommend:

> 1. *Funds for developing the materials and curriculur changes to increase the teaching of the "process of science"* (i.e. for the development of modules and to hire people to help facilitate changes in laboratories)
>
> *2. More TA lines and/or staff so that it is possible to have discussion sections for large science courses. Undergraduate peer tutors or undergraduate teaching assistants may also be used in some cases.* As noted in the above survey of science faculty, many faculty are trying to teach good courses but feel very constrained when they are lecturing to 150+ students and have no laboratory or discussion section. The most effective way for students to be actively involved in thinking about the process of science is for there to be small group sessions with opportunity for discussion and problem solving. At least for junior/senior "core" courses in the biological sciences, KU appears unusual among state universities in limiting its teaching to large lectures and not having discussion sections for student interaction (see Appendix 5).
>
> *3. Encouragement of faculty with interests in "science education" within the science departments in the College and establishment of new "science education" faculty.* To promote good science teaching on a broader level, we need faculty members in each department who have science education as a major focus. We recommend that additional scientists whose field of expertise is science education be hired. Many science fields have extensive literatures and expertise in the specifics of education in their field and major scientific societies have committees or subgroups devoted to education [for example, Physics (American Association of Physics Teachers) and Astronomy (Astronomy Education Board and Working Group on Astronomy Education)]. KU has already taken this approach in some departments where faculty with a science education focus have been hired. For example, Janet Robinson in Chemistry and Susan Gay in Mathematics/Education appear as "models" of this type of hiring approach. In addition to teaching their discipline and actively helping other faculty incorporate "process" in their courses, such faculty are likely to have a research focus in the area of science education and take a strong role in mentoring graduate students in good teaching skills. We also note that most of the current faculty with particular strengths and interests in science education were hired as "regular" faculty members. Care should be taken that administrative decisions, including tenure and promotion, do not make it difficult for such faculty to put time into innovative teaching. The excellent science teaching faculty that we have are doing a good job because they care about undergraduate education, but given the importance on research productivity and committee service, they are feeling "stretched" to the limit. By having several faculty with a science education focus throughout the science departments, faculty with such an emphasis would not feel isolated and could work together to promote science education at a broader level.

d. As already noted in part 4a3 above, we propose that departmental or school committees review the extent to which methods and process of science are taught in principal courses, both in the Physical, Natural, Behavioral, and Social Sciences, as well as in the humanities (e.g. Philosophy, Western Civilization). Such a review would also help provide information about whether more drastic steps should be taken than those outlined above. For example, if principal courses vary greatly in the degree to which the "process of science" is included, one could have some type of course "classification" to designate which courses have a focus on "methods" or develop new science courses that are specifically focused on the "process of science". Another option would be development of a course that is analogous to

"Western Civilization" that has a science focus.

5. Implementation of plan

a. To increase the teaching of the "process of science", all faculty, staff, and graduate students involved in teaching must see this as a priority. As seen in Appendix 4, many faculty are interested and supportive. However, there must be active "promotion" of the importance of teaching the "process of science". To be effective, concrete advice and specific examples must be provided so faculty can visualize how their courses could be improved. Faculty and graduate students are busy and are unlikely to go out of their way for extra meetings/workshops; thus efficient ways to promote these ideas must be found. Examples of ways this might be achieved include:

> 1. Discussion of these ideas at departmental meetings or seminars, including presentations by faculty who have successfully incorporated "process" into their courses.
>
> 2.Discussion of these ideas by small groups of faculty involved in teaching a particular course
>
> 3. Explicit discussion of these topics at TA meetings, both at the beginning of the semester and throughout the course.
>
> 4. Development of a series of workshops or discussions on the "process of science" by the CTE.

b. For these changes to occur, there needs to be a change in the "culture" of teaching science at the university level. At the minimum, this will require:

> 1. Increased recognition by departmental chairs, tenure and promotion committees, administrators, and legislators that quality teaching takes considerable time, and that this is an important activity.
>
> 2. Increased interest and interaction among science faculty in teaching. Many of us feel that it is only in the last year, with the "CTE teaching summit" and activities of this committee, that science faculty from a number of departments have met together to discuss problems and solutions in science education.

c. Faculty are likely to see curricular changes and recommendations as yet another demand on their time; morale and participation would be greatly enhanced if the university was committing new resources to this plan. Examples should include:

> *1. Hiring of new science/science education faculty to improve teaching quality for undergraduates, motivate faculty to consider new approaches, conduct research in science education, and mentor graduate student TA/s.*
>
> *2. Hiring of new science/science education staff*
>
> *3. Increasing the number of TA lines so that discussion sections could be offered for large science courses.*
>
> *4. Funds, such as summer salaries and RA help, for faculty seriously committed to improving their curriculum*
>
> *5. Hiring decisions that would reduce class size in science courses. It takes an exceptional teacher to effectively teach 200 - 300+ students and be motivated to keep this going on a regular basis.*

6. List of Appendices

Appendix 1 — Goals for undergraduate education (p. 14 of 1998-2000 undergraduate catalog)

Appendix 2 — Principal course distribution requirement (pp. 56-57 of 1998-2000 undergraduate catalog)

Appendix 1 — Goals for undergraduate education (p. 14 of 1998-2000 undergraduate catalog)

Appendix 2 — Principal course distribution requirement (pp. 56-57 of 1998-2000 undergraduate catalog)

Appendix 3 — Example of teaching "the process of science" in an undergraduate field ecology class

Biology 415, Field and Laboratory Methods in Ecology, was taught in Spring 2000 by Helen Alexander and Val Smith. The focus of our course was on teaching how ecologists approach scientific questions. We started the course with a discussion of "what is science" and more specifically, "what is ecology". In this discussion, we emphasized the range of approaches and questions that ecologists use. For the rest of the course, we focused on three different projects. In all three projects, our goal was for students to see the entire scientific process: i.e. asking questions, reading the literature, setting up a study, collecting data, analyzing data, and communicating the results to others by a written paper. Our first project was on forest composition and succession. We had students collect and interpret data on forest composition on a plot that had also been censused twenty years earlier to determine if the tree community was changing over time. Our second project was on aquatic biology, and involved a comparison of the physical, chemical, and biological properties of two ponds on campus. The third project was on the biology of an invasive plant, and involved setting up a large-scale monitoring program and assisting with a field experiment that evaluated the effectiveness of different approaches to control. By having a few detailed projects (as opposed to doing a different ecology project each week), we believe we did a better job of illustrating how scientists actually do their work.

Appendix 4 - Selected views of science faculty on teaching "science as a process":

(H. Alexander has a collection of these examples)

Appendix 5 — Examples of how other universities teach "core courses" in biology, in particular focusing on the importance of discussion sections in large lecture classes.

We asked colleagues at other universities to describe how junior/senior level "core" biology courses were taught. The following summarizes information we obtained about four universities that are comparable to KU. Our information suggests that courses in basic disciplines such as ecology, genetics, and evolution at these and other universities are accompanied by laboratory or discussion sections. In contrast, our ecology and genetics classes do not have a laboratory or discussion component (Separate laboratory courses exist, but they are not taught every time the lecture course is offered. Further, such laboratory courses can only enroll a fraction of the students in the lecture course and are taught without coordination with the lecture course). Thus the vast majority of students take a course like genetics in a large lecture setting with little opportunity for discussion or working with the concepts in a "hands-on" sense.

Michigan State University

The general ecology course has approximately 200 students. Ecology has 3 lectures per week plus a 3 hour lab (it is a 4 credit course). There were 4 TAs: 3 taught 2 sections of 30 students and 1 TA taught 1 lab section and also served as the lecture TA (helping with exams, etc). The lecture and lab were closely coordinated.

For the general evolution course, there are about 120 students and 2 TAs. Each TA teaches 3 discussion sections of 20 students (1 hour). There are 2 lectures and 1 discussion per week. Again there is close coordination between discussion and lecture. In discussion, students not only read papers but worked on Populus problem sets in microcomputer labs available on campus.

Washington State University

The general genetics course has an enrollment of about 130 students each semester. There are required discussion sections run by 2-3 TA's. The Evolution course has about the same enrollment but is offered once a year. It also has a required lab/discussion section that is run by 2 TA's

University of Nebraska

Biology majors are required to take 5 core courses, which are normally supposed to be completed in the first two years. These are Cell Biology, Diversity, Genetics, Ecology and Evolution, and a Molecular Biology/Genetics lab course. The first four are each 4 units. Cell Biology and Genetics each include a recitation section, and Diversity and

Ecology and Evolution each include a lab. The Molecular Biology/Genetics lab course is two units, and is 1 hour of lecture and a lab each week. The recitations and labs have assigned TAs, ~2/3 of whom are graduate students, the remaining are undergraduates. Each of these courses is offered each semester and has enrollments of 75-150 depending on the course (Genetics is higher, for example, because it is required for some majors other than biology, e.g. biochemistry, agronomy).

University of California-Irvine

All Biology majors are required to take an 11 quarter biology core sequence. The courses are offered one quarter a year and everybody takes them in lock step. They start with a course on diversity in the winter quarter of their freshman year and then other courses including ecology, physiology, neurobiology, and cell and developmental biology. The person we surveyed was most familiar with the diversity and ecology courses. He stated that there are now about 900 students taking it at once (an individual faculty member repeats the lecture 3 times a day to classes of 300-400 students). The courses are team taught, with three faculty dividing up each course. The diversity and ecology courses have accompanying discussion sections. These are hoped to be small (25-30 students), but in practice they have been large (60 to 90) because of the shortage of TA's and funds. Sometimes full time lecturers run these sections. There is no set format for the discussion sections and they are not mandatory (grade is completely determined by in lecture tests). Often the TA's go over problem sets during discussions; in other sections of ecology, the TA's discuss papers. In practice, the sections are so large that the TA's often re-lecture the material.

Appendix 6 — Examples of how "science as a process" is currently being taught at KU (Example from Dr. Stephen Shawl, Astronomy 191). An additional power point presentation is available.

How "Process" is used in ASTR 191

The following provides a description of how Prof. Stephen Shawl attempts to teach scientific process in his section of ASTR 191.

The course begins with definitions of three "astro" words: astronomy, astrophysics, and astrology. During the discussion, astronomy and astrophysics are said to be "sciences" while astrology is a "pseudoscience." The class then breaks up into groups of ~5 students with the task of coming up with 10 words they think of when they hear the word "science." They are then to come to consensus statement: "Science is...." Once done, some groups are called on to provide what they came up with, and a discussion follows.

The discussion moves on to definition of terms: hypothesis and theory. Examples are given. For "theory" we talk about Einstein’s *Theory* of Relativity and the fact that *every* experiment that has ever been done to verify the validity of it has shown the *theory* to be a valid way of describing nature. While I don’t expect them to understand the experiments, I do mention some specific experimental predictions that have been verified. Then, I bring up the *theory* of evolution. Since I’m not a biologist, I contacted an evolutionary biologist and asked him for "bullet points" that provide evidence favoring evolution. Thus, right off the bat, the concepts of science are discussed and used.

We also talk about the idea that scientific *truth* is not necessarily Truth (note the capital T!). We talk about science using models and metaphors. Examples that are given, which I indicate will be discussed in much more detail later in the course, include various models of light (ray, wave, photon), and models of the atom (a solar-system-type model and a quantum mechanical model).

Next, we talk about scientific reasoning, in particular induction and deduction. (I present the words' roots as ways of remembering what each word means.) Generalized examples are provided.

From here, what I call the "theory-observation cycle" is presented; it is a cycle that emphasizes the interaction between the predictive nature of scientific hypothesis, theory, or model, and the observations they predict. During this discussion, I discuss that Newton's theory of gravity (notice I use "theory" rather than "law") works perfectly for describing/predicting the motions of the Moon about Earth, but that it does not do well for the planet Mercury. Thus, Newton's theory of gravity had to be modified, by Einstein, to be able to provide a more accurate description of its motion. That does not, however, mean that Newton's theory is wrong, but that its applicability is limited only to certain realms of nature. (This also emphasizes truth vs Truth.)

Last, in these first lectures is a brief discussion of the ways in which astronomy interacts with (cross-fertilizes) other fields, such as math, physics, chemistry, meteorology, geology, engineering, computer science, and medicine.

The purpose of what I've described above is to lay the foundation for a semester-long discussion of, and multiple returning to, these ideas. In fact, the inclusion of these ideas has played a major role in making choices of what material to include or exclude in the course. In most cases, a topic that did not lend itself as well as others to a discussion of the interaction between observations and theory was dropped in favor of topics that do allow for that discussion. (The one thing that makes this difficult choice easier is that ASTR 191 is not a prerequisite for further course work; thus, my decision not to cover the planets, per se, will not negatively impact later course work.)

A summary of the ideas follows:

Topic	Details of use of process
Naked-eye astronomy (3 weeks)	• Interactions between what we observe and the Greek ideas requiring uniform circular motion.; need for epicycles to explain observations, given the Greek penchant (requirement) of circular orbits and uniform motion on them. • Lunar phases • Appearance of sky from different locations at different times
Historical quest to model the solar system (1-2 weeks)	• Some Greek astronomy • History (Copernicus, Brahe, Kepler, Newton, Galileo) • Proofs of Earth's rotation and revolution
Light (2 weeks)	• Present 3 models of light and discuss how each is useful (and how each is limited) in describing actual observations of light. Many demonstrations are used.
Properties of stars (2 weeks)	• While theoretical ideas are presented here, along with a variety of observations, this section is not as useful in showing process in the manner we've been using it. This material is needed for the coming section.

Stellar evolution (4 weeks)	• The physics needed to under the evolution of stars is presented. The ideas of physics are referred to as the "theoretical" ideas; this terminology is important, yet foreign, to students. • The discussion has 3 major subtopics: star formation, star life, star death. • In each subsection, theoretical ideas are presented first, and then the observations bearing on the topic are presented.
Solar System formation (1 week, or dropped if no time)	• Basic observations concerning the structure of the solar system are presented first. • A variety of historical hypotheses are presented, compared with the previously presented observations, and the present day conclusions then result.

Appendix 7 — Modification of currently existing class to include a greater amount of material on the "process of science".

Biology 152, "Principles of Organismal Biology", is the second semester course of a two semester majors introductory biology course. The course is relatively new, and was first taught in spring 1998. The course enrollment varies from 125-280, depending on whether it is offered in the fall or spring (typically students take it in the spring, after starting the first semester course in the fall). Two faculty co-teach the course; both faculty attend nearly all lectures. The course is four credits and consists of lecture and laboratory. We have put considerable effort into: a) standardizing the syllabus, so that students in more advanced courses will have had similar introductory material and b) coordinating lecture and laboratory components of the class.

In general, faculty teaching the course feel it has been a successful course. However, we are interested in expanding our focus on teaching "science as a process". This topic certainly has been covered (for example, at various times in the course, we describe "how we know what we know". For instance, classic experiments in plant physiology and ecology are central to the lecture discussions of these topics, and we provide examples on how data on current organisms can be used to infer evolutionary history).

The following are thoughts on how two of the BIOL 152 faculty (Helen and Dave Alexander) plan to increase our emphasis on "science as a process" in Fall 2000, when we next teach the course.

We plan to take three general steps:

1. *Insert 1- 1/2 introductory lectures on "science as a process" at the start of the course, to emphasize the importance of this topic.*

   We expect to start the course by stating that we are going to study the science of organismal biology, and thus we first need to focus on "what is science". In smaller courses, one of us (HA) has posed this question to students and gotten them to participate and provide answers. We would try this approach and put student responses on the board. We would then use this interaction as a way to introduce a lecture that would provide more details of "what is science", the approaches organismal biologists use, and the social importance of organismal biology. We may borrow an approach used at another university, where an introductory biology professor brings in many "props" on the first day to emphasize the variety of approaches used by biologists (i.e. electrophoresis gel, butterfly net, petri dish, computer program, etc.). Our emphasis would be on the diversity of approaches researchers use. For example, using the topic of community ecology, we could describe the integration of many different methods (i.e. use of current day observations of species, historical data that allows us to infer past associations, experiments in the field and laboratory, comparative data about communities in different areas, and analytical and simulation models).
2. *Throughout the course, highlight "how we know what we know" as much as possible.*

Students will quickly forget the details of the first lecture. Thus, the real issue is whether "the process of science" can be incorporated throughout the course. Topics covered in this course include animal and plant structure and function, diversity of life, evolution, and ecology. As much as possible, we would try to highlight how we know the details of particular processes. Some topics easily lend themselves to this (for example, we have discussed classic experiments in phototropism) but other topics (life cycles of organisms) have had less emphasis on "process". It will be particularly important to emphasize how hypothesis testing can be done with evolutionary questions. As we have already done in the past, it is also important to highlight the larger significance of studies in organismal biology (for example, problems with evolution of antibiotic resistance, studies of human population growth).

3. *Work with Julie Campbell, Director of Introductory Laboratories, and the graduate student teaching assistants to make the laboratory sections more "inquiry" based and less "show and tell" and to help the TA's address "science as a process" issues in their laboratory.*

Laboratories in this course, partly because of the nature of the material, often use a "observational" approach. For example, understanding the structure and function of plant and animals requires careful observation. We would strive to increase the amount of active "inquiry" based approaches in the laboratory. For example, we imagine adding a laboratory exercise where scientists infer the evolutionary relationships among species by having students work through the process with an actual data set.

In addition to promoting more "inquiry" based activities in laboratory, we think it is important for teaching assistants to constantly emphasize the "process of science" in their laboratory groups. Unlike the lecture setting, a true discussion and question/answer interchange is possible in these small groups. We can imagine giving a presentation to the TA's at the beginning of the semester on the importance of this subject, and suggesting particular questions/topics that could be brought up with particular laboratories.

Appendix 8 — Collection of articles on "science as a process" and bibliography (currently exists as a binder put together by H. Alexander)

Collection of books and articles that relate to teaching the "process of science" and more effective teaching of the sciences.

Books and articles that discuss curriculum reform or teaching in Biology

Bell, J. A. and Buccino, A. (eds). (1997). Seizing Opportunities: Collaborating for Excellence in Science Preparation. AAAS.

Handbook on teaching undergraduate science courses: a survival training manual. Saunders, New York, ISBN 0-03-025926-6.

The Liberal Art of Science. 1990. American Association for the Advancement of Science ISBN 0-87168-378-4. (discusion on scientific understanding, and examples of courses on science/technology/society)

Developing Biological Literacy: A guide to developing secondary and post-secondary Biology Curricula (1993). BSCS Innovative Science Education

Fulfilling the Promise. Biology Education in the Nation's Schools. (1990). National Research Council. National Academy Press.

Newman, J. H. 1998. Rapprochement among undergraduate psychology, science, mathematics, engineering, and technology education. American Psychologist (Sept. 1998)

Redesigning the Science Curriculum. A report on the implications of standards and benchmarks for science education.

(1995). BSCS.

Shaping the Future. New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology. A report on its review of undergraduate education by the Advisory Committee to the National Science Foundation.

Suter, L. E. (ed). The Learning Curve. What we are discovering about U.S. Science and Mathematics Education. National Science Foundation.

Science for all Americans. Project 2061. American Association for the Advancement of Science.

Beyond Bio 101. A report from the Howard Hughes Medical Institute.

Celebrations and Challenges. A Report on Science Education Improvement. (improvements on elementary science education)

National Science Education Standards. 1996. National Research Council. National Academy Press. Washington, D. C.

Examples of books that provide case histories of how particular fields of science have developed:

Hagen, J., Allchin, D., Singer, F. (1996). Doing Biology. HarperCollins College Publishers. ISBN 0-673-998638-7 (7-8 page sections on famous scientists and how they approached certain problems; very readable)

Lagerkvist, U. (1998). DNA pioneers and their legacy. Yale University Press. New Haven and London. ISBN 0-300-07184-I. (describes the origins of modern molecular biologists and the lives of pioneering scientists; very readable)

Weiner, Jonathan. (1994). The Beak of the Finch. Vintage Books. A Division of Random House, Inc. New York. (good description of how evolutionary biologists study finches on the Galapagoes; very readable)

In addition, the following is information about case studies in science developed by the National Academy of Sciences. In the following articles, scientists describe how basic research has led to some of today's most important technological and medical breakthroughs. Thirteen such articles have been produced and distributed to date. In addition to the print versions, all are accessible on the web site, http://www.beyonddiscovery.org. The full list of articles is below.

> 1. Ozone Depletion Phenomenon (April 1996)

> 2. Human Gene Testing (December 1996)

> 3. Modern Communication (December 1996)

> 4. Global Positioning System (April 1997)

> 5. Curing Childhood Leukemia (October 1997)

> 6. Sound from Silence: Cochlear Implants (August 1998)

> 7. Preserving the Miracle of Sight: Lasers and Eye Surgery (August 1998)

> 8. Designer Seeds (October 1998)

> 9. Sounding Out the Ocean's Secrets (March 1999)

> 10. When the Earth Moves (October 1999)

> 11. Polymers and People (November 1999)

> 12. Proteases and Their Inhibitors (January 2000)

> 13. Hepatitis B (February 2000)

> 14. Vitamin D (est. April 2000)

> 15. Nitric Oxide (est. April 2000)

> 16. MRI (est. May 2000)

> 17. Bimetallic Catalysts (est. June 2000)

Examples of books or chapters of books that address "the process of science" or issues related to social relevance of science

Audesirk, T. and Audesirk G. Biology. Life on Earth. Fifth Edition. Prentice Hall. ISBN 0-13-792615-4. (like many introductory biology books, this has a good section on "what is science")

Kneidel, S. Stenhouse. (1993) Creepy crawlies and the scientific method. Fulcrum Publishing. ISBN 1-55591-118-8 (a book for hands-on experiments with easy to find animals; for children, but easily modified for all ages)

Minkoff, E. C. and Baker, P. J. (1996). Biology Today: An Issues Approach. McGraw-Hill Companies, Inc. ISBN 0—07-042629-5. (textbook that starts with "biology as a science", and then has chapters that focus on particular issues as opposed to traditional subject matter)

Moore, John A. (1993) Science as a Way of Knowing — The Foundations of Modern Biology. President and Fellows of Harvard College. Cambridge.

Science and Creationism. 1999. A view from the National Academy of Sciences. National Academy Press. (available on line at www.nap.edu)

Shawl, S. J., Robbins, R. R., and Jefferys, W. H. Discovering Astronomy, 4th Edition. Kendall/Hunt Publishing Company (has useful chapter on science and pseudoscience)

Switzer, P. V. and Chriner, W. M. 2000. Mimicking the scientific process in the upper-division laboratory. BioScience 50:157-162.

Teaching about Evolution and the Nature of Science. 1998.. National Academy of Sciences. (available on line at www. Nap.edu/readingroom/books/evolution98)

Tobin, A. J. and Dusheck, J. 1999. Asking about Life. Second Edition Harcourt. College Publishers.

Appendix 5.c

Report from Sub-committee #3

Taskforce for Science Education

Subcommittee 3

DRAFT REPORT

1. Who are KU student populations; what are their "learning styles"

Professor Fred Rodriguez from the KU Center for Teaching Excellence outlined some of the different learning styles of students. Many students are "field dependent learners" who are sequential learners needing structure within their learning environments. Many others are "field independent learners" who can do it by themselves without much formal structure.

There is also another type of division of students in terms of social style. Some learn best in group activities while others learn best as individuals. Some students learn best with lots of graphics, others from readings, still others by audio while listening to lectures. There are also differences in desired outcome of the learning process among science and non-science undergraduates and between graduate students and undergraduates within the individual science majors.

2. Effective methods of instruction

The most effective method of instruction varies among professors, and also among individual students. To some degree the method of instruction should be guided by knowledge of learning styles. Professor Rodriguez outlined 7 key points of methods of effective teaching:

1. Provide for collaboration among students

2. Provide an active learning environment

3. Generate prompt and constructive feedback

4. Encourage contact with the professor

5. Allow time to digest material

6. Have high expectations of student performance

7. Provide a variety of ways of learning within a class period.

3. KU resources for change in curriculum and teaching methods

Obvious existing resources include the curriculum committees in CLAS and in each school. Some barriers to change include perceived needs to protect traditional turf in departmental disciplines. In many cases, the bottom line in these battles is protection of student credit-hour count, and the implied long term loss of faculty lines, GTA support, and other forms of resources that accrue to those departments and programs with large enrollments.

The Center for Teaching Excellence has begun to provide opportunities for improvement of classroom instruction by faculty.

4. Student/instructor evaluation and resources for evaluation

At the present time, the Curriculum and Instruction evaluation forms (or their equivalent) are the primary means of evaluation instruction. Other methods vary from department to department, but commonly include peer review on a random basis, especially for untenured professors. To a lesser degree, the various teaching awards on campus are a form of evaluation of the best teachers.

Clearly, implementation of new methods of instruction and new content precede and demand new methods of evaluation With regard to student evaluation, the task force mission implies that student knowledge of science as a process or a way of thinking will be a fundamental part of the student grade. This is not exceptionally difficult when a class has 20 students. With a class of 500, individual evaluation of students beyond performance on routine examinations is a daunting task.

5. Role of proposed science teaching facility in improving science education

The role of the proposed science-teaching facility depends on the other resources that become available to implement change. We first need to determine what is currently needed at KU with regard to improving science education before knowing what the role of the new facility should be. How will the new facility integrate with the CTE and the proposed CTL (NSF proposal)? CTE has responsibilities that go beyond the teaching of science.

6. Will improved methods increase # of underrepresented/underserved science majors

We predict that the answer will be yes for two reasons: underrepresented and underserved science majors are self-selected for potential science careers; and both groups theoretically arrive at KU farther behind in science instruction.

7. What KU science programs focus on K-12 environments

Perhaps K-12 teachers rather than k-12 students should be a KU priority because of exponential impact on numbers of students. The formal science education programs are in the School of Education — students who receive provisional teaching certificates; in-service K-12 teacher training

There are other informal science education programs including:

Natural History Museum: teacher training and students

Anthropology Museum: teacher training and students

Observatory: teacher training and students

KU Libraries

Continuing Education

Various school/departmental programs

8. What KU programs reach out with informal education to Kansas citizens

Public science outreach is part of mission of:

- Natural History Museum (exhibits, public ed programs, etc.)
- Anthropology Museum (exhibits, public ed programs, etc.)
- Kansas Geological Survey (e.g., maps, publications, etc.)
- Kansas Biological Survey
- Astronomy Observatory
- KU Visitor Center
- KU Libraries (e.g., Spencer Research Library exhibits and lectures)
- KANU Radio (e.g., Science Friday)
- Many department conduct public science outreach

- **Ideas:**
- Hands-on, inquiry-based science discovery facility for children (in planning at NHM)
- A "Science-Train" — a mobile science museum across Kansas; stops in every school district; partnership with fast-food chain/parking lot
- KANU call-in science show patterned after Science Friday and Car Talk and featuring KU faculty

Discussion of "The Scientific Method"

The ideas presented here are in part gleaned from the book "Shocks and Rocks" by National Academy of Sciences member Jack Oliver of Cornell University, one of the leaders in the development of the theory of plate tectonics in modern geology. From grammar school onward, we are taught about THE scientific method, as though it were the only method with any merit. This cherished method is commonly known as "hypothesis testing." At least two problems with this classical form of the scientific method come to mind.

First, investigators tend to get married to a hypothesis. That is, their egos become involved, and they are afraid to be wrong. As a result, they may not be willing to admit to a failed experiment, or they are reluctant to recognize that they were on the wrong side of the hypothesis at the outset, or they may carry the research well beyond the point of diminishing returns.

The second problem is that the hypothesis-testing method is so deeply ingrained in the competitive scientific-funding system in the U. S. that obtaining funding from such sources as the National Science Foundation is very difficult unless a proposal contains a testable hypothesis. Dr. Oliver points out in his book that, in addition to hypothesis testing, he has used two other scientific methods that have little to do with testing a hypothesis. He calls these two methods "Science by Synthesis" and "Science by Serendipity." As an example of the synthesis method, he cites the famous "Seismology and the New Global Tectonics" paper from 1967, of which he was a co-author. This paper is seen by many as the rational beginning of modern plate-tectonic theory. As an example of serendipity he cites the 1967 paper by Oliver and Sykes that reported the chance discovery, by means of earthquake seismic methods, of the sinking into the earth's mantle of crustal slabs or plates, which was one of the keys to unlocking the ways in which the dynamic earth works. To quote Jack Oliver, "The message here for young scientists is, of course, that no one style of doing science is obviously superior or should be exclusive, and furthermore that science would be less effective if forced into any one such mode. I hope this point is made sufficiently clear so that all peer reviewers will note it! I shudder to think of how backward science might be if all research of the past had been confined, as some peer reviewers have erroneously recommended, to only projects for which the hypothesis is "clearly and explicitly " stated or the problem "sharply defined." Dictionaries define serendipity as "the faculty of making providential discoveries by accident" and as "a gift for finding valuable or agreeable things not sought for." Such a gift favors those who are observant and well prepared-as well as lucky.

In summary, many of the most significant scientific discoveries of the past several hundred years could not have been foreseen or described in the form of a testable hypothesis, which seems to be necessary for submission to a funding agency such as NSF. My point is that the competitive Federal science funding system, as well as university graduate education systems are strongly biased toward proposals and thesis or dissertation projects in which hypothesis testing is the method of choice.

Reference

Oliver, Jack (1996) Shocks and Rocks, American Geophysical Union,

Washington, D. C.

Appendix 5.d

Report from Sub-committee #4

Recommendations for Science/Mathematics Teacher Preparation

I. Curricular

General Education Component:

1. Follow the guidance of the Teacher Education Governing Board and use the work of the Kansas Collaborative of Excellence in Teacher Preparation in the reform of introductory science courses for teacher education students.
2. Offer introductory courses in life science, physical science, and earth/space science tailored to the needs of elementary science teachers.
3. Offer introductory science courses, which are taken by middle-secondary science education students, that are inquiry-oriented and that align with National Science Education Standards. For these introductory science courses, offer a separate discussion session for middle-secondary science education students.

Content Preparation Component:

1. Follow the guidance of the Teacher Education Governing Board and use the work of the Kansas Collaborative of Excellence in Teacher Preparation in the reform of undergraduate science education for teacher education students.
2. Require all secondary science education students to complete course requirements comparable to a B.A. major in the science field they will teach (biology, physics, chemistry, or earth/space science).
3. Require all secondary science education students to complete an undergraduate science research experience.
4. Require all secondary science education students to complete a capstone course that addresses issues that integrate understanding of the history/nature of science, the major conceptual ideas in a science discipline, and the teaching of science.

Professional Education Component:

1. Follow the guidance of the Teacher Education Governing Board and Curriculum Committee in the reform of the teacher education program.
2. Strengthen the five-year teacher education program.
3. Reduce redundancy of content among courses in the teacher education program.
4. Upon entry into the teacher education program, form students into cohorts by license area (grade level and subject area) that will focus course work on issues of teaching and learning within their license area throughout each year of the program.
5. Form faculty teams to coordinate the planning and instruction of courses in the teacher education program.
6. Require students to complete field experiences in the schools and community every semester in the teacher education program. The content in the teacher education courses should link to the field experiences.
7. Increase the participation of school personnel in the teacher education program.

Program Infrastructure

1. Use the Teacher Education Division Governing Board to provide oversight to the teacher education program.
2. Form an Academy of Science and Mathematics Education (science teachers, science faculty, education faculty, business and industry representatives, and science education students) as a community to support science education, science teacher education, and the public understanding of science.
3. Form a Center for Science and Mathematics Education to encourage and support research, development, teaching, and service in science and mathematics education at the University of Kansas.

Personnel

1. Double the faculty positions in science and mathematics education within the School of Education to a minimum of five full time equivalents.
2. Add faculty positions in science education within each of the science Departments to address issues of

undergraduate science education and the content preparation of science teachers.

3. Create a position for a full-time director of a Center for Science and Mathematics Education.

Provide a support staff position for Center for Science and Mathematics

Appendix 6

Current Character of Science and Mathematics Education at KU

Appendix 7

Science Courses Currently Taken as General Education Requirements by KU Students

Current emphasis of the importance of teaching the "process of science" with respect to undergraduate education, as revealed by KU's goals and course requirements

1. **Goals of General Education at KU**

   The Undergraduate Catalog (1998-2000) lists 11 "Goals of General Education at KU" (p. 14), that were established by the University Assessment Committee (Fall 1989) (see Appendix 1). These include four goals that relate to the issue of teaching "the process of science":

   - No. 6: Gain a better understanding of the role of technology,
   - No. 8: Enhance capacity for critical thinking
   - No. 10: Increase capacity for innovative thinking.
   - No. 11. Increase knowledge of methods used by scholars to explain phenomena in the social sciences, humanities, and the natural, mathematical, and physical sciences

   It is our understanding that a current committee is drafting an updated "goals of general education at KU".

2. **Review of how KU is currently teaching students about the "process of science".**

. Current emphasis of the importance of teaching the "process of science" with respect to undergraduate education, as revealed by KU's goals and course requirements

   1. Goals of General Education at KU

      The Undergraduate Catalog (1998-2000) lists 11 "Goals of General Education at KU" (p. 14), that were established by the University Assessment Committee (Fall 1989) (see Appendix 1). These include four goals that relate to the issue of teaching "the process of science":

      - No. 6: Gain a better understanding of the role of technology,
      - No. 8: Enhance capacity for critical thinking
      - No. 10: Increase capacity for innovative thinking.
      - No. 11. Increase knowledge of methods used by scholars to explain phenomena in the social sciences, humanities, and the natural, mathematical, and physical sciences

It is our understanding that a current committee is drafting an updated set of "goals of general education at KU".

2. Principal Course Distribution Requirement

   Within the College of Liberal Arts and Sciences, students must take courses to meet their "principal course distribution requirement" from three broad divisions: humanities, natural sciences and mathematics, and social sciences (see Appendix 2). Three courses are required from each division, with no more than one course from any topical subgroup. In effect, however, students need only take two "science" classes, because of the four topical subgroups under "natural sciences and mathematics", one group is "mathematical sciences", which includes math and computer courses. Using data from 957 BA/BGS students receiving degrees in May 1994, for example, one finds that 10.4% took no biology courses, 29% took no earth science courses, 18.8% took no math/computer science courses, and 43.1% took no physical science courses. These data strongly suggest that most students use math/computer sciences to fulfill one of their science principal courses, and in the process they avoid taking physical science courses.

   Within the College, all principal courses should have a strong focus on the "process of science". Specifically, the College has stated: "The purpose of a Principal course should be to acquaint students with the nature of the subject-matter studied in an area, with the types of questions that are asked about that subject-matter, with the knowledge that has been developed and is now basic to the area, and with the methods and standards by which claims to truth are judged." (April 26, 1985, mail ballot to the College Assembly).

b. Review of critical courses within the College of Liberal Arts and Sciences where students should be exposed to "science as a process". We believe it is particularly important that introductory science courses stress "the process of science" since all KU undergraduates will be exposed to some of these courses.

   1. Natural Sciences

      . Introductory courses for non-majors: We believe that these are courses for which the instructor has a large amount of flexibility. Some departments offer one course for majors and non-majors, however.

        ANTH 104/304 Fundamentals of Physical Anthropology (3/4)

        ASTR 191 Contemporary Astronomy (3)

        ASTR 196 (1) (separate lab to ASTR 191)

        ATMO 105 Introductory Meteorology (5)

        ATMO 220 Unusual Weather (3)

        BIOL 100 Principles of Biology (3)

        BIOL 102 (2) (separate lab to BIOL 100)

        BIOL 110/MCRB 110 Microorganisms in Your World (3)

        BIOL 200/MCRB 200 Basic Microbiology

        BIOL 215 Evolution and Diversity in Shaping Our World (3)

CHEM 124 College Chemistry (3)

CHEM 125 College Chemistry (5)

EVRN 148 Principles of Environmental Studies (3)

GEOG 104 Principles of Physical Geography (3)

GEOG 304 Environmental Conservation (3)

GEOL 101 Introduction to Geology (5)

GEOL 105 History of the Earth (3)

GEOL 121 Prehistoric Life (3)

GEOL 302 Oceanography (3) (prerequisite is one science course)

PHSX 111 Introductory Physics (3)

(Note: an additional biology course, *BIOL 120 To know a bug: insects in your world (3)* is in the process of being approved)

b. Introductory courses for majors that are also principal courses, and can technically be also taken by non-science majors. To various degrees, the instructor has less flexibility in content because certain material must be covered to prepare students for other courses, accreditation, or tests such as the MCAT.

BIOL 150 Principles of Molecular and Cellular Biology (4)

BIOL 152 Principles of Organismal Biology (4)

CHEM 184 Foundations of Chemistry I (5)

PHSX 114 College Physics I (4)

PHSX 211 General Physics I (4)

c. Upper-level courses for majors

To some degree, all science courses at least "touch on" the topic of the "process of science". Some, however, probably do more than others. Biology 415 (Field and Laboratory Methods in Ecology) and Environmental Studies 460 (Field Ecology) are examples of upper-level courses that can be taught with a large focus on the "process of science", in that students are collecting their own data on various ecological research questions, analyzing it, and writing up their study in the form of scientific papers. See Appendix 3 for examples of how Biology 415 is being taught in Spring 2000.

2. Social science and behavioral courses

The social sciences, such as Psychology, perhaps because of their focus on humans, have historically had a large focus on methodology in their courses and textbooks. Faculty in Psychology are also introducing a new methods course for their major.

3. Humanities courses

There are numerous courses in History, Philosophy, and Humanities and Western Civilization with relevance to science education for non-science majors. Examples include:

History:

1998-2000 Undergraduate Catalog listings:

HIST 136, Early Science to 1700

HIST 137, History of Modern Science

HIST 305, The Scientific Revolution

HIST 306, Science and Western Culture

HIST 309, History of Chemistry

HIST 311, Great Lives in Science

HIST 404, Technology: its past and future

HIST 407, History of Science in the United States

Actually taught, 1998-2000, (all by Robert Dekosky):

Fall 1998, HIST 136 and HIST 407

Spring 1999, HIST 137 an HIST 309

Fall 1999, HIST 136 and HIST 407

Spring 2000, HIST 137 and HIST 305

Philosophy: general education logic courses and philosophy of science courses

1998-2000 Undergraduate Catalog listings:

PHIL 148, Reason and Argument* (offered every semester)

PHIL 620, Philosophy of Natural Science

PHIL 622, Philosophy of Social Science

PHIL 630, Philosophy of Mathematics

*The instructors for PHIL 148 have been using Robert J. Fogelin and Walter Sinnott-Armstorng, *Understanding Arguments*. The text and course include units on inductive reasoning and on probability, which together make up about 25% of the course.

Philosophy of science courses actually taught, 1998-2000:

Fall 1998, PHIL 620 and PHIL 630

Spring 1999, PHIL 630

Fall 1999, PHIL 622

Spring 2000 ----

Humanities and Western Civilization:

Western Civilization topics or units that are relevant to education about science for non-science students*

HWC 204:

-Hebrew Bible - creation stories in the Book of Genesis

-Early Greek philosophy as birth of science: Socrates, Plato, and Aristotle on reason, argument, and knowledge

-Thomas Aquinas on the spheres of faith and reason

-Galileo's *Starry Messenger* (a pioneer of modern science at work) and *Letter to Grand Duchess Christina (*science and religion)

-Descartes' *Discourse on Method* (foundations for and examples of his approach to scientific method)

HWC 205:

- Darwin, Wallace, and T. H. Huxley on evolution

- Marx, and Engels, Nietzche, and Freud: science vs. philosophy, what science is and is not

*The two Western Civilization courses are general education requirements for all B.A., B.G.S., and almost all B.S. students in the College, and for all Journalism and Social Welfare majors. They are also taken by some Business and Education students to fulfill part of their humanities requirements, and a few students from Fine Arts and Engineering take one or both courses as an elective. CLAS undergraduates make up almost 70% of KU's undergraduate population.

Humanities courses: HWC 510 Science, Technology, and Society*

*This course has been offered for some years, and always enrolls well. It used to be taught by Jack Davidson (Physics), Hal Orel (English), and Jim Carothers (English). It is currently headed up by Phil Baringer (Physics), joined this semester by Barbara Schowen (Chemistry) and Mohammed El-Hodiri (Economics). The course is currently being offered in the spring semester of alternative years. The topic varies from semester to semester, and the faculty in charge make extensive use of guest lecturers, discussion and oral presentation, and written assignments. Spring 1998 topic was "Science and the Burden of Proof"; Spring 2000 topic is "Life in the 20th Century". Current enrollment in HWC 510 is 30.

c. Comments by science faculty on the degree to which they feel that "science as a process" is important and the degree to which they cover this material in their classes (comments were gathered by informal requests for comments)

Appendix 4 provides examples. In brief, faculty agreed that teaching the "process of science" is important. Some felt that they were already doing it, either by introductory comments at the start of the course or by using articles in the news and relating that to the coursework. Many felt that it was a subject that deserved greater attention but that it was difficult to know how to do more. Several felt that it was very difficult to really teach the nature of science in large lectures with little opportunities for interaction.

d. *Review of how students in the professional schools learn about the "process of science"*

A survey of the curriculum of the professional schools was undertaken. Two of the professional schools, engineering and pharmacy, have obvious science curricula but differ in how students enter the schools. In the case of engineering, students enter the program as freshmen and are expected to have strong high school science and math backgrounds. While in the school of engineering students take many classes; including laboratories, where scientific principles are taught and tested. No course, per se, addresses the issue of "the scientific method" although the introductory courses could be modified to include a "module" on the scientific process which would then be reinforced throughout the curriculum by both didactic course work and laboratory assignments.

For the school of pharmacy, students enter this professional school after two years of prepharmacy course work curriculum. However, only about 40% of students entering the KU school of pharmacy perform their prepharmacy course work at KU with the remaining 60% take their prepharmacy requirements at other four-year colleges and community colleges. Within the prepharmacy and pharmacy curricula, the students have a number of courses and laboratories where the "scientific method" is applied, but there is no formal class where this is taught as subject matter per se. Within the prepharmacy curricula students are required to take approximately 30 hours of humanities and general studies. Many of the students take courses wherein the "scientific method" is probably discussed. It would not be difficult to have as part of the 30 hour humanities and social studies or basic science requirements, a requirement of at least one course where research and scientific methods are presented and discussed. Engineering requires only 12 hour of humanities and social sciences, so incorporating a requirement in those 12 hours is more problematic than for pharmacy.

The other professional schools: Journalism, Social Welfare, Education, Business, Fine Arts, and Architecture present a greater challenge. In each program the curricular requirements have been examined to find core science courses in which the scientific method is likely to be presented. Each school will be discussed separately. The School of Architecture requires 68 hours of Liberal Arts & Sciences courses, in which HSS courses must be taken. No explicit courses are given in the catalog to fulfill these hours. There is an introductory course that all majors must take, but that may not be an appropriate course for the subject. Therefore, explicitly requiring a class that would include the scientific method would require a curricular decision at the school level.

The School of Business requires Psyc 104 and a biological science course, one of which must be a laboratory science class. Therefore there is a reasonable probability that each student would be exposed to the scientific method. To increase this probability, a more explicit list of courses having this content would be needed.

In the School of Education, there appears to be a requirement in each of the degree programs for a biological science and/or psychology course. Thus the probability of learning and using the scientific method and its philosophy appears to be high.

The School of Fine Arts has a wide variety of degree programs and as broad a spectrum of general education requirements. However, all programs appear to have explicit biology and western civilization requirements except the following programs: the Bachelor of Music degrees, including Music History and Music Performance. Therefore requiring these majors to take a course that exposes them to the scientific method would appear to require a significant curricular change.

The School of Journalism requires students to take at least three courses in one department of the social sciences and three courses in another department in the College. The catalog lists approved areas of social science from which these courses might be taken, including psychology, geography, and sociology. It does not explicitly require any physical or biological science course. Thus to insure exposure to the scientific method, a more explicit requirement would need to be added. We are particularly concerned that journalism students have little exposure to science, given that future employment may require reporting on the sciences.

The School of Social Welfare has a mathematics requirement to enter the school and appears to have a natural science requirement including a laboratory. To insure exposure to the scientific method, a more explicit requirement may need to be added.

Appendix 8.a

Initiative for Expansion of the Kansas Ecological Reserves

Environmental Education and Outreach Programs at the Kansas Ecological Reserves

A proposal for expanded environmental education and outreach programs at the Kansas Ecological Reserves (KER): the Robinson Tract

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- Summary: The Kansas Ecological Reserves (KER) is KU's environmental field station and consists of 1700 acres of diverse biological communities close to campus. KER is administered by the Kansas Biological Survey (KBS). Since 1948, the Reserves have been used for three overlapping objectives:1) education and outreach, 2) research, and 3) stewardship of native habitats. We propose to increase KER's educational emphasis by expanding our outdoor educational programs. We envision the development of an environmental education program on the site that will be an important interface between the university and the public at large. Thus in addition to helping inform the public about the natural world, we will also introduce them to the types of research being done by university scientists and the approaches they use in their work. Our emphasis will be on "hands-on/minds-on" educational activities, so individuals of all ages have a better appreciation of both their natural environment and the scientific process. A 13 page "white paper" prepared by KBS provides more complete details of the proposed program. It is expected that the development of this program will help provide the conceptual framework for attracting private foundation support and funding.

- *Description of the Robinson tract:* The Robinson tract, 20 minutes north of Lawrence, was the original home site of the first governor of Kansas, Charles Robinson. This tract of land surrounds an 8 acre Oakridge site, privately owned, where the original home was located. The Robinson tract is a 112 acre area that already has an educational focus and is used for field trips for 1500 KU undergraduates each year. A geohydrological monitoring site on the Robinson tract is used for research and teaching by the Geology Department and the Kansas Geological Survey.

- *Proposed activities at the Robinson tract:* Our plan includes both formal and informal educational programs in a wide variety of subjects coupled with a web-based educational package. These subjects include nature study and wildlife biology, as is typical of outdoor environmental education programs. However, we also will include outreach programs on topics such as wetland and prairie restoration, ecological monitoring, ecological field research, and environmental history. These latter topics allow us to integrate our educational programs with ongoing scientific research being conducted at this and other locations on the Reserves. For example, KBS recently obtained support from the U.S. Fish and Wildlife Service and the Natural Resource Conservation Service for a wetland restoration project at the site. To help the public appreciate research projects such as this restoration study, we thus plan to develop demonstration areas and experimental plots showcasing different restoration techniques and use these in our educational programs. An overview of the types of programs we envision is listed below (see Appendix 3 of the full report for more details); as our plans develop, we will coordinate our efforts with others at KU and in the community who are involved in environmental education.

- K-12 students: modules that complement classroom curricula
- High school students: participation in research projects
- KU students and other university/college students: field trips, courses,
- and participation n research projects
- Teachers: in-service courses and short courses
- Environmental professionals: technical workshops and demonstrations
- Citizen groups and individuals: activities that target specific audiences
- including seniors culturally diverse groups, preschoolers, tourists, civic groups, policy makers, and the general public

-Advantages of the Robinson tract:

- Long term use as a teaching site. Since 1994, the Robinson tract has been extensively used for educational activities. The site includes an "ecology teaching trail", visited by 1500 students in introductory biology and geography courses each year. The geohydrological monitoring site has been used for training graduate and professional students in groundwater monitoring techniques since 1988.

-Diversity of natural habitats and cultural/historical features: The site includes native prairie, grasslands, a floodplain forest, woods, and a perennial spring. Wetland restoration projects are planned as noted above. These diverse habitats increase the types of educational programs that can be offered, and provide a breadth of natural experiences for an increasingly urban/suburban Kansas population. The historic nature of the site suggests opportunities for interdisciplinary programs that combine cultural and environmental themes.

-Logistics and support: The site is conveniently located 4 miles from Lawrence and only two miles from the Nelson Environmental Study Area, a KER tract where support staff are based. KBS staff have experience with management of natural areas and working with the public.

-Relationship between the Robinson tract program and other KER activities: A major focus at KER is research, with a scientific community of more than 50 faculty, staff, and graduate students conducting field studies at the Reserves. Additionally, we emphasize stewardship of land, especially appropriate management and protection of native prairie and forest lands. Given the focus of this proposal, we provide a brief review of other educational and outreach programs at KER:

- Undergraduate students: Land and facilities at KER are frequently used by undergraduate classes from a variety of KU departments and programs including Biological Sciences, Geography, Environmental Studies, and Geology. Numerous undergraduates conduct independent research projects at the Reserves (more than 20 in the last five years), and many others gain experience as assistants on faculty and staff research projects. Faculty associated with the Department of Ecology and Evolutionary Biology, the Reserves, and the Natural History Museum will be submitting a National Science Foundation "Research Experiences for Undergraduates" grant proposal this fall to further increase undergraduate

research experiences. Students from Haskell Indian Nations University and Baker University also use the facilities and have conducted independent research projects with KU faculty.

-Graduate students: Graduate students from several departments at KU (and from other universities) carry out their thesis and dissertation research at KER. Over the past five years, 47 separate graduate student research projects have been conducted at KER facilities. Since 1949, 139 theses or dissertations have been published based on KER-based research.

-Public outreach: KER has been the site for outdoor education for decades. In honor of KU emeritus professor Henry Fitch (who has educated thousands of Lawrence school children about natural history at the Reserves), the Henry S. Fitch Nature Trail was established at KER in 1996. A very conservative estimate is that 800-1000 people visit the trail annually. A series of informational signs posted along a county road that passes through KER property explains the history of a 40 year prairie restoration study to the public. KER facilities are regularly visited by school groups for field trips and special workshops sponsored by the KU Natural History Museum, and out-of-state programs such as Duke University's Talent Identification Program for junior high students.

Appendix 8.b

Description of the Redesign of Public Education Facilities at the Natural History Museum

Appendix 8.b

Initiative for a New Observational Astronomy Facility

Appendix 9

Sources of Demographic Information about KU Students

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Questions or comments should be directed to mailto:%20scienceeducationtaskforce@ukans.edu

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