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Establishing Doctoral Programs in Electrical Engineering, Materials Science and Engineering, and Computing in an Emerging Research Institution: Lessons Learned and Best Practices

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Establishing Doctoral Programs in an Emerging Research Institution: Lessons Learned and Best Practices

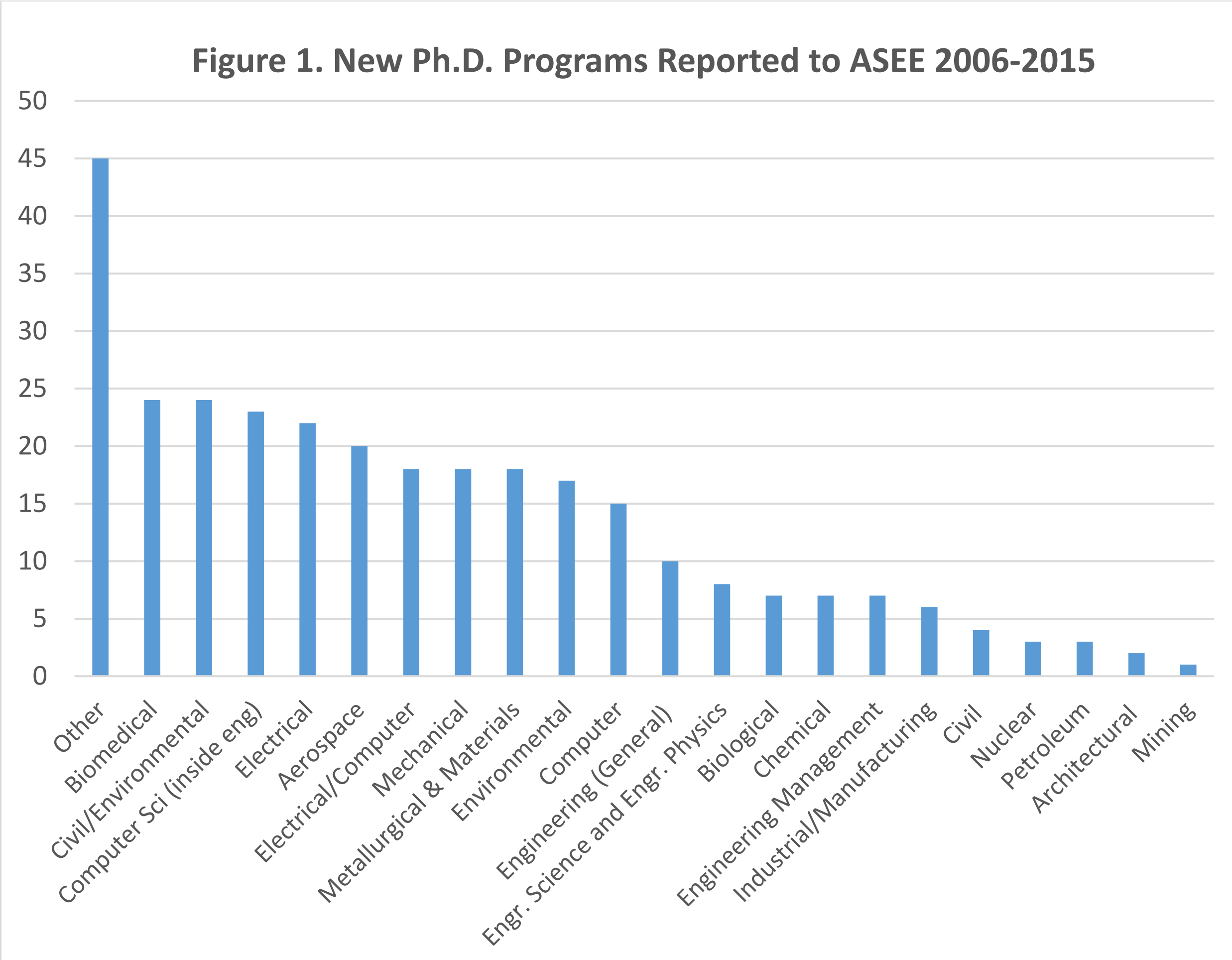
Abstract

Over the past decade, three doctoral programs have been launched at Boise State University. The first doctoral program established was in Electrical and Computer Engineering, selected because of the need for a trained workforce in the region. The other two doctoral programs, Materials Science and Engineering, and Computing, were from the start designed as interdisciplinary degree programs. That is, they were designed for the participation of not just program faculty within the division, but for the participation of program faculty with related research interests in other departments at the university. This paper presents the steps taken to launch the programs, lessons learned in initiating and administering the programs, best practices undertaken, and challenges faced by the emerging doctoral degree programs.

Introduction

Viewed as being essential to American technological research, manufacturing, and overall economic strength, the limited number of scientists and engineers with advanced degrees has long been a concern for the country's wellbeing. Science and engineering jobs have continued to increase at a faster rate (18.7%) than all other occupations (14.3%), with 59% in computer and mathematical scientist occupations.[1] The driving growth among science, technology, engineering and math (STEM) occupations, has caused more than 1.1 million computer and mathematical occupations to be added between 2005-2015.[2]

Although over 22,000 doctoral degrees are conferred yearly in the science and engineering fields,[3] questions remain regarding the nation's ability to meet the ongoing demands of the workforce. In the past several decades, higher education institutions have worked to rise to the challenge with increased degree production; for example, between 1990 to 2013 the number of PhDs awarded in computer science increased by 135% for residents of the US and 250% for international students. American universities have also approached the crisis by establishing innovative graduate programs, such as Nanoengineering,[4] Computational Science and Engineering,[5] Logistics and Transportation,[6] Control Systems Engineering,[7] and Telecommunications Systems Engineering.[8] In addition, on average, 30.7 new Ph.D. programs have been reported annually to ASEE in the time-frame between 2006 and 2015.[9] An analysis of the areas in which these new PhD programs have developed is presented in Figure 1. The category, "other" includes innovative or novel programs such as Nanoengineering, etc.



A rising research university in Idaho recognized the regional need for high tech professionals with advanced education. As a result, three doctoral programs were developed over a 10-year period, including one discipline-specific program in Electrical and Computer Engineering, and two interdisciplinary degree programs, Materials Science and Engineering, and Computing.

In researching the literature surrounding the establishment of doctoral degree programs, no peer-reviewed articles could be found. This paper is therefore presented with two primary aims – first to outline the steps typically needed to establish a doctoral program at a state university, and second, to disseminate some of the best practices that were developed, and lessons learned along the way. This is done by providing first some background on the university itself, followed by individual sections corresponding to each doctoral program. These sections provide rich historical details surrounding steps taken, and end with a closing summary of best practices/lessons learned for each program.

Background

The College of Engineering at Boise State University was formed in 1997 to meet the demands of an emerging high technology region. The state's economy had historically depended on agriculture, forestry, and mining but in the last 30 years realized an increased number of companies with a focus on microelectronics and computer technology. As a result, by 2005 the region was ranked first out of the 150 largest metropolitan areas in the nation as the best place for business and careers, eighth for job growth, and fourth for engineers as a percentage of the workforce.[10] The local availability of an advanced engineering talent pool, coupled with the need for career development opportunities, required the co-location of a strong engineering college with these high tech industries. Recently software development has also emerged as a new and growing industry leading to a desire to expand the talent pipeline for software engineers and computer scientists. Future growth and prosperity of the state's economy is dependent on the continued success of established companies, the ability to attract new companies to the region, an expanded talent pool, and the support of an entrepreneurial environment.

At the college's 2004 visioning conference, the keynote speaker Len Jordan, then general partner of Frazier Technology Ventures, described that the basic foundation of successful technology companies includes: (1) a compelling market opportunity, (2) research/science breakthroughs, (3) world class engineering talent with the ability to repeatedly solve complex problems better than any other competitor, and 4) proven entrepreneurial and business skills. He further stated that when evaluating a possible investment, a key criterion in assessing investment risk is the ability of the regional infrastructure and population base to be able to locally produce at least 30 percent of the doctoral level engineering and science talent that will be required by the startup firm. Thus, access to advanced academic research and development laboratories and advanced academic programs in engineering is critical to success.

Because of the need to further develop the high-tech economy, and with support from local industry and the state government, three doctoral programs were developed over the last ten years. The following three programs will be discussed, Electrical and Computer Engineering (ECE), the interdisciplinary program in Materials Science and Engineering (MSE), and the interdisciplinary degree in Computing. The program in ECE emerged first, followed by the MSE program, and most recently by Computing.

Electrical and Computer Engineering

Electrical and Computer Engineering was one of the founding departments in the College of Engineering, established in 1997 with a B.S. degree offering. In 2001, the master's degree program was created. Local industry benefitted from its high quality graduates at the bachelors and masters level. By Spring 2005, there were 254 undergraduate and 54 graduate students enrolled. The establishment of a doctoral program in ECE was in direct support of student interest and the regional community and was a specific goal in Boise State University's 2000-2005 Strategic Plan, which reflected an expanded mission with a focus on research. From its initial founding, the ECE department had significant collaborations with local industry and in particular from two major technology corporations that surrounded it. As the program grew and expanded, the need for a doctoral program was seen as a natural next step in the progress of the university and critical to serving the needs of local industry.

Since this would be the first doctoral program in engineering and only the third at the university, several challenges existed. The first was the high cost associated with such a program, the second was resistance to the university in moving from a comprehensive institution to a doctoral granting national research university, and the third was whether the program should be restricted to ECE or whether a doctorate in engineering would better serve the college. In the end, the college determined that the first doctorate would indeed be in ECE because of the uniform excellence in the program, its size and reputation, and the close connections to local companies. It was determined that the best chance for success was not to pursue a more general doctorate in engineering, which might have allowed a question regarding quality.

Even though other research universities in the state offered access to an electrical engineering doctorate, they were not co-located with high tech industries and produced collectively less than one graduate each year, simply not enough to meet demand. Thus, duplication was proven a non-issue. To help ensure a smooth approval process, collaborations were established with the two doctoral research institutions offering access to an electrical engineering PhD before a notice of intent was filed with the state board of education (SBOE). The collaborations included obtaining full access to the IEEE/IEE Electronics Library for all three universities, encouraging faculty to serve on doctoral committees outside of their own institution, promoting further collaboration on research, developing a mutually supportive recruiting network for graduate engineering students, and creating post-doctoral opportunities for recent graduates at sister institutions in the state. This provided a win-win situation that garnered support from the provosts and engineering deans at the other institutions and helped secure SBOE approval for the notice of intent (NOI).

As the dean at that time was an electrical engineer, she worked with ECE faculty to develop a full proposal and tackled the resource challenge before a SBOE external evaluation was conducted. The core sequence of the doctoral program built upon existing courses, including research methods. This allowed for students who had previously earned master's degrees or those currently in progress to seamlessly transfer into the doctoral program. It also allowed for resources to be phased in as students eventually moved into more advanced coursework and research. Based upon courses and student to faculty ratios, it was determined that five additional faculty members would be required.

Consideration was taken to allow for working professionals to pursue their doctoral program coursework on a part time basis in addition to full time doctoral students. Dissertation research of the working professionals could be funded by the student's employers and could be of direct interest to the employers, but must also meet standards expected of all dissertation research including accessibility of the results by the public. Such students were expected to be resident on campus for one year toward the end of their studies.

In pursuit of resources the dean entered into conversations with one of the global corporations headquartered nearby, Micron Technology, Inc., and with the provost and president. The dean secured two faculty lines from the university and funding for start-up packages for the new faculty from the Micron Foundation. The rationale for hiring these faculty was to strengthen the research base in the department, to augment the department's expertise in emerging areas of technology, and to manage the existing teaching load. These two faculty members joined the university in the fall semester of 2005 as the program was being approved at the state level. Interestingly, one of the new faculty members had most recently been a research scientist at the partner corporation and retained her close connection and access to the company as she joined the ECE department. This agreement to hire and fund two new faculty members was referred to as initial phase I funding. What was important in securing approval of the new doctoral program was faculty strength and program support, and the phase I plan was initiated prior to external review of the proposed program. With this donation, the corporation requested the university provide a phase II project proposal, after the program was approved, that would facilitate its rapid implementation.

An objective and independent external evaluation committee was sanctioned by the SBOE. This committee evaluated a number of factors critical to the success of the proposed program and unanimously agreed that the college was well positioned to move to the doctoral level. The committee provided a number of excellent recommendations that were incorporated into the program as it developed, and urged the university to move forward in support of this program, stating: "The faculty of the department is strong and fully qualified to implement a doctoral level program. The doctoral program needs to be implemented now." Materials submitted to the review team prior to their visit included the proposal to be submitted to the SBOE, summary documents of the proposal and a recruitment plan for the proposed PhD program, as well as supplemental materials on the ECE department, its faculty, the College of Engineering and the university in general. The review team was asked to comment on the curriculum, faculty, infrastructure, technology transfer, and student recruitment. Among their recommendations was that two to three more faculty should be added in addition to the five designated.

An executive summary and full proposal were submitted to the SBOE along with the evaluation committee report, the university's response to that report, numerous appendices and letters of support. The SBOE unanimously approved the doctoral program with a start date of spring semester, 2006. A phase II project proposal was submitted to the corporate partner that included a three-year phase in of the program. An agreement was signed that provided over a $5 million investment in the new doctoral program from the corporation's Foundation with a $2 million match challenge that was met one year ahead of schedule. This significant investment allowed the first engineering doctoral program to develop at a record pace.

Since its inception, the program has grown and prospered. Current enrollment is approximately 30 PhD students with two to three students graduating per year. The research productivity of the faculty members has grown over time along with their connections to local industry. One of the challenges in being the first doctoral program in the College of Engineering is that the other departments were not as capable of supporting the same level of research and some of the administrative processes in the university needed to be revised and expanded to support doctoral research. For example, an ECE doctoral program will often leverage faculty members and research in Physics and Computer Science. At the start of this program, these departments were small and necessarily focused on their undergraduate and masters programs. This lesson learned helped inform how the next two doctoral programs might develop as interdisciplinary from the outset.

One of the most important aspects and best practices in forming this new doctoral program was hiring and retaining outstanding faculty, and great attention was paid to forming excellent and diverse candidate pools. The faculty hiring process had recently been revamped by the dean to incorporate best practices from NSF ADVANCE grant recipients and others to recruit and retain more women, minority and non-traditional faculty. In addition to increasing gender, racial and ethnic diversity, the ECE department was also interested in a more global perspective among its faculty and specifically sought those with industry and commercialization expertise in order to connect with the region's high-tech industry. One of the two new faculty members hired in phase I had over ten years of industry experience in microfabrication and optoelectronic circuit design. As mentioned previously, she retained her close connection and access to the partner company and brought senior leadership in technology transfer and commercialization to the faculty. The second faculty member hired in phase I was direct from his doctorate. He brought with him a new area of expertise in nanophotonics and substantial patent activity. Both of these faculty had immediate connections to other departments both inside and outside the college and soon held joint appointments across disciplines.

Of the eight faculty members hired under phase I and phase II, two were female, two were international, and five had significant experience with industry including with the two global corporations headquartered nearby. Additionally, many had cross disciplinary appointments inside and outside of the college and several helped expand the department's expertise in emerging areas of technology.

Considering *lessons learned* in establishing a college's first doctoral program, it is always difficult to be the first, and the first doctoral program in a young college of engineering was no exception. The choice of area and discipline had to be very strategic, had to avoid arguments from the other doctoral granting institutions in the state, and had to leave no questions unanswered for the SBOE. The level of scrutiny for the program was exceptionally high and all efforts needed to show the benefit to the state and how the new program would fill an important gap statewide. The issue of duplication within a state is often the limiting factor, so the fact that the region was not being well served from the other doctoral granting institutions was critical.

Other *lessons learned* relate to program growth, and cost to the university. While this doctoral program broke the barrier of being the first doctoral degree in the college of engineering, it was costly, with only one program benefiting; this limits the set of qualified faculty who can sponsor doctoral students. The next two doctoral degrees developed, discussed below, were both deliberately selected so as to have a much broader constituent base – to be able to cross disciplines and bring together faculty expertise from across the university. The aim was to provide a way for more programs to benefit from the corresponding university investment. Both Materials Science and Engineering and Computing are interdisciplinary doctoral degrees, housed in a home department within the college of engineering, but with interdisciplinary doctoral governance and constituent faculty from other departments.

Materials Science and Engineering

The establishment of the PhD program in Materials Science and Engineering (MSE) required a combination of preparation, collective vision and philosophy, building of local and statewide goodwill, and considerable good fortune. The need for a PhD program arose from the relatively fledgling MS (established in 2003) and MEng (established in 2004) degree programs in MSE, which were established in the same time-frame as the BS program. By 2007 many of the graduates of the MSE program were leaving the state to pursue doctoral opportunities at other universities. The research successes of the faculty and possible student demand for a doctoral program did not go unnoticed by the university administration nor local industry, and so talk of the PhD program had a strong underpinning of support.

It was established upfront that the degree would be interdisciplinary, involving multiple departments in the College of Engineering and College of Arts and Sciences, and would be administered in part through the university's Graduate College. While a governance structure for the degree was not outlined in the early stages, it was understood that such an agreement would be critical to success. In this early stage of the process, trust between colleges and departments was a critical ingredient in formulating the notice of intent (NOI) expediently. A small team was formed in 2007 comprised of two MSE faculty, two from the Department of Physics, and one from the Department of Chemistry to benchmark and document, in the form of the NOI, the needs and costs of a sustainable doctoral program. The team communicated regularly with their respective departments in order to solicit input and keep the process as transparent as possible.

The "NOI team" thoroughly benchmarked MSE programs in the US, and analyzed the structure of various interdisciplinary programs. The team used this information, not to copy these other programs, but to guide their outline of possible curricula, degree requirements, teaching and research expectations, and staffing and infrastructure needs. The concept that was developed naturally built on the strengths of the existing faculty, but also considered the needs of regional stakeholders and potential employers. The team produced a document that outlined with minimal detail a vision and a proposed budget, as well as some analysis of the return on investment in terms of graduation rates and research productivity. The budget would support approximately eight new faculty lines, as well as staff, graduate stipends, operating and equipment funds. The program was projected to require an initial $13 million investment over three years which included the startup costs for the new program and new faculty members. This program would, therefore, be the most expensive graduate degree in the university's history in terms of both startup and continuing costs. The aim was not just to have a doctoral program, but to develop a world class program, that had the resources to provide strong start-up packages to incoming faculty, that provided baseline equipment associated with a research program, and good salaries that competed at the national level. The budget outlined sufficient baseline graduate assistant support, and sufficient faculty, staff, and technical support to launch a strong program.

In 2007, Boise University had over thirty master's degree programs, but only three PhD programs. The university was considered a regional comprehensive master's institution in the Carnegie classification system. At that time, the initial cost of the program, $13 million, was not viable for the university. Consequently, the NOI was effectively tabled at the end of 2008. The preparation, however, would later prove to be invaluable, and became a best practice for establishing any new doctoral program.

The vision of the university president, and his commitment to transforming and growing research at the university, was an important catalyst in the process that cannot be understated. In addition, the Dean of the Graduate College, the Vice President for Research and the Dean of the College of Engineering saw the investment in the MSE graduate program among the highest priorities for

Boise State University. Equally important was the commitment of local industry to the growing business, science, and engineering programs at Boise State University.

In the fall of 2010, the university president was approached by the CEO of a major industrial corporation about making a significant investment in the university. The Micron Foundation, the philanthropic arm of Micron Technology, Inc., had already funded across more than a decade, several academic programs as well as buildings and infrastructure at the university. This donation had the potential to be the largest donation in university history. The MSE chair and the deans of the College of Engineering and the Graduate College were involved in these early conversations as the president and CEO considered options. Critically, the arguments and data for investing in the MSE PhD program had been already partially documented via the NOI process, and a proposed budget had been defined. In addition, Micron Technology, Inc. had a strong interest in having a local university that could produce high quality PhD graduates in the field of materials science and engineering. By October of 2010 Micron had made a verbal commitment to the investment, but there were multiple additional hurdles that had to be overcome.

In the end, the Micron Foundation committed to fully funding the first three years of the program, a $13 million dollar investment. In order to secure this donation, it was necessary to not only get a full proposal written and approved in a short time-span by the SBOE but also to have an agreement in place that the costs of the program would be picked up by the university at the end of the third year. This negotiation occurred between the MSE department chair, Dean of the College of Engineering, Provost and Vice President of Finance. The Chair of MSE worked closely with officials at the other two public research universities to obtain their endorsement, develop the proposal and also develop a detailed budget timeline and phase-in plan. By early fall of 2011 everything was in place for final presentation to the Idaho State Board of Education.

After board approval, significant effort was required for the initial startup of the program. As an interdisciplinary program ultimately headquartered in the MSE department, the governing structure needed to be fully discussed and documented. New faculty members in MSE, Physics and Chemistry departments were hired through interdisciplinary search committees. Additional research and administrative staff were hired and students were recruited for the program. Across the entire process, transparency in governance, including financial commitments, has continued to be a best practice that has been followed.

Because of the interdisciplinary nature of the PhD program, and the number of faculty members across campus that were part of the program, the number of students grew rapidly. An expanding relationship with the national laboratory in Idaho also helped in developing new research programs. The program quickly grew to more than 50 students and graduated the first doctoral student in 2013. Now, five years after its creation, the program is on track to graduate four to seven students per year and more than 25 faculty across campus are serving as major advisors to PhD students.

One of the reasons that this program has flourished, relative to student enrollment, ties back with it being an interdisciplinary degree program, with a wider base of constituent faculty members from Physics, Chemistry, Mechanical and Biomedical Engineering and other programs. A second reason, described below, is a best practice based on recruitment.

From the earliest draft of a program budget, plans were made for the need to invest in recruitment. A recruiting plan was created that included developing a comprehensive website dedicated to the PhD program, placing advertisements in STEM-related publications, designing a graduate poster with tear-off postage paid interest cards distributed to universities worldwide, and establishing a social media presence, including Facebook, Twitter, Instagram, and LinkedIn. To launch the program, participation in national student conference graduate school fairs occurred including: Society of Women Engineers, National Society of Black Engineers, the Society for the Advancement of Chicanos/Hispanics and Native Americans in Science, the American Chemical Society, the American Physical Society, and the National Conference on Undergraduate Research. E-blast communications were developed and distributed throughout the year to give program information to student contacts made at conferences – these were lively, colorful, professional, and provided timely information.

Program faculty engaged heavily with regard to recruitment, as they attended conferences and gave invited talks at other universities. Materials were developed including a Graduate Programs Admissions Guide, a Graduate Student Handbook, Graduate and Career Fair exhibit materials such as banners, table throws, and other branding materials, including logo merchandise (swag) used for marketing at recruiting events. Now, with an established program, recruitment is at steady-state; fewer national conferences are attended, and more of the recruiting budget is devoted to hosting an overnight “Campus Closeup” experience in spring for prospective students. This event brings in approximately 15 students for a few days so they can meet the faculty and spend time with current and prospective graduate students considering the program.

One last best practice concerns staffing. Having a faculty member who also serves as graduate coordinator is not enough; you need a staff member who is dedicated to the graduate program and keeps track of everything. The MSE program has a staff member focused on the graduate program who works closely with the graduate coordinator, oversees recruiting and development of leads on graduate students, is their primary point of contact and who also provides ongoing support to the students once enrolled in the program.

In summary: *five best practices* were developed or resulted from the MSE program. The first – its interdisciplinarity, which provides a broader faculty constituent base, allowing enrollment to flourish. Second – plan early, and benchmark other programs, even develop a draft budget so you know what is needed to launch the program well. Having this in place ahead of time, and having external partner departments contribute to its content, was critical when interest from an external donor emerged. Third – be transparent of the process and program, from the very earliest stages of dreaming of a doctoral program, on up to present day. This has led to strong engagement by constituent departments who supervise doctoral students. Fourth – include recruitment as part of the program and earmark an ongoing dedicated portion of the program budget for this purpose. Last – ensure the budget has funding for a staff member who can focus on the graduate program.

Computing

Similar to the events leading to the doctoral programs in MSE and ECE, the PhD in Computing was launched because of interest from regional industries and from the Idaho National Laboratory. In the last five years, the Computer Science (CS) department at Boise State University experienced rapid and transformative growth in enrollments, new faculty, resources and support, and research productivity. During a five-year period, undergraduate enrollments increased from approximately 250 to over 600 students, and the graduate program increased from 25 students to 55. The number of department-funded graduate assistants increased from two to 23, and the department budget more than tripled. The number of full time faculty lines increased from eight to 27 full time faculty and lecturers. External grant funding increased by more than an order of magnitude, with over $4 million in research funding awarded in the last calendar year.

The CS department also significantly increased the strength of their ties with the local high-tech industry. In the last three years the department's Industrial Advisory Board (IAB) has become very active in providing curriculum guidance, and has been instrumental in obtaining resources for the department. In response to local technology industry requests, the university moved the CS department to a new building located in the heart of downtown Boise and within walking distance of more than 20 software companies. This location enables the local software industry to more easily participate in joint research projects, and also allows industry professionals to more easily interact with and participate in educating students.

Driven by this tremendous growth and change, the department began planning on establishing a PhD program. In the fall of 2014 the department formed a planning committee that included three faculty members to explore the possibility of a PhD program. The university's strategic plan called for continued growth in interdisciplinary programs and the strength of the interdisciplinary MSE PhD led to the exploration of an expanded and interdisciplinary PhD program in Computing. Accordingly, new members were added to the planning committee, including faculty from Mathematics and from Mechanical and Biomedical Engineering.

In February of 2015 the PhD planning committee brought together members of the numerous participating departments, including the departments of Computer Science, Mathematics, Biological Sciences, Chemistry and Biochemistry, Civil Engineering, Geosciences, Materials Science and Engineering, and Mechanical and Biomedical Engineering, and created an initial detailed timeline for the proposal process. These departments developed the curriculum proposal, which was approved by the Graduate Council in April of 2015. A full proposal was developed and submitted in September of 2015.

To provide external oversight on the proposed curriculum and plan, an external evaluation team composed of faculty from neighboring states was formed, and they visited Boise State University in December, 2015. Their review led to several revisions, and the final proposal was submitted to the SBOE in March, 2016. The Council on Academic Affairs and Programs met and approved the proposal, followed by final approval by Instruction, Research, and Student Affairs.

The program is built on a solid foundation created by the recent growth and investments at Boise State University in computing-related disciplines. The growth offered an unparalleled opportunity for expanding the CS program to become one of the premier programs in the region for both teaching and research. The expansion of the program has not gone unnoticed by top industry firms, such as Hewlett-Packard, whose Boise Vice President and General Manager stated in a letter of support:

> "that the continued success and growth of the CS department is vitally important for Hewlett-Packard, and for a multitude of other companies in Idaho, and will have significant, transformative economic impact on the Boise Regional Metro area and Idaho."

Boise State University had four broad objectives in the creation of the Computing PhD program:

(i) increase Idaho's capacity for solving complex interdisciplinary computing problems in the areas of computer science, computational science and engineering, and cyber security;
(ii) provide the local and regional high tech industry and agencies with a research and development base and opportunities for professional advancement for personnel;
(iii) enhance quality of existing undergraduate and graduate programs and increase faculty research productivity; and
(iv) increase opportunities for collaboration with other Idaho institutions.

Solving complex problems often requires multiple perspectives and multiple areas of expertise. The interdisciplinary PhD in Computing program brings together faculty members from the Departments of Computer Science, Mathematics, Biological Sciences, Chemistry and Biochemistry, Civil Engineering, Geosciences, Materials Science and Engineering, and Mechanical and Biomedical Engineering. The program is designed to train interdisciplinary scientists to use computing theories and engineering principles to contribute to basic research and solve applied problems.

The three areas of emphasis of the program (computer science, cyber security, and computational science and engineering) are areas of national priority, and a strong workforce in those areas is needed locally and nationally. The report from the President's Information Technology Advisory Committee in 2005 entitled "Computational Science: Ensuring America's Competitiveness" states that computational science is indispensable to the solution of complex problems in every sector, from traditional science and engineering domains to such key areas as national security, public health, and economic innovation. Locally, Idaho National Laboratory has requested that Idaho produce seven to ten graduates per year with skills in cyber security of industrial control systems. The CS IAB has asked that Boise State University focus on developing expertise and producing students in the cyber security arena.

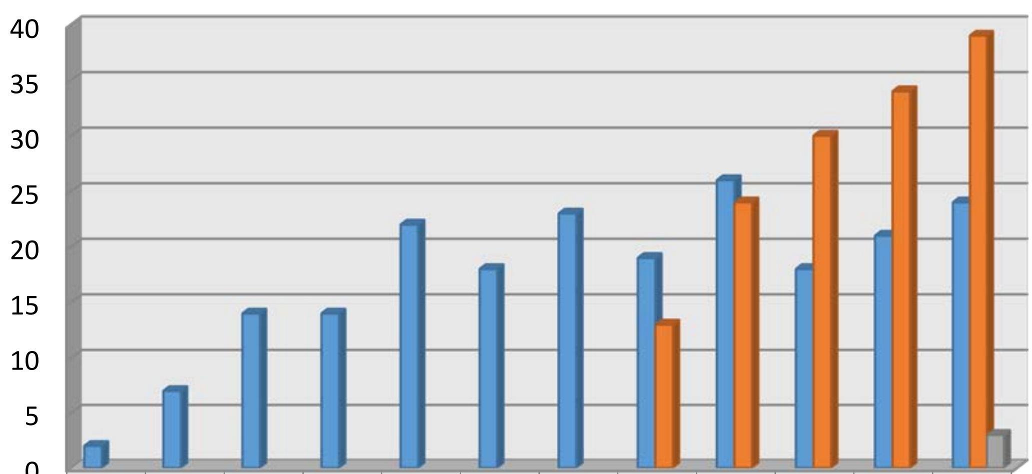
The PhD program in Computing also gives students, local and regional industry, and state and federal agencies in southwest Idaho access to a research-intensive program with strengths in computer science, computational science and engineering, and cyber security. The economy of southwest Idaho includes the largest concentration of high tech companies in the state. The growth of high tech companies has been heavily dependent on the ability of these companies to recruit science and engineering talent with advanced degrees from outside of the state. The PhD program helps satisfy the needs of the high tech companies in the region and contributes to the local economy in a more significant way.

It is too early in this program's history to have developed best practices or lessons learned. The interdisciplinary focus of the Computing doctoral program is a testament to the best practices developed at this institution. Lessons learned remain to be realized.

Results and Discussion

Figure 2 below, shows enrollment trends as a function of time in the ECE, MSE and the very recently launched Computing PhD programs. While the enrollment in ECE has reached what appears to be a steady-state level of approximately 22 students enrolled over the most recent five years, the enrollment in the doctoral program in MSE has not yet achieved an equilibrium level. This is a result of the fact that the program is interdisciplinary by design, and also, all new hires made in MSE for the PhD were junior faculty, who are not fully at mature career-level doctoral support levels.

Figure 2. Ph.D. Programs Enrollment Trends



	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
ECE	2	7	14	14	22	18	23	19	26	18	21	24
MSE								13	24	30	34	39
COMPUTING												3

The strategic investments by this university in the MSE and CS interdisciplinary doctoral degree programs have been in line with its 2012-2017 strategic plan, whose third goal is to *Gain* *distinction as a doctoral research university.* Associated objectives that support this goal include (1) Recruit, retain, and support highly qualified faculty, staff, and students from diverse backgrounds, (2) Identify and invest in select areas of excellence with the greatest potential for economic, societal, and cultural benefit, (3) Build select doctoral programs with a priority in professional and STEM disciplines, (4) Build infrastructure to keep pace with growing research and creative activity, and (5) Design systems to support and reward interdisciplinary collaboration.

As a result of these strategic investments, Boise State University was officially reclassified from “Master’s Comprehensive,” to “Doctoral Granting” in the 2015 review of universities that voluntarily contribute information to Carnegie. This resulted directly from (1) the growing numbers of doctoral degrees granted in the reporting year, (2) research and development (R&D) expenditures in science and engineering, and (3) other metrics that contribute to the Carnegie Classification.™ The Carnegie framework has been widely used in the study of higher education, as a way to represent universities on scales that relate to research activity, doctoral conferrals across both STEM and other fields, and more.

Summary

Best practices for an emerging research university interested in establishing doctoral programs include: (1) It’s difficult to be the first doctoral program in a college, as it requires engaging other universities in the state; developing a high quality program is critical. (2) Interdisciplinary degree programs are of high value, and provide a broad constituent base, allowing enrollment to flourish. (2) Take the time to plan, even if resources do not appear to be forthcoming. (3) Be transparent of the process and program, from day one. (4) Include doctoral student funding and recruitment as part of the required budget. (5) Having a faculty member who also serves as graduate coordinator is not enough; you need a staff member who is dedicated to the graduate program and keeps track of everything. (6) Ensure adequate funding for technical staff.

Lessons learned in the process, looking back over all three programs include the following. First, it is essential to have commitment from a critical number of faculty members toward investing their time and energy into developing and taking ownership of the program. It takes an extraordinary amount of work and time in creating a new PhD. It is surprising how much time can be spent on what seem like small items such as "What is the comprehensive exam – Oral? Written? Both? What material does it cover?" Second, documentation of decisions is critical both so that the faculty members understand the decisions and the students understand the processes, policies and procedures. Also, creating the program is just the beginning – sustaining the program is an ongoing process – policies and procedures need revision, and it all takes time.

Also, interdisciplinary programs are extra work involving many decisions about who controls resources, who votes, who needs to attend meetings, how resources are allocated, who "owns" the success of the program, who is responsible for appeals, and more. Interdisciplinary is a terrific way to reach "critical mass" of faculty in the program but also complicates decision making. Finally, resources are always scarce and often managed through the traditional department, housed in one college. Because of this, who advocates for resources when they are warranted?

In closing, establishing doctoral programs – both disciplinary-focused and interdisciplinary – have contributed significantly to the growth and stature of Boise State University as an emerging doctoral degree granting institution. Faculty hired as a result of the decisions to proceed with doctoral programs in Electrical and Computer Engineering, Materials Science and Engineering and Computing have enhanced the university in myriad ways. Being classified as a Doctoral Granting university has been a significant accomplishment that increases the ability of faculty to successfully compete for research funding, elevates the profile of the university, and increases the value of its graduates in the workplace.

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References

1. US Bureau of Labor Statistics, Employment Projections program, 201-20 Science and Engineering Indicators, 2014

2. US Department of Labor, Bureau of Labor Statistics, Current Population Survey, 2005-2015, Annual Averages, http://www.bls.gov/cps/tables.htm#annual

3. National Science Foundation, National Center for Science and Engineering Statistics. 2015. Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015. Special Report NSF 15-311. Arlington, VA. Available at http://www.nsf.gov/statistics/wmpd/.

4. Kelkar, A. D., & Ryan, J. G. (2011, June), *Innovative Graduate Program in Nanoengineering* Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC. https://peer.asee.org/18176

5. Mohan, R., & Radhakrishnan, N., & Tang, G., & Murray, K., & Kelkar, A. (2005, June), *Innovative Graduate Program In Computational Science And Engineering* Paper presented at 2005 Annual Conference, Portland, Oregon. https://peer.asee.org/14492

6. Sarder, M. B. (2016, June), *Developing Master's Program in Logistics & Transportation* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.26765 https://peer.asee.org/26765

7. Sathyamoorthy, M. (2002, June), *An Interdisciplinary Graduate Program At Wvutech* Paper presented at 2002 Annual Conference, Montreal, Canada. https://peer.asee.org/10523

8. Sluss, J. (2004, June), *A Graduate Degree Program In Telecommunications Systems Engineering* Paper presented at 2004 Annual Conference, Salt Lake City, Utah. https://peer.asee.org/12939

9. www.asee.org, data retrieved 2/3/2017, Brian Yoder.

10. Best Places for Business and Careers, Forbes Magazine, May 2005

11. http://carnegieclassifications.iu.edu/ downloaded 1/20/2017