Clemson University
College of Engineering and Science

Requesting to Offer a New Degree Program

Ph.D. Engineering and Science Education

February 15, 2011

Chief Executive Officer

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Classification:

Program Title:	Ph.D. Engineering and Science Education
Academic Unit:	Department of Engineering and Science Education
Designation of degree:	Ph.D.
CIP Code	15.1599
Proposed date:	August 15, 2011
Identification of Program:	New
Site:	Clemson University
Delivery Mode:	Traditional

Statement of Purpose

The purpose of the PhD program in Engineering & Science Education is to establish a nationally-unique graduate program in science, technology, engineering, and mathematics (STEM) education research. The Department of Engineering & Science Education (ESE) in the College of Engineering and Science at Clemson University is the only department in the country that includes both engineering education and science education in a College of Science/Engineering. As such, it includes faculty who are experts in science education and engineering education, and have active research programs in these areas. Students in this program will be exposed to the wide breadth of STEM education research under current investigation as well as be prepared to interface between the development of new theory in STEM education and the implementation of new research findings in practice. This Discipline Based Education Research (DBER) combines knowledge of teaching and learning with deep knowledge of discipline-specific science content. It describes the discipline-specific difficulties learners face and the specialized intellectual and instructional resources that can facilitate student understanding.

The objectives of the new PhD program will be to prepare students for academic careers in STEM education, science education policy in higher education or informal education institutions, or a range of other careers that require a deep disciplinary knowledge coupled with understanding of the factors that affect student learning, retention, and inclusion in STEM. Students who enroll in this program will be expected to be content experts in a STEM discipline with at least a Master's degree or equivalent in their content area of expertise. Graduates from this program will be prepared to become faculty in traditional departments of engineering or science, as well as STEM education

departments. They will be prepared to lead curricular and pedagogical reform at the post-secondary level as well as conduct research in the burgeoning fields of STEM education research.

Justification of Need

There are numerous calls for improvements in both the number STEM education graduates, and the quality of their experiences (Kenny 1998; Jackson 2002; NSB 2003; Augustine 2005). There is also a growing acknowledgement that there is a need for faculty (Bush 2008; Benson et al. 2010) versed in disciplinary content, current research on how students learn, how to attract and retain a diverse cadre of students, and what factors affect these outcomes. This demand is projected to grow as institutions are increasingly under pressure to improve student learning outcomes while cutting costs. Our experiences (and those of others) indicate that students who graduate with PhDs in STEM education research are in high demand as more colleges and universities realize the need for the expertise that they bring. In recent years the number of faculty positions advertised that specifically target chemistry education researchers has outstripped the number of qualified applicants (i.e., those graduating with a PhD with a research emphasis in chemistry education). Over the past five years, four PhD researchers in chemistry education at Clemson have graduated -- three of those students have taken faculty positions and one is in a postdoctoral research associate position. This trend is being observed in other engineering education programs as well. For example, the School of Engineering Education at Purdue University graduated ten PhDs as of August 2009. Of these, nine are employed in academic units in several capacities, including six assistant professors in engineering disciplines (Benson et al. 2010).

There is a high level of student demand and interest in our courses at Clemson, even with very little in the way of formal program promotion and no recruitment efforts outside of the institution. To date, 17 students have completed requirements for the Certificate in Engineering Education, and approximately 20 more students are enrolled in our graduate courses. Eleven students are actively conducting education research as their dissertation projects. Although they are, by necessity, housed in other departments (bioengineering, chemistry, civil engineering, computer science, industrial engineering, mathematics, and mechanical engineering), a number of these students would major in engineering and science education if the degree program was in place. While ESE faculty have fostered a growing cadre of undergraduate researchers (nine during the summer of 2010 alone), those students who would like to pursue a PhD in engineering and science education are currently applying to other institutions such as Purdue or Virginia Tech. For example, one student, an African-American male who graduated from Clemson's industrial engineering program with a 3.4 GPA, has been accepted into the PhD program in engineering education at Virginia Tech after conducting undergraduate research in our program. We have the faculty, the expertise,

and the funding to support a degree program at Clemson, and the student interest to populate it.

Centrality to the Mission of Clemson University

Clemson University was founded as a "high seminary of learning," and throughout its public land-grant existence has maintained an emphasis on the education of students in science and technology related to economic growth of the state of South Carolina. The new department of Engineering and Science Education has a significant role to play in providing support to this mission through active research which creates new knowledge and practice in these areas of learning. A doctoral program would help fulfill the university's legacy by not only producing valuable educational research, but expanding the ranks of experts capable of applying that research in the state, region, and beyond.

The synergy resulting from combining faculty from the sciences, math, and engineering makes this program unique among doctoral programs that emphasize discipline-specific educational investigations. This quality of uniqueness makes the program more attractive to potential students and funding agencies, and at the same time it contributes to the university plan of implementing strategic emphasis areas. The university and the College of Engineering and Science have demonstrated a commitment to this direction through creation of the department and addition of several new faculty hires. These faculty members in turn are committed to the creation of a vibrant doctoral program that will support the core educational needs in engineering and science.

The PhD in Engineering & Science Education has little overlap with the already existing PhD program in curriculum and instruction. The proposed ESE program targets students who aim to continue in higher education teaching, develop research programs, and coordinate programs primarily at the post-secondary level within the engineering and science disciplines. The PhD in curriculum and instruction typically attracts students whose goal is education at the K-12 level, be it research or teaching. While there are a small number of PhD candidates whose focus is STEM education at K-12 level in curriculum and instruction, most candidates are in other fields.

Relationship to Other Institutions

While this program is a unique program, there are a number of departments of Engineering Education (at Purdue, Virginia Tech, and Utah State) that offer PhD degrees in Engineering Education. There are also currently about 30 PhD programs in physics education and a similar number in chemistry education. We currently have a number of collaborations with these departments and faculty. For example we have a joint seminar program with the Engineering Education department at Virginia Tech. Our faculty also have collaborations with faculty at UC Berkeley, University of Colorado at Boulder,

University of Iowa, Iowa State, Purdue, Harvard, University of Virginia, University of South Florida, Ball State University, Indiana University, California Polytechnic-San Louis Obispo, North Carolina State, Tennessee State University, University of Houston, and University of Texas-El Paso.

Projected Total Enrollment

Faculty members in the Department of Engineering & Science Education are currently the major advisors for 8 PhD students who are housed within disciplinary departments but focused on STEM education research specialties. Thus, as a conservative estimate, we project that there will be approximately 8 PhD students who enter or transfer into the program in the Fall of 2011. Other students will be recruited through free advertising and booths set up at national conferences such as the American Society for Engineering Education (ASEE), the National Association for Research in Science Teaching (NARST), the American Physical Society (APS), and the American Chemical Society (ACS). The program will also be prominently featured on the department website as well as the college website. We plan to continue to increase our web visibility. At present, a search for "engineering and science education" yields our department as the first hit.

Currently there are 6 tenured or tenure-track faculty members in the department. Based on Fall 2009 enrollments, the university average ratio of PhD students to faculty is 2.05, and the ratio in the College of Engineering & Science is 2.40. It is projected that we will sustain 2.5 PhD students per faculty member. Thus, in building our program, a conservative estimate is to increase the PhD enrollment by 2014 from 8 to 15 doctoral students (see Table 1). We plan to maintain a steady enrollment of at least 15 PhD students in the program. It is expected that these students will all maintain full-time enrollment. However, this number will increase with new faculty hires and joint appointments with the department. As a comparison, the Department of Engineering Education at Virginia Tech has 19 enrolled doctoral students (Fall 2010) with 11 tenured or tenure-track faculty. Our projected numbers are well in line with sustained numbers from Virginia Tech. A recent *Science* article (Bush et al. 2008) also indicates that there is a national trend of increasing demand for STEM faculty with education research specialties, ensuring appropriate job opportunities for our graduates.

Table 1. Projected Total Enrollment from Fall 2011 to Summer 2016

Year	Fall		Spring		Summer	
	Enrollment	Credit Hours	Enrollment	Credit Hours	Enrollment	Credit Hours
2011-2012	8	192	8	192	8	192
2012-2013	9	216	10	240	10	240
2013-2014	11	264	12	288	12	288
2014-2015	13	312	14	336	14	336
2015-2016	15	360	15	360	15	360

Projected New Enrollment

Since several of the students starting in our program will be transferring from other programs, it is expected that the first cohort will take 2-5 years to complete doctorates. Thus, approximately two graduate students will complete the program and be replaced with new students each academic year, and with two additional new students joining the program for the first five years we expect a total of four new graduate students for the first few years. Subsequently, a steady addition of two to four students are projected to replace graduating/departing students each year (given the current 6 faculty count; 0.33-0.67 new students per faculty). These numbers are in line with Virginia Tech's Department of Engineering Education that approximates a new enrollment of four to six annually with 11 faculty (0.36-0.54 new students per faculty).

Table 2. Projected New Enrollment from Fall 2011 to Summer 2016

Year	Fall		Spring		Summer	
	Enrollment	Credit Hours	Enrollment	Credit Hours	Enrollment	Credit Hours
2011-2012	1	24	0	0	0	0
2012-2013	3	72	1	24	0	0
2013-2014	3	72	1	24	0	0
2014-2015	3	72	1	24	0	0
2015-2016	3	72	1	24	0	0

Admission Criteria

Students will be admitted into the PhD program in Engineering & Science Education in the fall, spring, and summer semesters. This flexibility will pose an advantage to both the university and students since students who are off cycle in completing pre-requisites can then immediately enroll in the program rather than waiting for the next fall term. All students admitted into the program must have at least a Bachelor of Science degree in a STEM discipline from a college or university that is acceptable to Clemson University, with preference being given to those who have a Master of Science degree. Thus, the program is designed for students who are content specialists in a STEM discipline who seek to pursue discipline-based education research.

Curriculum

Students in this program will be exposed to the wide breadth of STEM education research under current investigation as well as be prepared to interface between the development of new theory in STEM education and the implementation of new research findings in practice. Students will enter the degree with either a Master's degree or equivalent expertise in a STEM discipline. In addition students will take 12-14 hours of coursework in discipline-based research courses. **All of the courses discussed below are already approved by the graduate curriculum committee and are in the graduate catalog.**

Engineering & Science Education PhD Sample Curriculum:

Core ESE courses – 8 credit hours, consisting of ALL of the following:

- CES 800 - Seminar in Engineering and Science Education 1(1,0)
  - *Brings contemporary issues in engineering and science education research into the classroom. Experts from academia, industry and the corporate world give presentations on various issues, including recruitment of minorities, retention issues, technology integration into engineering curricula, distance learning, engineering content into K-12 curriculum, learning theories and education policy issues.*
  - The course is video broadcast in collaboration with the Department of Engineering Education at Virginia Tech. It includes a minimum of 11 seminar presentations originating from either Virginia Tech or Clemson. Students learn to critique engineering and science education research presentations and demonstrate knowledge of contemporary issues in engineering and science education research through reflective writings.
- CES 861 - Teaching/Mentoring Practicum in Engineering and Science Education 1-3(1-3,0)
  - *Practicum that includes teaching or mentoring undergraduates in Engineering and Science (General Engineering or student's home department). Counts*

towards a Certificate in Engineering and Science Education. May be repeated for a maximum of three credits.

- This one credit course is designed for graduate students who are mentoring undergraduate research or design activities (such as Creative Inquiry teams, summer research interns, and independent studies), or who are teaching assistants in an undergraduate engineering or science course. Upon completion, students will be able to:
  - Identify qualities needed for effective mentoring and/or teaching undergraduates in engineering and science
  - Describe potential changes, challenges, or obstacles present when mentoring and/or teaching undergraduates in engineering and science
  - Practice skills and strategies to help engineering and science students successfully complete projects or coursework
  - Design activities to guide undergraduate student learning in research or classroom environments

- CES 871 Engineering and Science Education Research Methods 3(3,0)
  - *Introduces methods and tools available for conducting pedagogically sound engineering and science education research. Quantitative, qualitative, and mixed methods are discussed and practiced.*
  - Students will develop a broad understanding of quantitative, qualitative and mixed methods and how/when they should be employed. As a depth requirement, students will employ one specific method in the design and implementation of a small research study which they will presented orally and as a written journal-style article.
- CES 870 or ED F 955 – Theoretical Basis of Instruction 3(3,0)
  - The purpose of CES 870 is to offer graduate students in engineering and the sciences a foundation in theories of learning with a particular focus on their application to the teaching and learning of science, technology, engineering, and mathematics

Supporting ESE courses – ONE course to be chosen from the following:

- CES 820/821 - Teaching Undergraduate Engineering/Science 3(3,0)
  - *Designed for engineering or science graduate students seeking a career in academe. Includes both discussion and practice of effective teaching techniques, assessments, and technologies, as well as an overview of current engineering and science education research.*
  - This three credit course is designed for graduate students who are seeking a future career in academe. Upon completion of this course, students will be able to:
    - Describe the attributes of effective teaching, and identify specific qualities needed for teaching engineering
    - Identify the skills that engineering/science students need to develop in order to prepare them for successful careers
    - Identify characteristics of "Millennials," and apply them to effectively teach

this generation of engineering/science students
    - Define learning objectives, classify them in terms of Bloom's Taxonomy, and formulate them for relevant courses in their own disciplines
    - Identify different teaching techniques such as cooperative learning and problem-based learning, and how they are used for effective teaching
    - Create assessment tools (problems, exercises, tests) that accurately measure student learning
    - Evaluate the usefulness of technology for enhancing teaching
    - Interpret current trends and literature in engineering/science education
    - Design lesson plans and learning activities for use in an undergraduate course in their own engineering disciplines
- CES 825 – Engineering and Science Student Strategies 3(3,0) (This course has not yet been offered; projected to be offered in Spring 2012)
    - *Provides evidence-based information for graduate students preparing for academic careers on effective strategies for their future teaching and mentoring.*
    - This course focuses on relationships between students' prior knowledge, problem solving skills and cognitive processes in undergraduate engineering and science courses. Focus will be on problem-solving strategies, how misconceptions are manifested in students' work, and how instruction can be structured to address those misconceptions. Upon completion, students will be able to:
        - Examine and classify how engineering and science students learn problem solving strategies
        - Identify successful and unsuccessful problem solving strategies, as well as errors and misconceptions, in terms of cognitive processes
        - Identify relationships between strategies and students' prior knowledge of science, mathematics and engineering
        - Identify and evaluate instructional interventions to improve student problem solving strategies.
- CES 875 - Current Topics in STEM Education Research 3(3,0)
    - *Designed for doctoral students who are interested in STEM education research. The two main objectives of this course are: (1) to guide students through current topics in STEM education research fields (including physics education, chemistry education, engineering education, and mathematics education research); (2) to provide students an opportunity to investigate a current STEM education research topic of their own choosing in depth. Research topics will be drawn from across STEM education disciplines and will be representative of the research techniques/methodologies that are in practice in these fields today.*
    - The topics that will be treated in depth are:
        - Diversity issues
        - Affect
        - Constructivism and inquiry science
        - Conceptual change and transfer

    - Impacts of technology on education
    - Methodological considerations
- CES 888 - Preparing for the Professoriate 3(3,0)
    - *Designed to mentor students in preparing to obtain a faculty position and achieving tenure in science and engineering disciplines. Students will develop a professional portfolio and prepare for the application/interview process.*
    - This 3 credit course is designed for graduate students who are seeking (or considering) a future career in academe. Upon completion of this course, students will be able to:
        - Prepare a professional portfolio, including a teaching philosophy, research statement, and cover letter.
        - Identify components of successful interview talks and grant proposals, and create mini-versions of these.
        - Begin to develop a network of career mentors in their field.
        - Identify key components of the tenure process in science/engineering.
        - Participate productively in the peer review process.

Additional Requirements:

- Enrollment in CES 990 – Thesis Research and Writing

- Supporting Areas – 3 credit hours, as approved by doctoral committee. Included areas:
    - Education
    - Psychology
    - Sociology
    - Statistics
    - Other as approved

- Disciplinary requirement – 12 credit hours at the graduate level in a single STEM discipline (i.e., mechanical engineering, physics, chemistry, etc.). Optional if student holds an M.S., M.E., or higher in a STEM discipline.

Comprehensive and Qualifying Examinations

In addition to the regular course requirements detailed above, students in the Engineering & Science Education PhD program will be required to pass a comprehensive examination as well as a dissertation qualifying examination before undertaking their dissertation research.

The comprehensive examination must be scheduled within 12 months after students have completed their required coursework. Upon successfully passing the

comprehensive examination, the dissertation qualifying examination will follow within another 12 months.

Dissertation committees will be formed while students are completing their coursework and will consist of at least four tenured or tenure-track faculty, of which at least two will be members of the ESE Department (including the committee chair). At least one committee member will be a content expert in the discipline of research chosen by the student (most often, the committee chair), and at least two members of the committee will be experts in at least two different major methodological approaches: quantitative, qualitative, or mixed methods.

The comprehensive exam will be in two parts: a set of written responses to questions determined by dissertation committee members and an oral exam afterwards to assess the adequacy of the depth and breadth of students' knowledge of their STEM discipline (if a Master's degree is not previously held) and knowledge of STEM education research methodologies (quantitative, qualitative, and mixed) and relevant research literature (current and prior). The dissertation committee will select a set of four questions which students will have 4 hours to answer and submit to the committee chair. The committee will schedule an oral examination based on these responses as well as to assess and evaluate any other aspects of student knowledge and preparation that have not been adequately addressed in the written component. After the oral examination, committees will award students one of three outcomes: failure, provisional pass (which will require a re-examination within 6 months), and pass. Only after a student has received a pass will they be allowed to proceed to the next stage.

Within 12 months of passing the comprehensive examination, students will be required to submit a written dissertation proposal to their committee and schedule a dissertation proposal defense meeting. The written dissertation proposal will be structured in the style of a standard NSF/NIH (as appropriate to student's discipline) research grant application and students will be expected to address all the central aspects of their proposed dissertation research at the level of a national peer-reviewed funding competition: motivations for the research, the relevant prior literature and theoretical basis for the research, a set of important and meaningful research questions, an acceptable methodological plan for addressing the research questions, the anticipated analyses, and implications/broader impacts of the research. After this proposal is submitted to the dissertation committee, an oral examination will be held in order to assess a student's preparedness for the dissertation research, and address shortcomings of the proposed research. Afterwards the committee will award the student with a failure, provisional pass (requiring a re-submission of the proposal and re-examination within 6 months), or pass. Once a student receives a pass, the proposed dissertation research may be pursued.

Once the dissertation research is completed and a dissertation is submitted to the committee, in accordance with the regulations and practices of the School of Graduate

Studies, students will submit to a final dissertation defense in order to complete their PhD in Engineering & Science Education.

Evaluation Plan

The evaluation plan will include a number of aspects:

- We will monitor numbers of students accepted into the program, graduating from the program, and their patterns of employment.
- We will also monitor collaborations and funding generated by faculty in the program and the rates of graduate student support.

Metrics for the evaluation plan:

1. Since our target (for the present number of faculty) is to enroll at least 5 students per year, the graduation rate for PhDs from the program should be 5 per year after the initial period (four years into the program).

2. These graduates should find employment, which we anticipate to be mainly in academic settings. We will monitor the careers of these students. However since the norm in sciences and engineering are somewhat different (post-doctoral work is the norm in science, while in engineering this is not necessarily the case), it will be some time before patterns of employment occur.

3. We will compare our employment rates and patterns to those of PhD students in similar programs (chemistry, physics, and engineering) at other universities. We expect to equal or exceed those employment rates.

4. At least two thirds of the graduate students in the program will be supported on research grants.

References

Augustine, N. R. Rising Above the Gathering Storm: Energizing and employing America for a brighter economic future. N. A. Press, Washington, DC (2005).

Benson, L. C., K. Becker, M. M. Cooper, O. Hayden Griffin and K. A. Smith. Engineering Education: Departments, Degrees and Directions. *International Journal of Engineering Education, 26* (accepted for publication) (2010).

Bush, S.D., Pelaez, N.J., Rudd, J.A., Stevens, M.T., Tanner, K.D., & Williams, K.S. Science Faculty with Education Specialties. *Science*, 322, 1795-1796 (2008).

Jackson, S.A. The Quiet Crisis: Falling Short in Producing American Scientific and Technical Talent, Building Engineering and Science Talent (BEST), San Diego, CA, http://www.bestworkforce.org (2002).

Kenny S. S. (Chair, Boyer Commission on Educating Undergraduates in the Research University), Reinventing Undergraduate Education: A Blueprint for America's Research Universities, Stony Brook, New York, http://naples.cc.sunysb.edu/Pres/boyer.nsf/ (1998).

National Science Board, The Science and Engineering Workforce: Realizing America's Potential. National Science Foundation, Washington, D.C., http://www.nsf.gov/nsb/documents/2003/nsb0369/nsb0369.pdf (2004).

Faculty

Faculty	Highest Degree Earned	Field of Study	Teaching in Field
Professor #1	Ph.D.	Chemistry	yes
Associate Professor #1	Ph.D.	Chemistry	yes
Assistant Professor #1	Ph.D.	Bioengineering	yes
Assistant Professor #2	Ph.D.	Physics	yes
Assistant Professor #3	Ph.D.	Physics	yes
Assistant Professor #4	Ph.D.	Materials Engineering	yes

No new faculty will be required to implement this program, however if the department expands we anticipate that new faculty will have the same kind of qualifications as the existing faculty. That is a Ph.D. in a STEM discipline, with an education research background. Most faculty will also have postdoctoral experience in this field.

Proposed Changes in assignment: We anticipate that there will be little or no changes in assignment for the existing faculty in the program. All the faculty are currently teaching the required graduate courses – many of which are also part of the Certificate in Engineering and Science Education, which is open to all graduate students in the University. Several of the faculty have been teaching in large coordinated introductory courses such as general engineering, calculus or chemistry. However in the past year these assignments have diminished due to the increased demand for graduate courses in engineering and science education.

Faculty Development: All the faculty in this department are qualified and capable to direct graduate students in this field. All faculty regularly attend conferences (at least two per year) and publish in this field. All faculty also have external funding from NSF in this field to support graduate students.

The institutional definition of FTE is 12 credit hours.

UNIT ADMINISTRATION/FACULTY/STAFF SUPPORT						
Year	New		Existing		Total	
Faculty	Headcount	FTE	Headcount	FTE	Headcount	FTE
2011-12	0	0	5	4.25	5	4.25
2012-13	0	0	5	4.25	5	4.25
2013-14	0	0	5	4.25	5	4.25
2014-15	0	0	5	4.25	5	4.25
2015-16	0	0	5	4.25	5	4.25
Total	0	0	5	4.25	5	4.25
Staff	0	0	1	1.0	1	1.0
2011-12	0	0	1	1.0	1	1.0
2012-13	0	0	1	1.0	1	1.0
2013-14	0	0	1	1.0	1	1.0
2014-15	0	0	1	1.0	1	1.0
2015-16	0	0	1	1.0	1	1.0
Total	0	0	1	1.0	1	1.0
Admin	0	0	1	1.0	1	1.0
2011-12	0	0	1	1.0	1	1.0
2012-13	0	0	1	1.0	1	1.0
2013-14	0	0	1	1.0	1	1.0
2014-15	0	0	1	1.0	1	1.0
2015-16	0	0	1	1.0	1	1.0
Total	0	0	1	1.0	1	1.0

Physical Plant:

The existing facilities will be adequate for the next five years. All faculty and staff have adequate office space, and new space has been recently renovated for 15 graduate students. We are located in enough space to expand should that prove necessary.

Equipment:

No major equipment is required for our research or teaching needs. We all have NSF funding that will provide for specialized equipment should that become necessary.

Library:

The Clemson University library holdings and electronic access are adequate. All major journals in our fields are already available either online or as open access.

Accreditation, Approval, Licensure, or Certification: Not Applicable

Articulation: there are no other similar programs of this kind in the state.

Estimated Costs

ESTIMATED COSTS BY YEAR						
Category	1st	2nd	3rd	4th	5th	Totals
Program Administration	$32,558	$33,535	$34,542	$35,579	$36,647	$172,861
Faculty Salaries	$248,412	$255,847	$263,523	$271,429	$279,572	$1,318,783
Graduate Assistant	$240,000	$270,000	$330,000	$390,000	$450,000	$1,680,000
Clerical/Support Personnel	$28,365	$29,216	$30,093	$30,996	$31,926	$150,596
Travel	$5,000	$5,150	$5,305	$5,465	$5,629	$26,549
Operations	$5,000	$5,150	$5,305	$5,465	$5,629	$26,549
Seminar	$5,000	$5,150	$5,305	$5,465	$5,629	$26,549
Equipment	$3,000	$3,090	$3,183	$3,279	$3,378	$15,930
Recruitment	$4,000	$4,120	$4,244	$4,372	$4,504	$21,240
Other	$5,000	$5,150	$5,305	$5,465	$5,629	$26,549
TOTAL	$576,335	$616,408	$686,805	$757,515	$828,543	$3,465,606
SOURCES OF FINANCING BY YEAR						
Reallocation of Existing Funds*	$336,335	$346,408	$356,805	$367,515	$378,543	$1,785,606
Tuition	$66,016	$74,268	$90,772	$107,276	$123,276	$461,608
Federal Funding**	$173,984	$195,732	$239,228	$282,724	$326,724	$1,218,392
Total	$576,335	$616,408	$686,805	$757,515	$828,543	$3,465,606

Most of the estimated costs of the program will come from reallocation of existing funds. The department is currently funded and teaching an approved certificate. Those resources will be used for the doctoral program. The only new funding is the $15,000 each year for travel and recruiting for the new department. The department of Engineering and Science Education was implemented to develop graduate programs in

Engineering and Science Education. Therefore all the necessary funds have already been allocated. In addition, existing and future external funding will provide a source of funding. For example, the current external funding level in the department is over $3 million.

* At present $60,000 per year is allocated in the departmental budget for graduate students.

Tuition is based on total student enrollment at $4162/semester

** The remaining graduate assistant budget will come from external federal grant sources. This funding estimate is predicated on continuous funding, however since the faculty have been successful already we feel this projection is warranted. If funding sources are not available, we will not recruit graduate students for that year. Conversely, if our funding continues to rise we will recruit more graduate students.

Institutional Approval:

The Ph.D. program in Engineering and Science Education was approved by

1. Provost, March 2010
2. President, March 2010
3. The Clemson University Board of Trustees, January 2010
4. The Department of Engineering and Science Education, September 1, 2010.
5. The Commission on Higher Education (ACAP), March 18, 2010
6. The College of Engineering and Sciences Curriculum Committee September 7, 2010
7. The Clemson University Graduate Curriculum Committee, November 12, 2010.

PURDUE
UNIVERSITY

DEPARTMENT OF CHEMISTRY

George M. Bodner
Arthur Kelly Professor of Chemistry, Education and Engineering

26 July 2010

Melanie M. Cooper
Alumni Distinguished Professor of Chemistry
259 Hunter Chemistry Laboratories
Clemson University
Clemson, SC 29634

Dear Melanie:

It is a pleasure to serve as the external consultant considering the merits of the Ph.D. program in Engineering and Science Education whose creation has been proposed for Clemson University.

Let me begin by establishing my credentials as an external consultant. As you know, I was one of two faculty responsible for the creation of the graduate program in chemical education at Purdue University (*cf.*, Bodner, G.M., & Herron, J.D., *J. Coll. Sci. Teach.*, **1984**, *14*(3), 179-180). Although the Division of Chemical Education will soon see its 30th anniverary, we recently reported on the 25-year period from the date of the *JCST* article (Bodner, G.M., & Towns, M.H., *J. Coll. Sci. Teach.*, **2010**, July/August, 38-43).

I also had an active role in the creation of the engineering education program at Purdue. A Department of Engineering Education was created five years ago (Haghighi, K. *J. Eng. Educ.*, **2005**, *95*(4), 351-353) that became the School of Engineering Education upon approval of its graduate program by the Indiana Commission on Higher Education. It should be noted that the School of Engineering Education has grown from four or five faculty at its inception to more than 20 faculty, and that one of these "ENE" faculty is the Dean of the College of Engineering, Leah Jamieson.

I am reasonably familiar with the Department of Chemistry at Clemson University, having visited it several times over the years; most recently in 2001. It might also be useful to note that I was the external reviewer of the chemical education graduate program at the University of Northern Colorado, a few years ago, when they were being reviewed by the Colorado Commission on Higher Education. Finally, I might note that I recently started working with the Higher Learning Commission as an accreditor for the North Central Association of Colleges and Universities.

In our original *JCST* paper, Dudley Herron and I wrote: "Only time will reveal whether what we have done represents a significant step in the growth and development of chemical education or merely an unimportant administrative reorganization in a single institution."

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In our most recent *JCST* paper, Marcy Towns and I noted that "[t]he best evidence that content-based educational research programs in chemistry now transcend the boundaries of a single institution can be found by noting that Ph.D. programs in chemistry education exist ..." at 23 different institutions.

When I look at a content-based education research graduate programs, such as the one being proposed at Clemson, I ask myself the following questions.

- Are their a sufficient number of faculty with expertise in content-based education research to adequately supervise graduate students working in the area of STEM education research?
- Is there evidence of a sufficiently strong record of interaction between faculty in the STEM-content departments and their colleagues in the School or College of Education that is so essential to the success of the program?
- Has the institution demonstrated the ability to produce individuals who can pursue academic careers that involve content-based education research, and is there a demonstrable need for the graduate program?
- Does the proposal contain realistic goals?

The first question is based, in part, on having met too many graduates of so-called "programs" at major institutions where none of the faculty have expertise in the area of STEM-based education research. Institutions, for example, where the faculty who consider themselves "chemical educators" do so because they are concerned about undergraduate teaching, not because they are ready to run a graduate program that focuses on *education research*.

The second question reflects our experience at Purdue, and at a variety of other successful programs. The faculty in chemical education at Purdue, for example, teach courses in their area of expertise — chemistry — and occasional special topics courses in the area of chemical education research. We rely on our colleagues in the College of Education to teach courses in their areas of expertise, including educational psychology, qualitative and statistical research methods, multi-cultural education, and so on. We also rely on our colleagues in Education to serve on M.S. thesis and Ph.D. dissertation committees, to bring the unique perspective to research that only collaborations between STEM content experts and faculty in Education can provide.

The third question reflects a characteristic that has played a vital role in the evolution of so many successful STEM-based education research programs. Rather than create a program and then demonstrate that the graduates of the program are sufficiently well-trained to hold academic positions, it is often useful to "grandfather" a few M.S. and/or Ph.D. students, whose success helps demonstrate the need for a formal program.

The question about realistic goals evolved from my experience working with the upper administration of an institution that promised their State Commission on Higher Education that their program would evolve to the point where they were producing four Ph.D.'s a year, whereas they never achieved more than one Ph.D. a year. A critical analysis of the list of 23 institutions whose web sites suggest that they offer a Ph.D. in "chemical education" would suggest that some of these programs are significantly stronger than others. Consider, for example, the post-doc I encountered several years ago who had obtained a Ph.D. in "chemical education" from an institution that is universally recognized as having one of the strongest Colleges of Education in the U.S. Unfortunately, this institution has graduated two Ph.D.'s in "chemical education" in the last 20 years, and this poor fellow suffered mightily from the consequences of the fact that he had no-one to talk to or work with as a graduate student.

Let's now apply these considerations to the proposal from Clemson University.

- The proposal calls for establishing a nationally unique graduate program in STEM education. To the best of my knowledge, they are correct. This would be the only program of its kind, bringing together diverse STEM researchers from science and engineering. As an individual who holds appointments in both Chemistry and Engineering Education, I commend them on trying to achieve this unique status.

- One of the advantages of creating a program with breadth in STEM education research is the ability to create a critical mass of graduate students, who can work with each other across disciplinary boundaries, from the inception of the program. This aspect of the proposal ensures that graduate students will not be isolated from peers with whom they can work and, more importantly, with whom they can learn.

- The proposal suggests that the students will be prepared for academic careers in STEM education. This is understandable, but I would suspect that students who complete the program may pursue other career paths, such as working in the area of policy, administration, curriculum development, or running in-service or pre-service programs that might not carry academic rank. The proposal presumes that all students in the program will have a Master's degree or its equivalent in their content area, which is a characteristic of the successful content-based education research programs with which I am familiar.

- One of the justifications for the proposed program is based on an argument that is cogent: There is, in fact, an abundant "need for faculty who are versed in both disciplinary content, and current research on how students learn, ..." A somewhat less cogent argument is based on the assumption that students who would like to pursue a Ph.D. in Engineering and Science Education are currently applying to other institutions. A more cogent argument would be based on the fact that the demand for programs that would lead to a Ph.D. in STEM-based education research is greater than these other institutions can meet.

- The proposal makes a cogent argument about the centrality of the program for the mission of Clemson. It is, indeed, consistent with the commitment that has been exhibited by the College of Engineering and Science through recent faculty hires.

- The proposal makes too much of the absence of overlap with the already existing Ph.D. program in curriculum and instruction. I would argue that it is *strengthened* by the existence of that program, inasmuch as the existence of the C&I program ensures that an adequate base of education research courses will be taught at Clemson.

- As someone who has visited many STEM-based education research programs over the years, I am pleased by the fact that this proposal builds on a current steady-state of about 10 graduate students, and has a realistic view of building to 20 graduate students by 2014. The experience of so many programs has shown that research groups with four or five graduate students, in programs that have 20 or more graduate students, have both the critical mass of graduate students to be successful and the faculty diversity necessary to meet the needs of a diverse group of graduate students.

- The proposed curriculum is consistent, in many ways, with our graduate program in Engineering Education, which has a large enough (and a diverse enough) group of faculty to teach their own courses in research methods. It is not consistent, however, with the graduate program in either chemistry, physics, biology or earth and atmospheric sciences at Purdue. These programs presume that research methods courses are best taught faculty for whom this is their area of expertise. Thus, the science graduate students at Purdue typically take at least one course in educational psychology that is taught by someone from our Educational Studies department, and at least three research methods courses (e.g., two courses in statistics and one in qualitative methods, or one in statistics and two in qualitative methods) taught by faculty outside of the STEM-content area, as well as an occasional special topics course in education (e.g., Action Research).

In summary, the proposal created by faculty from the College of Engineering and Science is one that I can enthusiastically endorse. The institution has demonstrated a commitment to this program, they have the faculty with both content-knowledge and education research expertise needed to adequately supervise graduate students, they have proposed what will be a unique program that appropriately reflects Clemson's mission, and their expectations for the immediate future are reasonable.

Best regards

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Current Status, Emerging Landscape, and Potential Impact of Engineering Education PhD Programs – Assessment for Clemson University

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PhD's devoted to engineering education research topics go back at least to the late 1920s. Currently there are over 450 engineering education related PhD dissertations (Strobel, Evangelou, Streveler and Smith, 2008). Science disciplines, especially chemistry and physics have had education PhD dissertations and programs for many years.

The early 2000s saw a flurry of activity focused on engineering education research, and the emergence of engineering education PhD programs. In January 2003, the Journal of Engineering Education (JEE) repositioned itself as an archival journal for scholarly research in engineering education. The 2005 Special Issue of JEE, The Art and Science of Engineering Education Research launched the journal as the "engineering education research" journal (Felder, Sheppard and Smith, 2005). Several JEE editorials emphasized the urgency for systematically studying engineering education as well as strong indications of the readiness of the community. (Gabriele, 2005; Haghighi, 2005; Fortenberry, 2005; Streveler and Smith, 2006). An NSF funded project, Rigorous research in engineering education: Creating a community of practice (originally funded 2004-2006) confirmed very strong interest on the part of many engineering faculty members (Borrego, Streveler, R., Miller, and Smith, 2008; Smith, 2006; and Streveler, Smith and Miller, 2005). A follow up project is focused on expanding the community and has created the Collaboratory for Engineering Education Research – CLEERhub.org (Streveler, Magana, Smith and Douglas, 2010).

In 2005 three research universities, Purdue, Virginia Tech, and Utah State launched engineering education PhD programs in their respective Colleges of Engineering. Engineering education PhD programs have also been developed in several other countries, including Sweden, Malaysia, Mexico, and India. In the past five years several additional opportunities for PhD students to earn PhD's in engineering education have emerged. U.S. universities with engineering education PhD programs include Arizona State, Carnegie Mellon, Ohio State, University of Washington, University of Georgia, Washington State University, and the University of Colorado – Boulder. Clemson University's Department of Engineering and Science is commonly seen as an early innovator and partner in the development for ESE research programs as documented for example in the International Journal of Engineering Education article, "Engineering Education: Departments, Degrees and Directions" (Benson, Becker, Cooper, Griffin, and Smith, 2010)

Given the close relation between science and engineering (and perhaps science, mathematics, engineering and technology – STEM in general), science and engineering education PhD programs are timely and important. The University of Minnesota, which has a College of Science and Engineering, recently launched a STEM Education minor in conjunction with their College of Education and Human Development. The University of Michigan launched an engineering education research certificate program in conjunction with their College of Education. It is likely that many more institutions will develop STEM or Science and Engineering PhD programs, minors or certificates.

The interest among prospective PhD students is strong. Purdue University's School of Engineering Education currently has over 50 PhD students, and 16 PhD graduates. The PhD graduates were all able to find jobs. Virginia Tech as over 20 PhD engineering education PhD students and they, too, indicate that interest among prospective students as well as job prospects are strong. The recent emergence of engineering education PhD granting departments and programs will surely contribute to a continually growing number of PhDs, and correspondingly, a deepening understanding of engineering and engineering education.

Given the national and international concerns about STEM education and STEM education research, the strong indications of interest among prospective PhD students, those currently enrolled in engineering education PhD programs, faculty and prospective faculty, and higher education research funding agencies (especially NSF); Clemson University is well positioned to provide leadership in science and engineering education PhD programs.

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