Board 235: Design and Implementation of a Professional Development Course for Interdisciplinary Computational Science Graduate Students

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Abstract

Students in computational science graduate programs have unique challenges due to the interdisciplinary nature of this field. Students entering interdisciplinary graduate programs must quickly adapt and gain knowledge in other disciplines, learn to communicate across disciplinary boundaries, navigate ambiguity in what it means to be an interdisciplinary expert, and face challenges from the lack of clarity in any pathway to developing interdisciplinary expertise and uncertain career paths,. Helping students navigate these challenges, creating awareness of their unique opportunities and challenges in the pursuit of careers as interdisciplinary scientists, and helping them discover models for interdisciplinary identities required a concerted and tailored approach to provide academic support and professional development.

This paper presents the experiences and lessons learned in the design and development of a professional development course designed for first year graduate students in an interdisciplinary computational science program, under an NSF S-STEM grant funded project titled "Academic Support, Career Training, and Professional Development to Improve Interdisciplinary Graduate Education for the Next Generation of Computational Scientists and Engineers". Herein we discuss the development and implementation of this two-semester course sequence (1 credit each semester). The course modules included (a) Understanding the academic challenges, goals and timelines in the interdisciplinary computational science program, (b) Individual Development Planning, (c) Career Exploration, (d) Communication Skills, (e) Networking, Finding Mentors & Mentoring, (f) Understanding and Exploring Pathways to Interdisciplinary Careers, (f) Leadership and Entrepreneurship Skills for career success, (g) Professional & Responsible Conduct, (h) Mental Health & Wellbeing. These topics were tailored specifically for the needs of computational science students with a goal to increase their awareness and preparation for interdisciplinary careers. This paper discusses the modifications and adaptations made to foster the success of first year graduate students from diverse academic backgrounds through navigating interdisciplinary computational science and developing peer cohorts and pathways to careers.

Course learning outcomes and students’ development were assessed using assignments and reflective writing. Results after three successive years of offering this course show that a tailored professional development course helps students better understand their academic pathways, better understand career options, utilize opportunities for professional growth, develop effective peer cohorts, and express more satisfaction with their experiences as graduate students.

Introduction

Challenges faced by first year graduate students and the support provided to them play a significant role in their academic success [1], [2]. Professional development training for graduate students that complements their development of expertise and disciplinary knowledge leads to better future career success [3]. Professional development courses complement the training provided by research mentors, ensure commonality and consistency of experiences of students in a program, are effective in community and cohort development [4], [5], and can help them successfully overcome initial barriers and establish a path towards their academic and career goals [6].

Challenges faced by first year graduate students play a significant role in their academic success [2]. Such challenges include making the academic transition to graduate studies, navigating new academic cultures, assuming and navigating new responsibilities and identities as student researchers, and experiencing imposter syndrome. Community building and professional development courses for graduate students in the early stages can help them successfully overcome these barriers and establish a path towards their academic and career goals. However, professional development courses that are developed for a general broad audience, do not provide the context or connect with the specific needs of graduate students in interdisciplinary STEM fields.

Students in computational science graduate programs have unique challenges due to the interdisciplinary nature of this field. Computational Science sits at the convergence of Applied Mathematics, Computer Science, Data Science, Engineering, and Biological Science. Students from mono-disciplinary fields entering interdisciplinary graduate programs must quickly adapt and gain knowledge in other disciplines, often facing challenges not previously faced. The undefined nature of what it is to be an interdisciplinary expert and lack of clarity of their pathway to such expertise contribute to their challenges. Helping students navigate these challenges and creating awareness of their unique opportunities in the pursuit of careers as interdisciplinary scientists and models for interdisciplinary identities require a concerted and tailored approach for providing academic support and professional development.

This paper presents the experiences and lessons learned in the design and implementation of a professional development course tailored for first year graduate students in an interdisciplinary computational science program. This course was developed as a component in the NSF S-STEM grant funded project titled "Academic Support, Career Training, and Professional Development to Improve Interdisciplinary Graduate Education for the Next Generation of Computational Scientists and Engineers" [7]. This paper discusses the evolution of this course over a decade through informal professional development activities offered to graduate students in computational science, before implementation as a two-semester course sequence (one credit each semester) for first year graduate students in computational science. For context, what follows is a short review of literature on training interdisciplinary scientists followed by a description of the field of computational science and the evolution of the computational science graduate programs at our institution.

Training Interdisciplinary Scientists –Past Findings and Recommendations

The need for interdisciplinary (ID) research expertise has been recognized and pursued for more than three decades (See reports [8] and [9]). “Convergence”, described as the transdisciplinary integration of disciplines in research, is now recognized as a key for solving complex scientific questions to address urgent societal challenges [10]. Convergence is considered an evolution of transdisciplinary, interdisciplinary and multidisciplinary research paradigms. It exceeds older paradigms in that convergence leads to the creation of new frameworks for communicating and synthesizing ideas and integrating diverse expertise to innovate and create new solutions. National Research Council reports on Interdisciplinary and Transdisciplinary research [8] and recent convergence research [11] highlight the need for intellectually diverse teams of scientists and engineers to be able to communicate across disciplinary barriers and establish collaboration modalities using new frameworks and language that influence even the very framing of research questions.

To achieve success in interdisciplinary convergent programs, graduates must understand a broad range of disciplinary approaches, ask creative questions, answer those questions with diverse tools, probe and explore problems, locate and critically evaluate information, collaborate effectively as team members, and communicate research findings to others. Although interdisciplinary programs have been established, many challenges remain. Structural challenges include separation of physical university locations [11] and disciplinary–based incentive structures for faculty research [12]. Interdisciplinary training must bridge language and jargon [13], and methodologies [14] across disciplines. Programs must also help faculty and students resolve ambiguity in mentorship roles [15] and provide support for navigating interdisciplinary teams [16].

The NRC 2014 [10] report recommends that convergence efforts include (a) bringing together teams with depth and breadth of expertise, (b) including diverse perspectives, (c) introducing new culture and supporting structures (d) changing faculty structures and reward systems, (e) creating facilities and workspaces designed for convergent research (f) developing new education and training programs to foster convergence (g) forming effective partnership arrangements and (h) securing sustainable funding. A growing body of educational research on interdisciplinary programs [17] describes concrete strategies to overcome common barriers in interdisciplinary training to fulfill the NRC recommendations. For example, programs can create common shared spaces and structured opportunities for regular research team and cohort meetings to define convergent project goals and build cohesiveness [11], [18]. Programmatic research groups can define focal themes ([18], [19], and identify mentors and/or co-mentors with established interdisciplinary relationships who can support students in interdisciplinary publishing and networking strategies ([16], [19].

Evolution of Computational Science as an independent and interdisciplinary field

Computational Science evolved to gain recognition as its own discipline in the last three decades [20, 21]. Most Computational Science degree programs originally started as an offshoot within applied mathematics, applied statistics, computer science, applied sciences (e.g. computational physicist or chemist) or engineering disciplines. Institutions had to create a separate space or track to recognize that solving problems with computational tools required more than expertise in just a single discipline. Over the last decade, Computational Science has become recognized as the convergence between Applied Mathematics, Computer Science, Statistics/Data Science and the Engineering/Science disciplines. At present, graduate students in computational science must develop knowledge in math modeling, differential equations and numerical methods, high performance computing, database, software development, advanced statistics, machine learning and courses in the science or engineering through coursework, independent learning, and research.

SDSU's Computational Science Research Center (CSRC) recognized the need for computational scientists more than three decades ago and created graduate degree programs with curriculum aimed at training students from science, engineering, mathematics and computer science to enter careers in interdisciplinary research. At present, a core group of 54 professors from 12 departments participate and support 51 doctoral students in the program. CSRC collaborates with many local industries and national labs and has successfully placed students and graduates in summer internships and jobs. The CSRC maintains collaborations and educational partnership agreements with a number of southern California's high-tech companies through its Applied Computational Science and Engineering Student Showcase (ACSESS) program. ACSESS provides members of the technology industry with access to engineers, scientists and researchers, helping these businesses directly address critical industrial problems in a range of areas, and in return getting CSRC funded projects on which students can hone their practical problem solving skills.

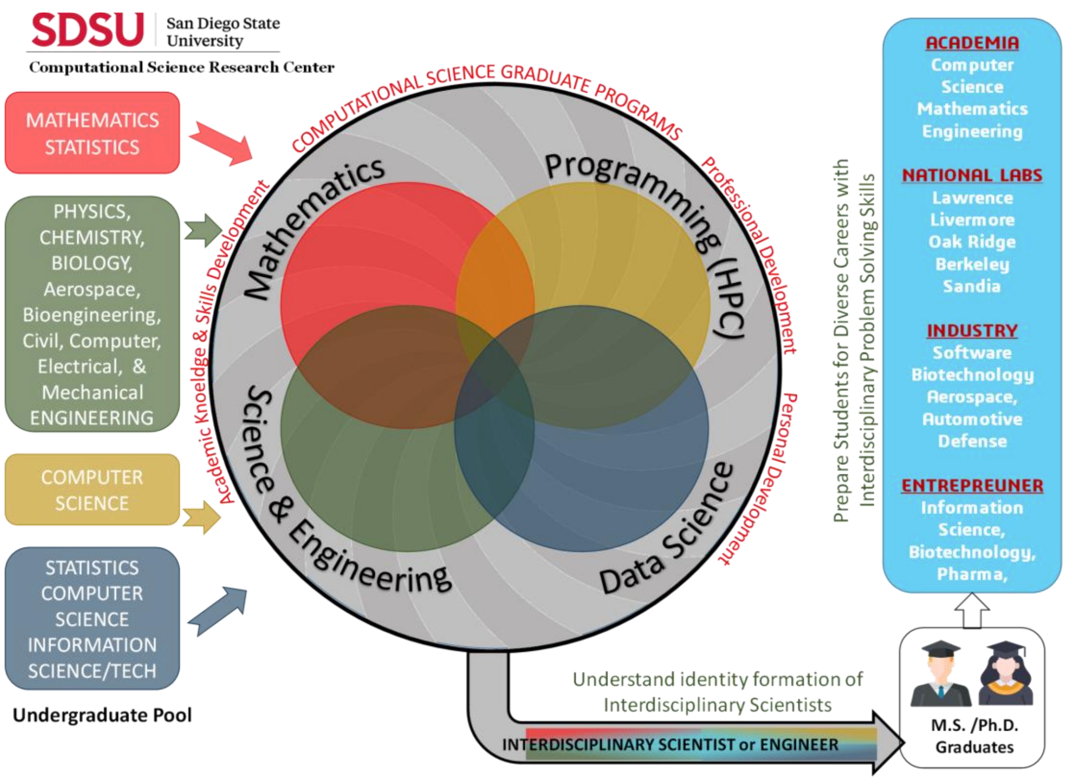

Figure 1: A Schematic drawing representation of Computational Science Discipline and the Computational Science Graduate programs at SDSU.

The computational science graduate degree programs at SDSU are housed within the Computational Science Research Center (CSRC). The CSRC is not a part of any department; instead, it draws faculty from the Colleges of Engineering, Science, Health and Human Services and Business who participate as affiliates. Participating faculty must have a strong interest in using computational methods to solve problems in their disciplines, be interested in using existing tools or methods from other disciplines to solve problems, or be working to advance or create new methods or tools to overcome existing shortcomings. At SDSU, students who enter the interdisciplinary graduate degree program in Computational Science have typically completed undergraduate degrees or master's degrees in specific disciplinary fields (e.g. Mathematics, Statistics, Computer Science, Sciences or Engineering. These students take more or less the same core courses to prepare them as computational scientists and are expected to become computational "tool users" and "tool makers" and apply this knowledge and skills to solve practical science and engineering problems in. Figure 1 is a schematic of the computational science program at SDSU.

One of the principal current goals of the Computational Science program is to train interdisciplinary computational scientists and engineers with the knowledge and skills to solve challenging important problems at the intersection of different disciplines. The CSRC celebrated its 25th anniversary in 2021. The program has graduated over 100 PhD students to date. Graduates have successfully entered careers as computational specialists in industry, national laboratories, and academia.

However, in following the careers of past graduates we noticed that most graduates assumed their first job as a computational expert in an area proximal to the area of their disciplinary training. This was not surprising, since their disciplinary knowledge helped them apply their computational skills to solving problems in that discipline. However, there was a concern that these students were missing the opportunity to work on truly interdisciplinary topics in other areas. In fact, the core curriculum they pursue is supposed to give students the same common skill sets and knowledge that can be applied to solving problems in many different fields.

This migration back to their undergraduate field of specialization elicited the following questions: Why were students not embracing the identity as an interdisciplinary computational scientist? How comfortable and skilled were they to work on/in interdisciplinary projects/teams? Were they missing career opportunities by restricting their choices to positions proximal to their undergraduate discipline?

Furthermore, based on their interactions with our students, our industry advisory committee informed us that although students in our program are skilled and prepared for interdisciplinary research and problem solving, many lacked confidence and self-awareness of their potential to apply their skills to diverse problems. Some did not see connections between approaches in different disciplines, and the confidence levels needed to pursue interdisciplinary challenges varied among our graduates.

NSF S-STEM Program

The CSRC leadership team's critical challenge is to train graduates with sufficiently deep knowledge in primary areas of expertise and skills to interact effectively with experts in other disciplines. CSRC is interested in implementing and evaluating the effectiveness of academic support, training activities and informal learning mechanisms that can complement formal education components to enrich student experiences that contribute to the successful development of interdisciplinary scientists. To achieve these goals, the CSRC team applied for an NSF S-STEM grant to implement a scholarship, academic support, and training program aimed at developing interdisciplinary computational scientists and engineers. The program sought to support talented students with financial needs with scholarships to encourage their enrollment in computational science graduate studies. Students in the program were supported with academic counseling and professional development activities. The knowledge generation part of this S-STEM grant set out to understand what factors influence students' confidence in their abilities as interdisciplinary scientists, what influences the development of identities as interdisciplinary experts, and how professional development activities can help shape these identities and facilitate pathways to interdisciplinary careers.

The S-STEM grant has supported 29 graduate students during the first fours year (2020-2024). Of these 12 were doctoral students and 15 master's students. The gender division of participating students were 13 female and 16 male. All participants had an undergraduate degree in a STEM field. The BS degrees of participants were as follows: Physical Sciences -8, Computer Science -1, Math/Statistics -9, Engineering -10, and Biological Sciences 2. It is to be noted that the total numbers here add up to greater than 29 (the number of participants) because few students had dual degrees as undergraduates. The small fraction (~20%) of students attracted to the interdisciplinary computational science programs have minors or dual degrees. Among the 12 doctoral students participating in the S-STEM program, seven entered doctoral studies directly after their undergraduate degrees. All students in the cohort take courses to develop expertise in mathematical modeling, numerical methods, programming, data science and high performance computing. Their thesis/dissertation research requires them to develop and apply new computational methods to solve practical problems in a science or engineering topic . The application areas of student's thesis/dissertation research were as follows: Engineering Science – 10, Biological Sciences – 6, Data Science - 6, and Physical Science - 6. All S-STEM grant funded scholarship recipients were required to enroll in the professional development courses. However, the course is open to all graduate students in Computational Science program. Over the three years, 14 students (7 MS and 7 PhD) not funded by the S-STEM also enrolled for the professional development courses. Their undergraduate degrees fields of these students were as follows: (Geosciences -1, Engineering -2, Computer Science -5, Mathematics -6). Their thesis and dissertation application areas are as follows: Engineering Science – 3, Biological Sciences – 3, Data Science - 4, and Physical Science - 4.

Before we could embark on improving student training to become interdisciplinary scientists/engineers we had to establish what the prevailing views of students and faculty at our institution were on what it means to be "interdisciplinary", especially in the context of computational science. To start, we conducted surveys of faculty members and students in CSRC.

This survey asked faculty members to what extent their research was interdisciplinary, did they think being interdisciplinary gives them an advantage, did they identify themselves as interdisciplinary scientists, and to what extent they engaged their students in interdisciplinary research or encourage them to gain skills for interdisciplinary research.

Perspectives of our Faculty in Computational Science

The views of faculty members were quite varied. Most of the faculty members responded that they were interested in interdisciplinary research. However, the degree to which they claimed they were engaged in interdisciplinary research or actively training their students for interdisciplinary research varied. At the lowest level were those who claimed they pay attention to research in fields outside their own to bring ideas and tools to solve problems in their disciplines. The next level of interaction or engagement in interdisciplinary research was where a faculty member in the science or engineering field consulted with or collaborated with other faculty members within the computational science group in mathematics, computer science or data science. In many cases this collaborator was a member of their student's thesis or dissertation committee. At the best level, we found several faculty working in teams where in order to contribute to solving the complex problem, each person had to learn to communicate, trust and work with researchers from different disciplines. These groups seemed to have established a clear identity for their teams, while within each team there were clear roles and responsibilities for individuals and their disciplinary contributions. This confirmed that students in the program were in lab environments with varying degrees of interdisciplinary collaboration.

Faculty responses regarding how important it was for their students to be trained to be interdisciplinary scientists, revealed widely split attitudes and opinions. A significant portion of the faculty indicated that it was necessary for their students to first establish themselves as disciplinary experts before they focus on developing expertise in interdisciplinary skills. This response was typical of faculty who saw themselves as experts in a discipline and whose collaborations with other faculty in the computational science program were proximal to their own fields. Faculty who were actively involved in interdisciplinary research in team settings also encouraged their students and trained them to develop skills and experience in working in interdisciplinary settings. Faculty also pointed to existing institutional barriers in academia for placing interdisciplinary experts.

Perspectives of our Students in Computational Science

The current SSTEM program admitted its first cohort in fall semester of 2020. In the midst of the pandemic and being restricted to virtual meetings, the first year was focused on providing academic and emotion support for students, and building a cohort through virtual meetings, and professional development. In addition to lectures/discussions about academic planning, career exploration, time management, mental health and wellbeing, we also developed activities to help students understand the opportunities and challenges in interdisciplinary careers, particularly for interdisciplinary computational scientists. We developed two activities that year that we continue to use., The first was a series of three panel discussions on the topic of "Opportunities, Pathways and Challenges in Interdisciplinary Research" featuring academic faculty at various stages in their career progression and researchers from industry. These panelists described their academic preparation and field of current research and how they developed their interdisciplinary research skills and portfolio. They discussed the challenges, opportunities, and what motivated them to be interdisciplinary scientists. The second activity developed in year one was student participation in a journal club activity to review papers published by the Society of Industrial and Applied Mathematics (SIAM) Journal , one in 2001 [20] and the other in 2018 ([21]. The 2001 article ([20] was published two decades ago when Computational Science was emerging as its own separate field. It discusses the creation of Computational Science programs and the justification for it to be a standalone field. The SIAM 2018 [21] article provides a nice overview of the developments in research and education in computational science during the last two decades and identifies some emerging areas of need. Together, these two articles provide a broad overview of how the computational science field has developed, the current challenges, and emerging areas of need.

At the end of the first semester students participated in an exercise where they were asked to highlight what they perceived to be the Strength, Weakness, Opportunities or Threats (SWOT) in pursuing an interdisciplinary degree program. We found from the SWOT exercise first year students have significant concerns (angst) and conflicting views about the interdisciplinary nature of their field. A summary of these student SWOT comments is included in Appendix A. The same set of students perceived that being an interdisciplinary expert was both an opportunity and a threat. The opportunities in working on problems that require their unique skills excited them, but they were concerned it might lead to a weakness in that they may end up as jacks-of-all-trades and masters-of-none. Students also expressed concerns that their peers with expertise in mono-disciplinary fields could develop more in-depth knowledge and therefore be more competitive to employers. What was clear was that these highly successful students (admitted to the master's or doctoral) program were suddenly confronted by challenges in having to navigate courses where they were less prepared than other classmates. A predominant theme that also emerged was that students were uncomfortable in explaining to others their expertise, or were afraid that they would be mistaken for applied mathematicians or computer scientists (i.e., a dilemma of identity). The SWOT was a clear indicator that it was not enough to inform students of the interdisciplinary nature of their program and the opportunities interdisciplinary training could offer then for future careers. Formal and intentional professional development activities were needed to help them plan and navigate their education, develop skills, and gain necessary experiences to fully understand what it means to be an interdisciplinary scientist. They also needed to be educated about different models or identities possible for interdisciplinary scientists and decide which fit them best.

Envisioned model for interdisciplinary identity

We originally envisioned that graduates from our program who enter the program with training in different specific disciplines and different academic backgrounds would all meld and graduate as interdisciplinary scientists. These graduates would have basic levels of competency and expertise in the sub-disciplines that constitute the pillars of computational science, in depth expertise in one of the sub-disciplines and technical and communications skills to work across these boundaries effortlessly. As a result, the identity of interdisciplinary computational scientists would replace any disciplinary identity they had developed previously as undergraduate or master's students in their specific STEM discipline. We have since come to realize there are many different forms of identities or models to being an interdisciplinary scientist and this does not have to replace identities formed from previous educational experiences. A companion paper [22] presents an in depth analysis of identity formation in graduate students in interdisciplinary computational science programs.

COMP 600 course–Professional Development for Interdisciplinary Computational Scientists & Engineers

The COMP 600 course titled "Professional Development for Interdisciplinary Computational Scientists & Engineers," is tailored for students in interdisciplinary computational science and engineering program. This course evolved over the last 10 years (over two S-STEM grant programs) as informal professional development activities organized for computational science students until it was formally offered as a course starting in 2021-2022 academic year. This is a two-semester course sequence (Fall and Spring) that awards one credit each term. The goal of this course is to help students develop an individual development plan that helps them successfully complete their graduate studies and identify and plan for activities and explorations that help prepare them for success in their future careers. The course components include:

- Academic and Individual Development Planning
- Communication,
- Teaching and Mentoring
- Exploring Pathways to Interdisciplinary Careers
- Leadership and Entrepreneurship
- Career Exploration and Networking
- Professional & Responsible Conduct
- Health & Wellbeing

This course also was designed to provide opportunities for cohort development and networking between current students and alumni of the program. A copy of the syllabus from Spring 2024 is provided in the Appendix B.

Formalization of the professional development activities for graduate students in the interdisciplinary computational science program into a two-semester course was done to provide structure and means to have a steady cohort of participants in these activities though out the year. Attendances varied with informal seminars, and it was harder to assess directly the impact of the professional development activities on the students. Developing a course required developing explicit learning outcomes and related assessments to allow evaluation of the effectiveness of the various elements of the course. Furthermore, studies have shown that professional development of students requires concerted and explicit effort. A well-designed professional development course increases student research productivity, engagement, and morale and prepares them for careers beyond graduate school. Participation in such activities early in the graduate studies is more effective than later.

The various course components and their implementation are described below. Information about specific activities to customize the modules for interdisciplinary computational science graduate students is included

Academic Planning and Individual Development Plan

Training in developing an individual development plan (IDP): A series of lectures/seminars were offered to educate students on the need, importance, and process by which to develop a first draft of an IDP. Students were given feedback on their IDP drafts and asked to develop a revised this IDP. Most of the challenge was to get students to formulate reasonable for near- and long-term goals and teach them to develop rubrics for assessing how well those goals are reached.

IDP module has been modified significantly over the last several years based on feedback from early participants and our own growth in understanding student's needs and challenges in navigating an interdisciplinary program. In the early offerings of the course, we introduced what an IDP is, why it is important and how to use it to assess progress and plan for the future. Students fill an IDP template with help and feedback from the course instructor (and sometimes their research advisors). Student feedback and reflections showed that students struggled with the IDP exercise.

The current implementation of the course spends three to four lectures that building up the motivation for IDP development. The first lecture gives an overall view of the professional skills graduate students need to develop and how these skills help them succeed in their academic coursework, research and future careers. The next week they write a recommendation letter for their future selves for a dream job they might be applying to in future. During the class discussions students categorize all aspects they included in their letter into academic preparation, technical or scientific expertise and skills, experiences, professional skills, and personal traits. This information is used to initiate the conversations on how to develop a timeline for developing these expertise and skills (long term planning). Students are also asked to consider the how to ensure that their reference letter writers learn these things about them in order to write a strong letter. A variant of the exercise, called "*Envisioning the best possible self*", asks students to imagine that everything went as planned when they were students and they have successfully entered their careers. Now they are asked to introduce their future self in third person at a professional conference. These exercises teach students to start imagining or envisioning their future selves. This is followed by a discussion about academic milestones and timeliness for their degree programs (MS and PhD). Students are taught how to make effective plans using the S.M.A.R.T. (Specific, Measurable, Achievable, Relevant and Time bound) plan framework.

The lecture on IDP (What, why, how) then follows. We find that after spending time on motivation, students were more eager to work on the IDP. At this stage, we introduce the discussion on what it means to be interdisciplinary and expose them to the idea that not all labs provide the same level or environment for developing interdisciplinary skills. Therefore, students have to look for complementing educational experiences that can help them gain such skills. Some of the suggested pathways are participation in internship in national labs and industries that have highly interdisciplinary research, collaborating with faculty and students in other disciplines to contribute their computational science knowledge to solve a problem in a different field, attending conferences outside their own main discipline, and participation in design challenges and hackathons.

One continuing source of dissatisfaction in the IDP was the use of a template. Although the chosen template (from Rutgers University) is comprehensive and applies to STEM graduates, it has elements that do not apply to Computational Scientists and misses some critical elements that ought to be included for computational scientists. The template is also tailored for doctoral students which makes it difficult for masters' students use. To overcome this difficulty and to give students agency over the IDP process, we asked students to work as a team to suggest and make changes to the IDP template to customize it for computational science students and encouraged each student to further customize it to their needs. Students submit a first draft of the IDP for comments and feedback from the instructor. Students revise their IDPs again at the end of the semester.

As part of the IDP, students are taught how to develop good skills for budgeting time and to balance the short time and long-term goals based on realistic time budgets that consider academic growth, professional development and personal wellbeing and health.
Students are constantly reminded that the goal of this exercise is not to create an end product (IDP) but instill in them a habit by which they continually update their IDPs, use the IDP to set SMART short term and long-term goals, and assess their successes. We find that these pre-activities not only motivate students for doing the IDP exercise, but also really cement the need for IDPs in students' minds and contributes to students taking agency over their professional development. In addition, early exposure to unique aspects of the interdisciplinary aspect of the computational science program and the expectations for the academic and professional development to advance in their careers help students make informed decisions on their IDP development.

Communication Skills Development (writing and oral presentations)

Communications skills development focusses on both written and oral communication workshops. For written communication, we organized three sessions, on (a) Practical tips for effective writing, (b) Outlining and organizing large writing projects and (c) Use of effective graphical formats for conveying results clearly.

Oral communication modules focused on (a) interpersonal communication, (b) formal communication as conference and poster presentations and (c) Short persuasive speeches, blitz presentations and elevator pitches.

A common emphasis in the oral communication exercises is for students to be able to explain their research to an educated but diverse audience. The class participants provide an audience of STEM graduates from different backgrounds. Students are taught how to frame the background and introduction so the peers from other fields can understand their work. They are trained to carefully avoid any acronyms or technical lingo that only people within the field may understand. We use these exercises to impress on students that succeeding as interdisciplinary scientists will require them to develop the ability to communicate across disciplinary barriers. Students practice giving effective presentations in interdisciplinary settings and also to ask clarifying questions early in such research discussions. After these initial training, students are asked to comment on how well the presenter tailored the talk to the diverse audience and what techniques they found were effective and worth emulating.

In a one-credit course that meets 15-16 times during a semester for two semesters, the depth of coverage of any the topics cannot be comprehensive. So, the goal is to instill in students the importance of developing these skills, give them some training to gain a rudimentary start to developing these skills, showing them the various opportunities available to further develop and hone these skills, and above all, to teaching them to integrate these activities into their professional development goals.

Teaching and Mentoring

Graduate students in the programs that were supported as teaching assistants TA's were provided formal training in pedagogical techniques. Awardee students who are not TA's participants in the program have the option to register for a 6-hour training certificate course on teaching that spans three weeks. We find that not all students were signing up for this easy opportunity to develop skills and add to their portfolio. This is because students think that such is for those aspiring to enter academia. To dispel this notion and motivate students to pursue some teaching activities, we developed a lecture in collaboration with SDSU's Center for Teaching and Learning, titled, "Teaching – Using teaching experiences to become an effective science communicator". In this lecture, we emphasized how teaching develops good communication skills and why that is important to graduate students irrespective of the fields they will enter. We also educated them on the fact that in a short time after joining a lab or industry they will have to lead groups and train new employees or members that join their team. Learning how to communicate and help team members learn and adapt to become productive will also reflect on their skills and the productivity of their team. We also emphasized that this development of teaching skills does not have to be in formal classroom settings. Some of the other ways for students to develop such skills is by developing short teaching or training modules for other students. We particularly asked students what one area of knowledge or skill they would consider as their strength, and asked if they would develop an in-person or recorded 30-minute presentation. The students interested in live presentations were given an opportunity to present them to undergraduate students in the SIAM student chapter events. We found that 40% of participants in the course voluntarily signed up for the 6 hours teaching certificate course. In addition, anther 20% of students developed short teaching modules for fellow students in their lab or developed advising and mentoring talks for undergraduate students. We found that these activities not only help hone their communication skills but also act as confidence building activities for graduate students in their early years.

Mentors and Mentoring

This module has several class discussions and guest lectures on the role of mentors and developing skills as mentors. First and foremost, we educate students on the mentor-mentee relationship between their research advisors and themselves. For graduate students who have yet to choose their research advisors or master's students planning to apply to doctoral programs, the presentations cover how to choose mentors that match the level of support they need and desire, and match with their personality. For those students who have already chosen a mentor, we discuss how to develop effective communication and trust with their mentors, how to maximize this relationship and adapt to idiosyncrasies of the mentors. For the adapting discussion, we do point out that given the power imbalance between advisor and student, the adapting often needs to come from student. However, we also teach students there are a number of things they can do to communicate their preferences and modalities of interactions with advisors in direct and non-direct ways. For the rare cases where the differences can be irreconcilable, we also advise students how to handle this situation and the stress it causes.

Another topic of emphasis is the importance of finding multiple mentors as students as well as professionals in the future during career advancement. Here we developed a mentor map for graduate students to identify mentors for various needs they will face. This mentor map covers academic, careers, professional and personal development. We include that, because they are in an interdisciplinary field, students will require finding mentors in sub-areas of computational science to help them in their scientific or technical development.

In addition to finding good mentors for themselves, we also train students to become mentors themselves. All second year participants in the NSF funded S-STEM program were matched with incoming first year graduate students to serve as peer mentors. The two activities that they contribute most to are: (1) helping new students in developing their IDPs and (2) discussing with students their first year experiences to allay any fears and worries new students have. The latter is facilitated by inviting past students from the course to come meet with the current cohort and facilitate a discussion on their first-year experiences and how they navigated their challenges. Over the years, we find that the optimal time for this is around the 10^{th} week of the 16 week-long semester, when incoming new graduate students report they are most stressed. We found the interactions from these meeting continues beyond the classroom. Student's reflections at the end of the semester were very positive on having peer mentors. They commented that this helped them overcome self-doubts and feeling like an impostor.

Exploring Pathways to Interdisciplinary Careers

The computational science research center (CSRC) organizes a weekly colloquium that brings experts in computational science from academia, industry and national labs. Speakers were explicitly asked to discuss how they developed the skills and knowledge to pursue interdisciplinary research, how they train students to work in interdisciplinary topics, and/or unique challenges they faced when working at the intersection of multiple disciplines.

Three years ago, we organized a series of three panel discussions titled: "Opportunities for, Pathways to, and Challenges in Interdisciplinary Research". These panels were about an hour long each and panelists were asked to answer some questions, before opening up the panel for questions from students. The three panels featured faculty at different stages of their careers (early, mid and late) and in different fields: (Panel 1: Assistant professors working in Autonomy and Machine Learning, Panel 2: Associate professors and industry researcher in Bioengineering, Biomathematics and Bioinformatics, and Panel 3 Full professors working in Neural biosensors and neuro science.) Recorded videos from these panels are used for discussions in the Professional Development course. Students in the class are divided into teams and assigned to watch two videos and summarize one panel discussion in a class presentation. They then discuss the common themes that emerged across the three panel discussions and what stood out as unique aspects. They were also asked to reflect how they felt about their path towards developing as interdisciplinary scientists. The reflections from students indicate that from watching these panel discussions and learning how these researchers (faculty and industry experts) went from their traditional doctoral training in specific disciplines to establishing themselves successfully as interdisciplinary scientists, gave them confidence in their own advancement as interdisciplinary scientists and made them feel more confident that they are better positioned to do so by being in an interdisciplinary program.

As mentioned earlier, students also read and participate in journal club type discussions of the two SIAM journal papers that describe the evolution of computational science, its growth and the future needs and emerging topics/areas.

Career Exploration and Networking

For this module, we present what career exploration entails and why graduate students should start this from day one in their program. The idea is to educate themselves on the various career paths they can choose from, understand what each path expects in terms of academic background, experiences, skills and expertise. Lectures include, "Career Exploration–What is it and why now?, Curriculum Vita and Resumes, Strategies and Techniques for Networking at Job fairs and Conferences, and Developing social media presence (LinkedIn, Research Gate and GitHub) to establish visibility and enable networking.

We organize annually two alumni discussion panels (those with MS degrees and those with PhD degrees) from industry, academic and national labs with ranges of work experience from 2 to 15 years to ask the panelists to share how they have navigated their careers, how they have dealt with keeping up with the evolving field, and the interesting, challenging, and exciting aspects of interdisciplinary projects in their jobs. We also ask these alumni to state their current or past job titles and experiences they have held.

As an activity for career exploration, students do a search for jobs that can be a good fit for computational scientists. We help them understand through these exercises that not all jobs explicitly state in their title "computational scientists" nor that they require interdisciplinary skills. Students learn how to parse though job advertisements to look for language and descriptions that indicate they are jobs for computational scientists and require interdisciplinary skills (or that having would be advantageous). They are asked to tailor their resumes to the job and identify what they see as missing expertise, skills or experiences to make them a good fit for this job. We then remind them they should use this to update their IDPs.

Finally, while most graduate students are aware of career paths in industry, national labs and academia, seldom are they aware of careers as entrepreneurs. The CSRC has a number of alumni that have gone on to become technical entrepreneurs. We organize a panel discussion every year on Entrepreneurial Career Paths for Computational Scientists, that feature diverse speakers (disciplines/fields, gender and age groups). The panelists share why they chose the entrepreneurial path, entry points into such careers, and some of the challenges in becoming an entrepreneur. One thing that emerges from these discussions is that success as an entrepreneur requires quick adaptation and the ability work with teams with complementing skills and expertise. We highlight the similarities to working in interdisciplinary fields and being an entrepreneur.

Leadership and Entrepreneurship

The course emphasizes not only career exploration but also things students should think about for career advancement. In that context, from discussing with alumni and our advisor board members, we decided it was necessary to educate our students on the skills they need to develop that will help them in leadership roles when they advance in their careers. Therefore, we invite our alumni who are now in national labs or industry in technical leadership roles to be guest lecturers. They come share their experiences, discuss how they grew into or made the transition into these roles, and what they enjoy most in their leadership roles. They are also asked to comment on what they did as graduate students that helped them become leaders, and what they would advise students to do based on their experiences.

Students are encouraged to become student officers in the SDSU SIAM (Society for Industrial and Applied Mathematics) Club and use this as an opportunity to develop some leadership and organizational skills.

Professional & Responsible Conduct

All students complete an online training program for Responsible Conduct of Research. SDSU research foundation contracts the training services from CITI program that is available to all graduate students. We also require all S-STEM scholarship recipients to register for a one-credit graduate level research ethics course. In addition, we host guest lectures and discussions on ethical issues that arise in research (particularly in the context of computational modeling and data science), reproducibility of research, and open-source sharing of data sets and codes from research.

Health & Wellbeing

It is no secret that stress affects the wellbeing and health of most graduate students. The sources for these stresses vary from adapting to the rigors of graduate level academic course work, adjusting to new academic environments and universities, meeting advisors' expectations for research productivity, balancing time devoted to academic studies, research and teaching duties, financial stress, to name a few. Lack of good habits and lack of intentional planned activities for personal time that improves mental and physical health add to stress.

First year graduate students in particular are more prone to problems that can significantly affect their success in graduate studies. Some of particular factors for these students are: Isolation and lack of peer interaction when they first arrive on campus, difficulty to balance work and personal life, inability to communicate or collaborate with students and faculty, time management, motivation, sense of not belonging in the program (Impostor syndrome?), Anxiety due to uncertainty of future career options, financial concerns (immediate and future). These are common challenges for most graduate students. Our students face additional stress: the academic challenge of taking graduate courses outside their area of expertise or training to meet the interdisciplinary course work requirements.

To address this, in our weekly meeting we allocate time/sessions to discussions of personal challenges and concerns and learning from peers how they faced or overcame similar problems. Establishing peer cohorts and near peer mentors has been an effective way to address some of these challenges. But most importantly, openly discussing these difficulties in a classroom setting, and encouraging students to speak up and advocate for themselves has encouraged students. Adding personal growth, metal health and wellbeing as categories to include in IDP, long and short term goals and in-class discussions has emphasized the importance of personal physical and mental health. We find these activities also contribute to cohort development. We also invited guest lecturers from the School of Psychology and from the Center for Psychological Services at SDSU for guest lectures.

Cohort development

Weekly meetings in the professional development course are tremendously useful for cohort building and interaction with peers. We invite senior students a few years ahead of the current cohort as well as recent alumni to meet with the current cohort to share their experiences. When students find that their peers also faced similar problems and were able to overcome the barriers, it helps ease their anxiety. Most importantly, having a peer support group helps them make stronger connections with their peers. The course is scheduled on Friday afternoons just before the weekly Computational Science Colloquium that starts at 3:30 PM in the same room. Coffee and cookies are provided prior to the colloquium. This deliberate planning of time and venue was to encourage students to stay after the class and chat with each other. We find this strategy has helped improve cohort building and peer support for students in the cohort.

Findings and Conclusions

Based on student reflections and feedback from program evaluator, we find the professional development course has been effective in

(a) helping first-year graduate students in overcome the angst they face,
(b) develop a better understanding of career paths and tools for career path explorations, (
(c) understand and appreciate the interdisciplinary aspects of computational science and
(d) develop agency in pursuing activities that help them develop needed skills and experience to make suitable choices for future career paths and interdisciplinary identifies.

From data gathered, students participating in the professional development course are less likely to drop out, take more control on their career advancement, and are more active in pursing internships and opportunities to broaden their experience. In general, they are happier with their experience as graduate students. '

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APPENDIX –A

Summary of unique sets of comments from students responding to identify the Strengths, Weakness, Opportunities and Threats in Pursuing an Interdisciplinary Degree Program

STRENGTHS	WEAKNESS
Flexible/Versatile/Adaptable skills sets Unique background (Math+ CS+ Big Data+ +Science/Engineering) Essential skills to bring together teams with different backgrounds Critical/analytic thinking Broad understanding of computational tools/methods/algorithms Fun field – can work on many different types of problems	Requires mastering knowledge in many fields Can be perceived as jack of many skills and master of non Discounted by disciplinary specialists Hard to pick focus and depth in diverse topics Feel like an impostor Others don't understand your degree Not common specialty that general public understand Mistaken for computer science majors Available job titles do not explicit align with degree Fast and constant changing field Hard to communicate w/ so many other fields
OPPORTUNTIES	**THREATS**
Diversity of career opportunities Research experience applies to many fields Can work in multiple fields and adapt to changing markets More variety in job opportunities Teaches adaptability to new technologies Meaningful careers as applied scientists Can foster collaborations Can be valuable in teams developing new technology High value on most projects Can make big money $$?	Have to complete with specialized scientists Rapidly changing technology -> skills can become obsolete Disciplinary fields are starting to incorporate more computational training Takes longer to earn a PhD (due to breadth of areas to learn) Disciplinary experts may have advantage for jobs Breadth of knowledge may requires compromising depth Trouble finding jobs not aligned to interdisciplinary skills Difficulty in deciding what to specialize in Bad model accuracy (sic blamed on computational scientists) Many interesting opportunities in restricted jobs/ organizations

APPENDIX B -COMP 600 Course Syllabus

COMP 600: Professional Development for Computational Scientists
Spring 2024

This is the second part of the two semester course sequence

COURSE INFORMATION

Class Days: Friday
Class Times: 2:00 – 2:50 pm
Class Location: GMCS 314
Mode: face-to-face
Platform: [Canvas]

Instructor: Dr. Satchi Venkataraman
Phone: (619) 594 6660
Email: satchi@sdsu.edu
Office location: E309
Office hours: TBA,

PREREQUISITE: Registration and completion of COMP 600 in Fall 2023. Enrllment in a graduate program in any STEM related field.

COMP 600 - SEMINAR

CATALOG DESCRIPTION:

Comp 600 - Seminar
Units: 1-3
Prerequisite(s): Consent of instructor.
An intensive study in advanced computational science. May be repeated with new content.
Maximum credits: six units applicable to a master's degree.

COURSE DESCRIPTION:

Lectures, discussion and activities to develop professional skills to be successful as graduate students and in future technical careers in academia, industry, government, and other sectors as computational scientists and engineers. This is a two semester course sequence (to be taken in Fall and Spring semesters). Prerequistes: Graduate student in Computational Science or Engineering.

COURSE MODULES:

Academic, Career and Personal Development Planning
Communication,
Teaching and Mentoring
Exploring Pathways to Interdisciplinary Careers
Leadership and Entrepreneurship
Career Exploration and Networking
Professional & Responsible Conduct
Health & Wellbeing

COURSE MATERIALS:

Required: None

Recommended: *A PhD is not enough – A Guide to Survival in Science*, Peter J. Feibelman, Basic Books, revised edition, ©2011.Available electronically at SDSU library.

Provided: Supplement reading material (e.g. journal or conference papers, articles and book chapters) assigned for reading and in class discussion will be provided as digital copies through the Canvas course site.

COURSE DESIGN:

- The course will meet face-to-face (*or virtually when needed*) weekly for 50 minutes. For each lecture, there will be preassigned reading and post lecture activities (homework) to complete.
- It is expected that the workload (including the lecture) will not exceed 5 hours weekly on average.
- Assignments will include written summaries of readings and dicussions and reflections (and peer reviews), individual development plans, items developed for your academic and professional portfolio, video recording of your short presentations (and its peer review), contributions to online discussions on professional development topics.
- In class activities will require participation in discussions (with adequate preparation and planning), organizing panel discussions and interacting with panelists.

STUDENT LEARNING OUTCOMES

1. Create and/or update an Individual Development Plan
2. Explore career different options and identify the skills, experiences and expertise needed to be successful in these careers
3. Develop communication skills – different forms of written, oral and digital media communications
4. Develop a network for mentorship, mentoring and career development
5. Comprehend opportunities, challenges and rewards of interdisciplinary research careers
6. Identify leadership and organization skills needed for career advancement and opportunities to develop them as a student
7. Learn the unique professional skills to gain as a computational scientist/engineer
8. Learn practices of responsible conduct of research and research ethics
9. Explore holistic approaches for academic, professional and personal development

GRADING POLICIES

Course grades will be determined by (a) Participation (20%); (b) Assignments (20%); (c) Portfolio development (10%); (d) Online discussion contributions (10%); (e) Video presentations (20%) and (f) Final paper (course reflection) 20%

100 – 95	**A**	82 – 80	**B-**	69 – 67	**D+**
94 – 90	**A-**	79 – 77	**C+**	66 – 63	**D**
89 – 87	**B+**	76 – 73	**C**	62 – 60	**D-**
86 – 83	**B**	72 – 70	**C-**	≤ 59	**F**

COURSE POLICIES

Attendance in class is mandatory. This course requires active class participation during the lectures, and these particpations will be graded. If you cannot attend to class due to illness or university approved excused absences, please let me know in advance. I will do my best to make accommodations by either enabling access to join the class virtually by Zoom™ or post class lectures recorded via Zoom and assign alternate work to make up for the class participation. Three or more unexcused absences will result in a one letter grade reduction.

TECHNOLOGY

Canvas. The university Canvas website will be used for disseminating course announcements and supplementary materials. The Canvas account uses the same login information as the SDSUid. http://canvas.sdsu.edu/

COMMUNICATION

Students are provided with an SDSU Gmail account, and this SDSU email address will be used for all communications. University Senate policy notes that students are responsible for checking their official university email once per day during the academic term. For more information, please see Student Official Email Address Use Policy here.

My preferred gender pronouns are he/him/his. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name and/or gender pronoun. Please advise me of this early in the semester so that I may make appropriate changes to my records. I prefer to be addressed as “Dr. or Professor Satchi (pronounced Saa-chee) or Venkataraman (pronounced as Venn-kaa-taa-raa-maan). Please let me know how you prefer to be addressed. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records.
To communicate with me regarding this course or any professional development matter please contact me by email (satchi@sdsu.edu). If it is an urgent matter and can be answered by a short email I will repond within 24 hours. If it will take time to research or will need a lengthy email to respond, I will respond within the week (Mon-Fri). I generally do not answer emails on weekends. You may also come visit me during office hours (open walk in and first-come-first served) for discussions or make an appointment if the office hours conflict with class times.

FINDING HELP ON CAMPUS

Need help finding an advisor, tutor, counselor, or require emergency economic assistance? The SDSU Student Success Help Desk is here for you. Student assistants are available during the academic term via Zoom Monday through Friday, 9:00 AM to 4:30 PM to help you find the office or service that can best assist with your questions or concerns. Don’t forget to also visit the Center for Student Success in Engineering for more information about internships, advising, tutoring and related events.

A complete list of all academic support services—including the Writing Center and Math Learning Center—is available on the Student Affairs’ Academic Success website. Counseling & Psychological Services (619-594-5220, sdsu.edu/cps) offers a range of psychological services for students. Emergency support is available after hours at the same phone number. The San Diego Access and Crisis Line can also be accessed 24 hours/day (1-888-724-7240).

ACCOMMODATIONS

If you are a student with a disability and believe you will need accommodations for this class, it is your responsibility to contact SDSU Student Ability Success Center. To avoid any delay in the receipt of your accommodations, you should contact the center as soon as possible. http://go.sdsu.edu/student_affairs/sds/

ACADEMIC HONESTY

Plagiarism: SDSU Student Conduct Code expects all students to be honest in all academic work. Academic honesty requires that you acknowledge any source of information that you have used for materials submitted for credit. Failure to comply with this commitment will result in disciplinary action. Examples of plagiarism include presenting someone else's work as your own (even with the other person's consent), using sources not approved by the instructor in completing course assignments, not citing sources from which you took information, etc. Any plagiarism will be immediately reported to the SDSU Judicial Procedures Office.
http://go.sdsu.edu/student_affairs/srr/conduct.aspx

Student conduct:

I consider this classroom to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

Unauthorized recording or dissemination of virtual course instruction or materials by students, especially with the intent to disrupt normal university operations or facilitate academic dishonesty, is a violation of the Student Conduct Code. This includes posting of exam problems or questions to on-line platforms, copying, in part or in whole, from another's test or other examination, obtaining copies of a test, an examination, or other course material without the permission of the instructor, altering or interfering with grading procedures, etc. Violators may be subject to discipline. The California State University system requires instructors to report all instances of academic misconduct to the Center for Student Rights and Responsibilities. Academic dishonesty will result in disciplinary review by the University and may lead to probation, suspension, or expulsion. Instructors may also, at their discretion, penalize student grades on any assignment or assessment discovered to have been produced in an academically dishonest manner.

RELIGIOUS OBSERVANCES

According to the University Policy File, students should notify instructors of planned absences for religious observances by the end of the second week of classes.

LAND ACKNOWLEDGEMENT

For millennia, the Kumeyaay people have been a part of this land. This land has nourished, healed, protected, and embraced them for many generations in a relationship of balance and harmony. As members of the San Diego State University community, we acknowledge this legacy. We promote this balance and harmony. We find inspiration from this land, the land of the Kumeyaay.

COURSE SCHEDULE

See canvas course Canvas website for course schedule details.