Honors Science Track and Minor Description

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Involving *all* students in Applied Learning and Research in our Introductory Science Laboratory Courses

Over the past decade there has been a growing interest in incorporating more active teaching and learning into undergraduate science courses. This emphasis on inquiry-based teaching is especially important in laboratory courses where students are applying the process of science. In fact, the National Science Foundation (NSF) and National Research Council (NRC) have both called for an increase in active teaching since the mid 1980s (Tuss *et al*, 1998; NRC, 2003a). This push gained more strength when the American Association for the Advancement of Science (AAAS) once again emphasized the need to incorporate inquiry throughout the undergraduate science curriculum and to use scientific approaches to assess faculty teaching and student learning. In fact, the *Vision and Change* report, published by AAAS in 2011, called for the involvement of *all* students in research. This echoes Wichita State University's vision to become "internationally recognized as the model for applied learning and research."

Despite these repeated calls for increased inquiry-based teaching and learning in undergraduate science curriculum, most college scientific laboratory exercises give students well-defined problems that have already been solved and therefore deprive them of the experience of dealing with the messiness of solving authentic, real world problems. Instead we need to invite our students into labs to tackle problems that we don't know can be solved and let them learn to design experiments, troubleshoot, and learn to deal with failure. While there are many constraints that faculty members face when transitioning to teaching methods that require greater mentorship of students in order to fulfill the goal of involving *all* students in applied learning and research, we need to envision how to incorporate open-ended and research-based approaches in courses to a greater degree, especially in introductory courses. The value in terms of learning outcomes has been shown to be worth the money and effort and has been shown to help retain students in science majors and to prepare them for the workplace (Weaver *et al.*, 2008). A recent meta-analysis of the literature suggests that inquiry-based learning can increase student-learning gains significantly and that the greatest effect seems to be found in introductory courses and courses that incorporate research, as opposed to those that are merely guided inquiry (Beck *et al.*, 2014).

Clearly applied learning and research programs in science promote a variety of skills that are essential for success such as critical thinking and problem solving, creativity and innovation, communication, collaboration, and entrepreneurship. However cultivating students who have developed skills through inquiry-based learning and who know how to carry out research will yield more qualified postgraduate students and also provide those not going on to undertake

further research with the knowledge of how science is done. This is empowering and potentially beneficial to society as a whole.

The Current and Future Need for STEM Graduates

Employment in science, technology, engineering and math (STEM) occupations has grown 79% since 1990, from 9.7 million to 17.3 million, outpacing overall U.S. job growth. Yet, current economic projections suggest that the U.S. will need to generate approximately 1 million more STEM professionals than the current rate over the next decade if the country is to retain its historical preeminence in science and technology, according to the President's Council of Advisors on Science and Technology (PCAST). The National Academies' report *Rising Above the Gathering Storm* highlighted troubling issues in a number of areas: low STEM retention rates, a relative decline in the number of U.S. citizens enrolled in science and engineering graduate school, and lower percentages of STEM graduates than those of other developed countries. These sentiments were echoed in a 2012 report by the U.S. Congress Joint Economic Committee, which stated that the current STEM workforce was falling short of demand in both STEM and non-STEM occupations. According to PCAST, the United States will need to increase its yearly production of undergraduate STEM degrees by 34 percent over current rates to match the demand forecast for STEM professionals.

Evidence of this increase in STEM jobs is evident in the Wichita region with the recent expansion of Pfizer (previously Hospira) in McPherson, the new Cargill Protein Headquarters being built in downtown Wichita and the growth of smaller companies such as Fagron Sterile Services. These augment the well-established aviation industry (Textron, Bombardier, Spirit AeroSystems, and AirBus), healthcare industry, and chemical manufacturing (Koch Industries and OxyChem). In fact, both private and public sectors reported that the 21st century workforce would require more in-depth knowledge of math and science, plus the ability to integrate and apply that knowledge to solve the challenges facing our nation.
A 2013 report from the US National Science and Technology Council indicated that "current educational practices are not leading to a sufficiently large and well-trained STEM workforce." To improve our STEM recruitment and retention efforts our proposal advocates for a shift in the classroom that will encourage student inquiry, feed curiosity and deepen student understanding of scientific concepts across multiple introductory science courses. In these core laboratory courses teachers will create projects where concepts become apparent as students work through real-world challenges.

Honors College Supply and Demand

The goal of the Cohen Honors College to "challenge ambitious students in any major to build a better future through rigorous classes, problem solving across disciplines, independent and collaborative research, and community service" aligns well with the aims of this proposal to provide a more active and challenging approach to learning across scientific disciplines. Currently there are several different ways to earn an Honors distinction, including several "tracks" for students interested in exploring a topic or a future career interest. Each interdisciplinary track is made up of a core course, directed electives and experience-based learning. The currently defined track options are limited to "Law and Public Policy" or

"Leadership," while students are also given the freedom to create their own "Interdisciplinary" track. Students may also earn an Honors Minor by combining general education and research-based learning with interdisciplinary study and application, with the goal of preparing students for graduate study and professional success. As currently defined, the minor requires students to complete 24 credit hours in the Emory Lindquist Honors Scholar track and an Honors Interdisciplinary track. In the broadest sense, the Honors Minor requires a minimum of 24-credit hours or eight designated Honors courses.

The Honors College has grown tremendously since its inception and the last three years have witnessed freshman classes of 200 to nearly 300 entering students this year. The majority of these Honors College students (60-63%) intend to major in STEM fields, yet there is currently a limited selection of Honors special topic seminars (HNRS courses) offered. Therefore, it has long been a goal to establish an Honors Science Track and/or Minor.

The crux of the proposal is the creation of honors lab sections for our entry-level major science classes. These classes would replace the normal laboratory experience with inquiry-driven experiences as a way to create more innovative and creative scientists and engineers early in their college careers. Students would enroll in the honors lab sections and the normal lecture sections and receive honors credit for the entire course. We have identified a set of common core experiences (Table 1) as well as themes (Table 2) that will be emphasized in all of these introductory labs as a way to unite these courses and to better reflect the objective of Honors Tracks or Minors.

Course Requirements

Honors Science Track -

1. Students complete three courses from the following Honors option lab sections:
   a. General Chemistry I (CHEM 211H) = 5 CR: 3R/4L
   b. General Chemistry II (CHEM 212H) = 5 CR: 3R/4L
   c. General College Physics I (PHYS 213H) or Physics for Scientists I (PHYS 313H/315H) = 5 CR: 4R/3L
   d. General College Physics II (PHYS 214H) or Physics for Scientists II (PHYS 314H/316H) = 5 CR: 4R/3L
   e. General Geology (GEOL 111H) = 4 CR: 3R/2L
   f. Historical Geology (GEOL 312H) = 4 CR: 1R/6L
2. Capstone Research Experience – (CHEM 669/690, PHYS 600, GEOL 698 *or* in other STEM departments) = 1-4 CR - honors thesis completion after 2 semesters of research in one of these departments

Total Honors Credits = 14-19

Honors Science Minor - Students enroll in the Honors option for all six of the Honors option lab courses in Chemistry, Physics, and Geology:

1. CHEM 211H + 212H= 10 CR
2. PHYS 213H/313H + 214H/314H = 10 CR

3. GEOL 111H + GEOL 312H = 8 CR
4.Capstone Research Experience (CHEM 669/690, PHYS 600 *or* GEOL 698) = 1-4 CR - honors thesis completion after 2 semesters of research in one of these departments

Total Honors Credits = 29-32

Resources Required

The resources required for this transition are primarily the investment in the time of the laboratory instructors (faculty, staff, and graduate teaching assistants) who will be responsible for transitioning these introductory science labs from their current teacher-centered approach to one that helps students work through concepts, design their own experiments, and interpret their results. This move will take students from a lab where they follow step-by-step instructions to a much less structured environment that requires ongoing intellectual engagement of the students. Several resources exist that will facilitate this change in each field:

- *Discovering Biological Science 1 and 2 Lab Manual Experiments* from MacMillan
- 40 Inquiry Exercises for the College Biology Lab from NSTA
- S.L. Black. *General Chemistry Laboratory—Scientific Inquiry: 157 New Experiments in One Semester. J. Chem. Educ.*, 1996, 73 (8), p 776
- *Investigating Chemistry Through Inquiry*, D. L Volz & R. Smola
- *Laboratory Inquiry in Chemistry* from Cengage Learning

Laboratory course redesign and effective implementation of an inquiry-based curriculum can be challenging, particularly when teaching assistants (TAs) are responsible for instruction (Wheeler, 2017). Therefore, it will also be critical to provide inquiry-based training for the graduate students involved. As part of our proposal, we will also initiate an advanced teaching assistant program that would recruit and train graduate students who will work with instructors involved in these inquiry-driven lab courses.

Logistics

The Chemistry, Geology, and Physics faculty involved in teaching the courses included in the Honors Science Track/Minor plan to offer one or more laboratory sections that will be open to students in the Honors College beginning as early as the Spring of 2019 (CHEM 212). Both students in the Honors College and departmental Honors students majoring in Chemistry, Geology, or Physics are eligible to pursue these classes.

The Advanced Teaching Assistantships will be advertised and applications accepted from graduate students interested in teaching and developing these new lab sections. Our focus will be on GTAs that plan to have careers involving teaching upon graduation. Before the semester begins, all of the selected Advanced GTAs will take part in a scientific inquiry teaching workshop led by faculty who have experience in using these methods with support from Instructional Design and Access and the Graduate School.

The role of the Honors College will include promoting and marketing the Honors Science Track and Minor. The Honors College will assist in recruiting prospective students as well as direct

current Wichita State students (Honors and General undergraduates) interested in a STEM field to pursue a track or minor in Honors Science. The Honors College also has supportive funds for qualified students to help provide internship, study abroad, or NSE opportunities that may further advance a STEM student's academic experience.

Looking forward

While this proposal seeks to stimulate recruitment and retention of STEM majors by offering a new series of inquiry-driven labs, we seek to identify many other options to strengthen and broaden the STEM pipeline as this program develops. In particular, electives for the Honors Science Minor could include courses in Philosophy of Science, History of Science, Science Policy of Law, Scientific Writing, and Scientific/Engineering Ethics. An ultimate goal also includes integrating these newly designed inquiry labs into a broad spectrum of undergraduate labs to provide all students with more opportunities for applied learning in the classroom. In conclusion, we see this Honors Science Track and Minor as a unique opportunity to heighten aptitude and interest in STEM in undergraduate students, while also providing a distinctive teaching experience to strengthen and thereby improve both undergraduate and graduate student potentials for graduate school and further desired career paths in STEM.

Table 1: Common Core Experiences

- Emphasize transition from expository lab experiments to course-based undergraduate research and/or guided-inquiry labs.
- Focus on the thought process and improving experimental design skills rather than following directions exactly, or even getting expected results.
- Students develop plans of action to solve the problems, carry out those plans, assess the results, and report their findings.
- Students will gain an understanding of the application of fundamental scientific principles to societal issues and problems.

Table 2: Themes or Guiding Principles

- Nature of science – scientists seek a systematic organization of knowledge about the universe and its parts.
- The fundamental elements of the scientific method, such as formulating a hypothesis, designing an experiment to test the hypothesis, and collecting and interpreting data.
- Facts are determined by observation and measurement of natural or experimental phenomena.
- Scientific knowledge is based on explanatory principles with verifiable consequences that can be tested by independent observers.
- Although the goal of scientific inquiry is to approach true explanations as closely as possible, its investigators claim no final or permanent explanatory truths. Science changes. It evolves.
- Basic principles that guide scientists, as well as many other scholars, are those expressed as respect for the integrity of knowledge, collegiality, honesty, objectivity, and openness.
- Scientists are trained and employed to be skeptical observers, to ask critical questions, and to challenge knowledge claims in constructive dialogue with their peers.

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