

Curricular Affairs Committee of the Faculty Senate

MEMO

To: The UVM Faculty Senate
From: Curricular Affairs Committee of the Faculty Senate, Laura Almstead, Chair
Date: December 8, 2017
Re: Approval of a proposal for a new PhD in Complex Systems and Data Science submitted by the College of Engineering and Mathematical Sciences in Conjunction with the Graduate College

At its meeting on December 8, 2017, the Curricular Affairs Committee approved the actions recommended in the following memo.

The Curricular Affairs Committee approved a proposal for a new PhD in Complex Systems and Data Science (CSDS), submitted by the College of Engineering and Mathematical Sciences (CEMS) in conjunction with the Graduate College. The Curriculum Committee for the PhD program includes six faculty in the departments of Mathematics and Statistics, and Computer Science, and the program director will be Peter Dodds, Director of the Vermont Complex Systems Center and Professor in the Mathematics and Statistics Department. If approved by the Faculty Senate and Board of Trustees, the program will be offered beginning fall 2018.

Program Description and Rationale

The newly proposed PhD in CSDS will be a pan-disciplinary program housed in CEMS, but drawing in faculty from units across campus who have been involved in the Complex Systems Transdisciplinary research area and who do research and teaching in complex systems and data science. Among the objectives of the program are to train students to understand and solve data-rich, complex systems problems across disciplines. The proposal notes that this is a new and growing area, in which students trained to approach data analysis from a complex systems perspective are in high demand for jobs in a range of industries.

Among the specific objectives of the program are to prepare scientists versed in tools and techniques for data collection, hypothesis development and analysis. Coursework and independent research will train students in:

- 1) Industry standard methods of data acquisition, storage, manipulation and curations
- 2) Visualization techniques, with a particular focus on building high quality web-based applications and communicating results in visualization projects accompanying their research
- 3) Finding complex patterns and correlations through techniques like machine learning and data mining
- 4) Hypothesizing, searching for and extracting explanatory stories for complex systems

The proposed PhD program is designed to fill demand from students currently completing the Certificate of Graduate Study in Complex Systems (currently 19 enrolled students) and MS in Complex Systems (currently 11 enrolled students) for a degree at the next level. It is important to note that the Certificate of Graduate Study is currently available to students in other UVM MS and PhD programs, and that it is anticipated to be a “feeder” for the proposed PhD. Given the unique nature of the program, the program is also projected to attract some students at the regional, national and international level.

Justification and Evidence for Demand

Nationally, there are few completing programs at the PhD level providing degrees in data science or complex systems; there are none integrating both complex systems and data science. However, there is clear student demand from students currently enrolled in the Certificate and MS programs, and the proposers report that programs like Northeastern's program in Network Science is only able to accept 10% of their applicants. The proposers also indicate clear demand in industry and academia for scientists with advanced training and independent research experience in this area. The proposers cite data indicating that "Data Science" is a rapidly growing, well remunerated field, and that research funding in the area of Complex Systems continues to grow.

Relationship to Existing Programs

There are no similar or competing PhD programs at UVM. The newly proposed PhD in CSDS would be an extension of the MS program already offered, with the additional of independent, dissertation-level research. As such, it is not expected to compete with existing PhD programs offered by UVM, and may enhance the profile of the MS and Certificate programs by creating a clear pathway to advanced study, and by increasing enrollment in graduate-level courses serving these programs. Students in the MS program will be allowed to apply to the proposed PhD program.

Curriculum

The overarching aim of the newly proposed PhD in CSDS is for students to gain a sound breadth of knowledge in Complex Systems and Data Science with a solid foundation in mathematics, programming, and statistics. A minimum of 75 credits (at least 30 credits of research and 30 credits of graduate-level coursework) are required to complete the degree. The curriculum involves four central core courses (see table below). In addition to these core courses, students elect other fundamental coursework in complex systems and data science, computer science, and statistics as well as have the option to take one of eight elective paths (Energy Systems, Policy Systems, Biomedical Systems, Evolutionary Robotics, Environmental Systems, Transportation Systems, Distributed Systems, or a self-designed disciplinary path) as a means to tailor their program to a particular field.

Required Core Courses

Number	Name	Credits
STAT 287	Data Science I	3
CSYS/MATH 300	Principles of Complex Systems	3
CSYS/CS 302	Modeling Complex Systems	3
STAT 387	Data Science II	3

Students' progress through the program by completing the necessary coursework, passing a comprehensive exam covering the core coursework, developing a dissertation proposal, as well as having two published or accepted peer-reviewed manuscripts and a third, at least, in peer review prior to orally defending their written dissertation. Students are expected to take four to five years to complete the PhD program, with students entering with an MS finishing faster than those students entering with a BS.

There are no new courses associated with the PhD program, except for the dissertation course, as all courses already exist within the CSDS Master's degree or graduate certificate. All of the core and elective courses are being taught and have capacity to absorb the new doctoral level entry students in CSDS. Students will work

closely with their Primary Advisor and the Studies Committee in designing and conducting their research (see Advising section). No formal clinical experience is required for the degree although the program will facilitate summer internships if desired.

Admission Requirements and Process

Admission requirements include a Bachelor's or preferably a Master's in a relevant field and prior coursework in foundational disciplines, including computer programming, calculus, linear algebra, probability and statistics. Additional preferred training include training in areas such as statistical mechanics. Students may be accepted provisionally if they are lacking these prerequisites, in which case they will complete remedial work in their first year. Candidates will be judged on their GRE scores, academic background, letters of recommendation and other indicators of potential for excellent research. Acceptable TOFEL scores will be required for students for whom English is not their first language. The Curriculum Committee will make decisions regarding which students will be admitted.

Anticipated Enrollment and Impact on Current Programs

Anticipated enrollment is expected to be five to ten new PhD students per year, with the upper limit of ten students being reached over the long term. Impact on current programs is expected to be positive, as the incoming students will contribute to existing courses in which there is already sufficient capacity. Over time, with the introduction of new faculty and the availability of these additional advanced students, other courses will also be developed to meet demand. These courses may also be suitable for students in the MS and Certificate programs.

Advising

A student must have a CSDS advisor prior to being accepted into the program and, within their first semester, form a Graduate Studies Committee. The primary advisor will serve as the student's research mentor while the Studies Committee will guide and monitor course progression. Each PhD student must complete an annual progress report and meet with their studies committee to review progress. Program-centered advising related to individual student needs and post graduate plans will be offered by the CSDS Curriculum Committee who can incorporate this advising responsibility into their current responsibilities. Incoming students will be given a full group advising session at the start of their first year and second year and there will be intentional mechanisms and opportunities for peer advising and mentoring throughout the program.

Assessment Plan

The PhD in CSDS Curriculum Committee will be responsible for overseeing and evaluating the proposed program. The CSDS Curriculum Committee will meet annually to review the program with reports submitted to both the CEMS leadership as well as the Graduate College. Student feedback, course evaluations, increasing enrollment numbers, retention and graduation rates, research productivity, and successful placement of graduates in industry, government and academia will be used to assess program effectiveness. In addition to this local review, the PhD in CSDS will undergo regular review via the University's Academic Program Review process.

Staffing Plan, Resource Requirements, and Budget

The proposed PhD in CSDS requires no additional faculty or staff by which to carry out the program; however, the program will benefit from a current-year cluster hire search for five new Computer Science and Complex Systems faculty. Current college faculty will serve as the Curriculum Committee for the PhD and no new positions are needed to oversee the program beyond the creation of the Graduate Program Coordinator (an already existing faculty member) and the CSDS Curriculum Committee. No additional costs or library services are warranted. Some additional office space for graduate students may be needed and will be provided based on current CEMS policies and Dean discretion.

Students in the PhD program will be funded through faculty research grants, gifts to the Complex Systems Center, industry grants, personal funds, and revenue from the MS in Complex Systems and Data Science Program. Future support may be available through the use of Graduate Teaching Assistantships in CEMS. The proposers offered a budget that clearly delineated tuition revenue, teaching payments to units outside of CEMS, non-personnel direct expenses such as marketing costs, and indirect expenses related to student cost pools. The program is expected to be revenue generating after the second year with an almost doubling of revenue in each of the three years following.

Evidence of Support

Each of the current Chairs in the College of Engineering and Mathematical Sciences have fully supported the creation of the proposed PhD in CSDS. The new degree program has received the full support of both the CEMS faculty and the CEMS college curriculum committee. Additionally, letters of support were submitted by: Dean Garcia of CEMS

Associate Dean Waterman of the College of Arts and Sciences

Dean Vogelmann of the College of Agriculture and Life Sciences

Dean Mathews of the Rubenstein School of Environmental and Natural Resources

Dean Morin of the Larner College of Medicine

Dean Forehand of the Graduate College

the Graduate Executive Committee

Summary

The central aim of the PhD in Complex Systems and Data Science is to train emerging data scientists to understand and solve data-rich, complex systems problems spanning many disciplines comprised of natural, technological, and social dimensions. The proposed PhD builds an independent research framework into the current CSDS Master's degree. While the program will be housed in CEMS, the training allows students to choose projects from a wide variety of disciplines. All needed courses have already been established and the faculty clearly have the expertise and capacity to support the new PhD and its students. Offering a PhD in CSDS will enable UVM to prepare a segment of talented students for careers in complex systems and data science related fields, in which there are significant employment opportunities. Nationally and regionally there are very few programs offering similar training, and none that have curricula comparable to that of the proposed UVM PhD in CSDS. Thus, the newly proposed PhD in Complex Systems and Data Science has the potential to attract new graduate students and will be an excellent addition to UVM's graduate degree offerings.