The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #42677

ConGrad: A Graduate Education Framework for Convergence Research and Experiential Learning

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ConGrad: A Graduate Education Framework for Convergence Research and Experiential Learning

Tess B. Meier, Ceren Yilmaz-Akkaya, Yunus Doğan Telliel

Abstract

Graduate STEM programs are designed to produce the next generation of experts in industry and academia. In parallel to recent advances in science and engineering, convergence research — the merging of diverse knowledge — is being called upon to solve complex problems at the intersection of science and society. To align graduate STEM education with the need of convergent approaches, graduate students are expected develop skills in problem solving, collaboration, systems thinking, and communication. This article describes ConGrad, a convergent graduate education framework that combines transdisciplinary methodologies, experiential learning, and learning by teaching, within the context of a project-based curriculum. Using the ConGrad framework, we propose a program in which graduate students advise interdisciplinary undergraduate projects with societal impact. With such an opportunity to practice convergence research methodologies via project-based learning, graduate students will acquire new capabilities of solving complex problems as leaders of trandisciplinary teams, further removing the barriers against convergence research in industry and academia. We present one graduate student's experience as preliminary qualitative evidence in support of the proposed program built with the ConGrad education framework.

1 Introduction

Conventional graduate STEM education is designed to create young professionals who are experts in their chosen field of study. These graduates are well versed in their disciplinary topic and demonstrate a high capability for learning, which are two important skills according to employers[1,2,3,4]. Students with graduate STEM degrees go on to become leaders in industry and academia, leading diverse teams towards various research goals. With recent advances in engineering sciences, from artificial intelligence to robotics to biomedical sciences, there is a growing wave of possibilities to integrate specialized fields with each other. The increasing demand for integrative problem solving requires the future leaders of the STEM workforce to have capabilities for navigating across multiple fields with teams comprised of diverse experts. One distinguishing feature of this integrative problem solving is that there is more emphasis on social context of STEM knowledge. For instance, Fox et al. recently examined the skills that companies have been looking for in the field of quantum sensing, networking, and computing[1]. According to this study, in addition to advanced mastery of fundamental sciences such as physics and mathematics, employers valued engineering skills including hardware design and troubleshooting. The researchers also added that the current nature of the field necessitates preparedness for cross-disciplinary collaboration, team work, and awareness of businesses operations.

Others have conducted similar studies across STEM disciplines, asking employers what skills they value in the workplace. Across these studies, most discussed so-called 'soft skills' included problem solving, collaboration/team work, systems thinking/design, and communication[1,2,3,4,5]. While there is a common recognition and appreciation of such nontechnical skills within the context of the STEM workforce, they are not explicitly taught in traditional graduate education programs in STEM. Given the individualist and isolationist nature of graduate students' research projects, there are often very few opportunities to cultivate and exercise these skills. In response to this, concepts and methodologies of **convergence research** prioritize the skills that are currently missing in traditional graduate education[6]. Convergence is defined as the merging of diverse knowledge practices across traditional disciplinary boundaries to address complicated challenges surrounding society and technology. Convergence thus requires researchers to communicate, collaborate, and cooperate with other researchers, as well as to understand the broader context as they progress towards their shared goal of situating engineering and science for the benefit of the general public.

Noble et al. suggest that future leaders would ideally learn these convergence skills as a part of their graduate STEM education, developed in close connection with skills of technical mastery that are already taught in STEM education[7]. Even though this ideal future may be something most researchers seek, it is unclear to many how we will reach this future. As this article argues, one possible vehicle for integration is **experiential learning**. Experiential learning is effective in helping students cultivate convergence skills because it requires contextualization of STEM solutions, application of STEM knowledge, an awareness of differences in theoretical perspectives and cultural norms, as well as expectations of communication and social relations[8].

Incorporating convergence and experiential learning can be accomplished in a number of ways. Our approach is focused on developing a framework for convergent graduate education that gives graduate students an opportunity to **practice convergent methodologies** as they mentor interdisciplinary teams doing projects that are (1) transdisciplinary and (2) relevant to society. The experience of **learning by teaching** within the context of **project-based learning** has the potential to prepare graduate students to tackle challenging problems in industry and academia after graduation. In the article, we first define convergence methodologies, and review the literature related to the initiation, adoption, and barriers of convergence research. We then share our proposed **ConGrad Education Framework** that uniquely combines convergence, learning by teaching, and project-based learning. We discuss the goals and requirements of this experiential learning program. We offer one graduate student's experience as preliminary support for the proposed program.

2 Literature Review

The concept of **convergence** has been gaining traction in the world of academia, since the launch of the National Science Foundation's (NSF) Convergence Accelerator program in 2019, which funds teams to solve societal challenges through convergence research and innovation[9]. The NSF defines convergence as “the merging of innovative ideas, approaches, and technologies from a wide and diverse range of sectors and expertise.” While this definition is broad, it contains two important words: “merging” and “diverse”. This definition has been further developed by others in the field. Convergence is explicitly defined by Peek et al. as,

> An approach to knowledge production and action that involves diverse teams working together in novel ways—transcending disciplinary and organizational boundaries—to address vexing social, economic, environmental, and technical challenges in an effort to reduce disaster losses and promote collective well-being[10].

Going beyond conceptualization into implementation needs coherent methodologies and dedicated training programs in STEM education. The United States National Science Foundation (NSF) is aware of this need. NSF is currently administering a funding program to support *NSF Research Traineeship Programs* (NRT) which are “dedicated to effective training of STEM graduate students in high priority interdisciplinary or convergent research areas[11].” North American research universities are designing graduate programs with similar objectives. For instance, one university implemented a year-long research experience to teach graduate and undergraduate students about interdisciplinary research, responsible conduct of research, and mentor–mentee relationships, incorporating some convergence methodologies[12].

We define **convergence methodologies** as conceptual knowledge for the practical execution of convergent projects/research. Some of the convergence methodologies that we have identified are **1) collaboration** across disciplines, including teamwork and individual development; **2) communication** across disciplines and audiences, including science communication and translating project language/ concepts from one discipline to another; **3) systems thinking**, including user experience design, ethics and broader impacts; and **4) problem solving** applied to real-world issues at the intersection of science and society. We identified these our convergence methodologies by our examination of the NRT Future of Robots in the Workplace – Research and Development (FORW-RD) NRT Program at Worcester Polytechnic Institute (WPI), as well as similar programs funded by the NSF[11].

While convergence research is being adopted by some pioneering universities, there are barriers that persist in the execution of convergent research projects. Some of the **barriers to convergence research** lie within academic structures such as “departmental siloing, conflicts in policies, procedures, and budget models across disciplines that often impinge upon interdisciplinary student development[13].” Institutions sometimes struggle to make the leap to convergence research because of the time needed to build relationships of trust among diverse research teams as well as to translate unfamiliar concepts, methods, terminology, and values across disciplines[6]. Therefore, even if students learn convergence skills in programs such as NSF-funded NRTs, they may not be able to translate these skills into practice within their own research.

As mentioned previously, **experiential learning** is a technique which allows individuals to practice academic skills, leading to deeper understanding and increased confidence in applying academic concepts. It has been shown that skills learned by practice are more transferable than skills learned in theory alone[14]. There are several techniques of learning and pedagogy that fall under the umbrella of experiential learning, two of them being **learning by teaching** and **project-based learning**.

Learning by teaching is an experience-based pedagogical method which has been implemented at every level of education to increase motivation to learn, improve understanding of material, develop important non-technical skills, and encourage creativity[15]. In graduate education, it is common for students to have opportunities for learning by teaching, for example by holding teaching assistant positions, presenting at international conferences, and peer mentorship within their research lab. Mentoring undergraduate research can impact graduate student development positively for future faculty careers as they gain skills in project management, supervision, and communication[16]. Because graduate students are familiar with this style of learning, it could be largely beneficial to cementing convergence methodologies in the process of teaching the methodologies to undergraduates or peers.

Project-based learning (PBL) is a type of experiential learning based on the application of knowledge towards a goal, further characterized by students' autonomy, constructive investigations, collaboration, and communication[17]. Similar to learning by teaching, this educational methodology has been shown to improve student engagement, retention, and learning across in K-12 and higher education[18]. Worcester Polytechnic Institute surveyed alumni to understand what impact PBL had on their development of professional skills. A majority of alumni reported that PBL had an impact on their ability to solve problems, function effectively on a team, integrate information from multiple sources, communicate with written and visual material, and make connections across disciplines[18].

PBL is not inherently transdisciplinary or convergent, but PBL can be used to teach and address convergent problems. While PBL is not the only way to learn convergence methodologies, it can be an efficient "means" to the "end" which is understanding and implementing convergence methodologies. It emphasizes the process of question identification and framing as much as problem solving, encouraging students to iterate and seek feedback, and to reflect on their approach and proposed solution. Additionally, outcomes of PBL are similar to the skills needed for the future of convergence research in industry and academia. For these reasons, we approach PBL as the primary educational context for the 'learning by teaching' of convergence methodologies.

3 Proposed Convergent Graduate (ConGrad) Education Framework

Overview

Through a synthesis of the studies on the topics of convergence, experiential learning, learning by teaching, and PBL, the following ConGrad Education Framework has been created (Figure 1). This framework offers universities a guideline for the creation of graduate programs designed to train students in convergence methodologies, to teach skills in team work, systems thinking, and communication, and to be better equipped to solve real-world complex problems.

Motivated by complex problems between science and society, and supported by graduate education infrastructure, we envision providing graduate students with the opportunity to learn, practice, and teach convergence methodologies in the context of an interdisciplinary real-world projects. This unique combination of experience in leadership, teaching, mentorship, convergence research, and real-world problem solving can be applied to any combination of STEM fields and

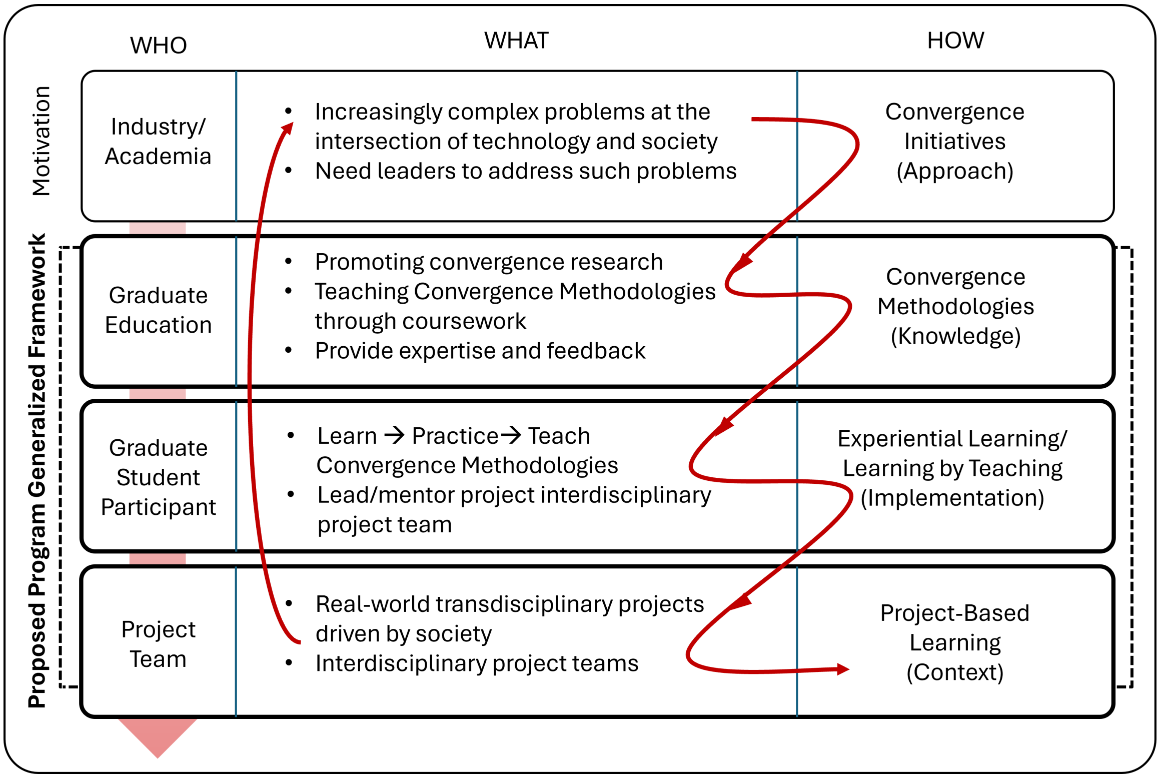

Figure 1: Convergence Graduate (ConGrad) Education Framework

contexts. This generalized framework can be implemented in many ways, from an industry-based internship program, to a summer cross-discipline project mentorship programs.

Industry and academia are tasked with solving increasingly complex problems in the fields of medicine, environmental science, economics, technology – to name a few. There is a need for emerging leaders from graduate school to lead the charge in developing and implementing convergence initiatives which require the involvement of many stakeholders, entities, and experts. Convergence within academia may look like engaging with faculty from different departments, or with a local hospital, government agency, or company. Convergence within industry, similarly, may involve collaborators with different disciplinary orientations situated in different kinds of for-profit and non-profit organizations.

Graduate education is uniquely positioned to provide the proper training and ecosystem for STEM graduate students to prepare them to take on these leadership roles. Graduate educational programs within universities can promote convergence by teaching relevant methodologies through coursework, seminars, workshops, summer programs, and extracurricular experiences. In a university, this training could be supported by externally funded programs such as the NSF's NRT programs or internally funded cross-departmental programs. In any case, faculty and staff would need to provide support and mentorship for graduate students during their ConGrad experience.

A program created using the ConGrad education framework will enroll graduate student participants who are interested in implementing their theoretical knowledge of convergence methodologies, and then teaching the convergent methodologies to a project team. The teaching aspect of this experience is centered on the mentorship of interdisciplinary project teams. This mentorship could take place within a course, summer research experience, extracurricular program, or internship program.

The project team will set out to solve a real-world problem motivated by academic and nonacademic stakeholders, which requires a convergent solution, and therefore a diverse team. The interdisciplinary project team will be the recipient of the graduate student's *mentorship*, receiving advice and guidance on their project and teamwork, and *teaching* of formal topics within convergence methodologies such as user experience design or data ethics. The project team may be made up of high school, undergraduate, and graduate student researchers, as well as faculty researchers and other academic and nonacademic experts. This project-based experience will facilitate the team's experiential *learning* of the convergent methodologies while the graduate student is concurrently learning through the experience of *teaching* the convergent methodologies, further solidifying their ability to conduct convergence research.

By teaching the next generation to be excited about and capable of creating and facilitating convergence research opportunities, we can further mitigate the barriers currently faced by graduate students today. Programs created using this framework to teach and promote convergence research can build communities of professionals who have an extensive network of classmates trained to collaborate and execute convergent research projects.

Institutional Environment

In order to develop, implement, and sustain a graduate program based on the ConGrad framework, universities need to establish intellectual and resource infrastructures. We propose that the following areas of institutional investment are considered in establishing ConGrad and similar programs.

1. **Institutional Resources**: funding is required to pay faculty and staff for facilitating this education program, like teaching courses and mentoring students, as well as project materials and costs. Graduate students may also require funding for their participation in the program. Funding can come from nationally funded programs like the NSF-funded NRTs or the NSF Convergence Accelerator funding program.

2. **Committed Culture of Collaboration**: meaning faculty, staff, and students should be incentivized by the university or internally motivated to collaborate across fields. University culture can impact whether faculty and students are encouraged to pursue inter-departmental, and external collaborations.

3. Existing **University Initiatives**: courses such as ethics and broader impacts, or existing project-based experiences, summer camps, cooperative programs, and internship programs, can provide infrastructure that can be utilized to create a ConGrad education program.

4. **Stakeholder Buy-in**: in addition to having resources and infrastructure, important stakeholders need to be interested in and committed to the execution of the program. In order to create a program with this framework, graduate students, faculty, staff, department heads, and deans need to agree on its value.

4 Proposed Program

Using the presented ConGrad framework, we constructed a program in which graduate students learn convergence methodologies by teaching as a mentor to interdisciplinary undergraduate teams who tackle a society-based problem (PBL) in an international setting. This program was executed at Worcester Polytechnic Institute as a proof of concept and foundation for future evaluation and iteration.

Institutional Context

Since 2019, WPI has secured funding for two National Science Foundation Research Traineeship Program grant awards, which provide resources to establish convergence-promoting curricula. The WPI Circular Economy and Data Analytics Engineering Research for Sustainability (CEDAR) NRT Program trains graduate students to solve problems surrounding sustainability and material regeneration using the latest data science tools. The WPI FORW-RD NRT program aims to train graduate students in convergence research relating to the development and adoption of robotic interfaces and assistants in the workplace.

The WPI FORW-RD Program consists of seminars, workshops, and career development sessions to arm the interdisciplinary cohorts of graduate students with training in ethics, user experience, science communication, and convergent research project development. The program is organized and led by a diverse group of faculty from Robotics, Mechanical Engineering, Computer Science, Material Science, Business School, Social Sciences, and Humanities, offering a model of collaborative cross-disciple efforts. The student fellows enroll in courses from a curated list of university hosted curricula such as Robot and AI Ethics from the Humanities and Arts Department, or User Experience Design from the Business School. These courses and sessions are leveraged for the proposed program.

As a polytechnic university, WPI provides a project-based STEM curriculum for both undergraduates and graduates [19]. This experiential approach to learning develops skills in problem solving, creativity, and critical thinking. Two of the major projects each WPI undergraduate completes are the senior capstone design project, or Major Qualifying Project (MQP), and the junior year Interactive Qualifying Project (IQP) [19].

In an IQP, undergraduates complete a project sponsored by a local organization, business, or government at any of the 70+ project centers around the world. The students are put into interdisciplinary groups and asked to propose and prepare a project for a given local organization and then travel to the project center to execute the proposed project. This experience challenges the undergraduates to work on problems of societal importance—problems that matter to people and communities [19]. This project experience is facilitated by WPI Global School. The IQP is the backbone of the proposed international immersive pedagogy experience in convergence research, as an established and robust educational infrastructure within WPI. Additionally, the Global School can provide trainings on travel safety and interpersonal relations to prepare graduate students for their advisory roles.

Stakeholders for the proposed program include the graduate students and their research advisors, the department head, the FORW-RD Program, and the faculty and staff of the Global School.

These entities agreed on the merit of the preliminary graduate student experience and supported the endeavour. Long term commitments—supported with a sustainable financial plan—would be necessary to ensure the longevity of the proposed graduate student immersive pedagogy experience.

Overview

The proposed graduate student experience was designed based on the ConGrad education framework to incorporate theory and practice of convergence methodologies such as collaboration and teamwork, complex problem solving, systems thinking, and communication. In this international project-based pedagogy experience, graduate students from engineering and science fields will work with faculty from the WPI Global School to advise and lead undergraduate interdisciplinary projects at WPI Project Centers around the world, including a number of Project Centers within the United States, as they address real-world issues. The first seven week course, the Preparation Period, will teach graduate students theories and methods of convergence research, PBL, mentorship, STEM & Society, and social science. The second seven week course, the Project Period, will be an international experience in which the graduate students will work with faculty co-advisors to guide undergraduate project groups as they tackle real-world challenges, allowing the graduate students to practice and reinforce the material they learned in the first seven week course.

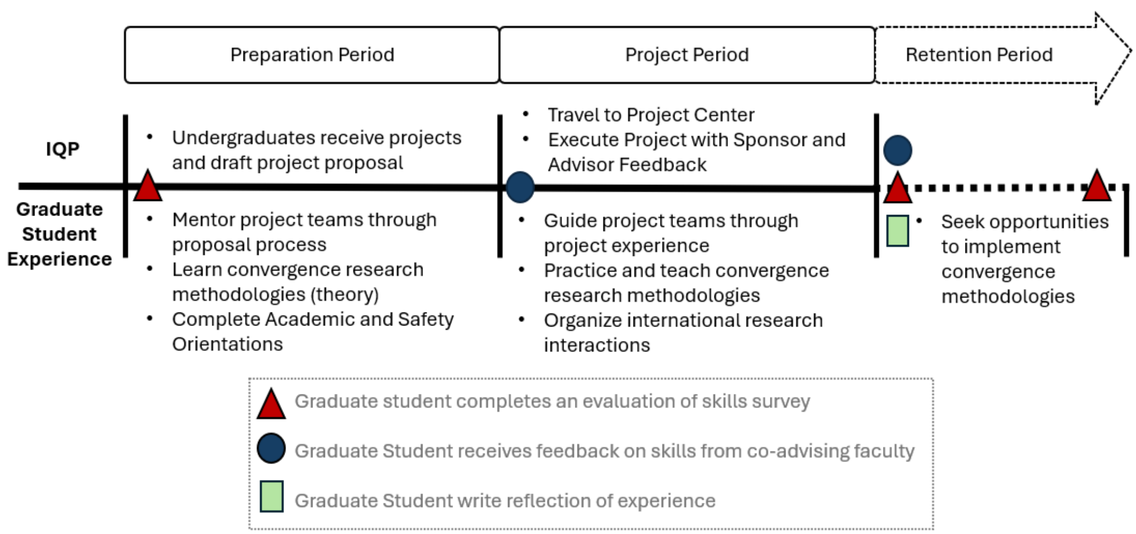

Figure 2: Timeline of proposed program with respect to IQP timeline

The Preparation Period

The theory-based course was created using informed curriculum design and consists of coursework, guest lectures, and an orientation. Aspects of the theory course have been inspired by material and activities from the FORW-RD NRT Program. This theory course will take place during the seven-week Preparation Period prior to the undergraduates' Project Period.

WPI project teams are sponsored by local organizations, businesses, and governments to do **projects that are human-centred in nature**. As the undergraduates formulate, research, and propose their group projects, the graduate student assigned to the class will meet with them and the faculty advisors weekly to offer guidance and considerations for their project planning. During these meetings the graduate student will observe how the faculty advisor guides the team, and will offer their own suggestions, questions, and considerations. The graduate student will assist the undergraduates as they create project proposals, work on team dynamics, and explore different social science research methods.

In addition to the weekly meetings with the undergraduate project groups, the assigned graduate course instructor will use weekly class time to **introduce the theories and methodologies surrounding convergence research, mentorship, communication, and team building**. This instructional material will be augmented with a series of guest lectures organized by the course instructor to provide a deeper understanding of each topic. One guest lecture will be on the Ethics and Broader Impact of Technology on Society. The material learned in this lecture will allow the graduate student to discuss and encourage ethical conversations as the undergraduates are developing their project. Another guest lecture will be on User Experience Design and Research Methods, as the projects being developed by the undergraduates need to focus on the real-world user within their project scenario.

A guest lecture could be given on bias awareness and cultural sensitivity. Because the graduate students will be traveling with the undergraduate class to an international location, it is imperative that the graduate student learn methods of cultural respect and become aware of any biases they may have so that professionally navigate the experience and set an example for the undergraduates during the term abroad. A member of the WPI Global School administrative staff will give a guest lecture on the academics of advising undergraduate projects and mission of the global school and we will have a separate guest lecturer from the Department of Learning Sciences to discuss the different learning styles that the undergraduates may have and how best to work with an teach a diverse group of students.

The third and final component of the theory course is the official orientation for the students as they prepare for their term abroad and the orientation for faculty as they prepare to advise teams during the term abroad. The graduate students would join both student and faculty orientations as learners and facilitators, respectively. The faculty orientation also includes safety and emergency training.

The Project Period

The second seven week course is an opportunity for the graduate students to put the knowledge learned in the previous term to practice. Graduate students will travel with their assigned undergraduate class and faculty advisors to the Project Center where they will advise the undergraduate projects in real-time. In addition to having a cultural experience themselves, they will be learning how to guide students in defining the scope of their project, teaching them how to communicate across disciplines, and challenging them to consider the effect of their project on the surrounding community. This is an example of **experiential learning through teaching**; the graduate student is solidifying their understanding of convergence methodologies and increasing their confidence in implementing them.

During the seven weeks at the international project center, the undergraduate students present proposals to their project sponsors, they conduct and execute their project and conclude the term by presenting their final project and writing a final report. The undergraduate students are benefiting from **experiential learning within their project-based experience**. The undergraduate project groups will be working in local communities with real-world considerations and constraints, which means the project scopes will likely shift and the circumstances may be different than their expectations. This requires the graduate student and the team to exercise problem solving skills to bridge the gap between expectations and reality to execute a meaningful project. The graduate student will learn from the faculty advisors how to guide the students through these challenges as the project develops. The graduate students will develop skills in critiquing written reports and presentations and giving constructive feedback to the undergraduate students.

Graduate students will also be tasked with connecting with the international research community by presenting their research at a university or college near the project center. Because most of the WPI Project Centers are international, the students will have to consider potential communication challenges and cultural awareness. This is a unique opportunity for graduate students to initiate global conversations and collaborations, as well as learn about research other universities are doing in their field as international networking is critical to a career in academia and industry.

Evaluating the Program

To evaluate the proposed program, we plan to employ a variety of quantitative and qualitative assessments, acquiring feedback from the major stakeholders before, during, and at the conclusion of the program iteration. Each graduate student participating in the program will be given a survey prior to their involvement asking questions related to their knowledge and capabilities of implementing different convergence methodologies as well as their comfort level with mentorship and teaching. They will fill out the same survey at the conclusion of the Project Term and again six months post-experience to make a direct comparison to post-program skills and retained skills, respectively.

The graduate students will be given a written evaluation by their faculty mentors, with whom they are co-advising the undergraduate projects, at the conclusion of the Preparation Term and again at the conclusion of the Project Term. The graduate students will be asked to write a reflection on their experience in the program and the skills they learned, practiced, and taught. The graduate student will receive course evaluations from the undergraduates. Six months after the experience, when the graduate students take the survey for a final time, there will be additional questions on retention of skills and reporting of accomplishments or initiatives born from participation in the program.

Additional surveys will be provided to the project sponsors and faculty advisors to assess the impact and efficacy of the graduate student's participation on both project success and graduate student growth. The results from the surveys will also be used to make changes to the program as appropriate.

5 Preliminary Graduate Student Experience

In 2023 Spring, the university decided to invest in a preliminary experience, enlisting one graduate student to gain insight into the potential impact of the proposed program. The WPI FORW-RD Program provided the funds for the preliminary graduate experience.When asked to summarize and reflect on her experience, Tess Meier, one of the co-authors of this article, shared the following testimony. We present her perspective on the proposed program and presented framework.

When asked to reflect on **preparation** for the experience, she responded with the following:

> *As a second year PhD student in Robotics Engineering and a fellow in the WPI FORW-RD program, I expressed an interest in advising undergraduate IQP [projects] through the lens of convergence research towards my goal of becoming a research faculty in academia. The FORW-RD Program organized an opportunity for me to work with the Director of WPI Global Project Center in Eilat, Israel and an additional faculty advisor to mentor three out of six of the undergraduate projects teams in both their Preparation Period and their Project Period in Israel.*
>
> *After attending numerous seminars, workshops, and colloquium on convergence research, broader impacts, and science communication through the FORW-RD Program, I felt prepared with the theories, excited to practice them and subsequently teach them. I took a Robotics and AI Ethics course and a User Experience Design Methods course which I felt furthered prepared me to lead interdisciplinary undergraduate teams as they addressed real-world challenges through their society-based IQP [projects].*

Meier's education in convergence research was facilitated by a WPI NRT program, which provides infrastructure and institutional support for the learning of convergence research methodologies. The education she gained through fellowship activities constitutes the "theory" aspect of her education. The material in these fellowship sessions inspired the course design for the "Preparation Period" described in Section 4 4.

When asked to reflect on **participating** in the experience, she responded with the following:

> *When we arrived in Israel at the start of the Project Period, each team faced challenges of expectation vs. reality. Even after researching their topics and creating project proposals during the Preparation Period, the students could not be fully prepared for the reality of their environment, the sponsors' vision, and the available resources. The first step for the undergraduates is defining the scope of their project, a step that in some cases is not finished until they present their final project. Once they communicate with their sponsor, and get an idea of how the sponsors organization or business is operating, they can start to identify problems and figure out how to solve them as an interdisciplinary team, towards the goal of delivering a meaningful and useful project.*
>
> *One of the student teams was tasked with creating an algorithm to sort through trail camera images and identify foxes and jackals in dessert terrain to assist a desert ecologist's efforts to track their populations and movement in the area. This project*

> *required students from computer science, robotics engineering, and biology to work together and with their desert ecologist sponsor to create an algorithm that successfully classified the animal images but was also seamlessly integrated into the desert ecologists workflow (as she had no knowledge of algorithm development or maintenance). As their mentor, I taught the students about algorithmic ethics relating to transparency, trust, and explainability. I also taught them to consider the user's experience, as they had to understand the software, workflow, and knowledge of the desert ecologist to ensure their solution would actually work for her in the long run. Their project was a success and saves the desert ecologist approximately 20 hours of manual image labeling a week. This was a great example of convergence for me because the computer scientists needed to gain an understanding of desert ecology in order to create a successful algorithm, and their desert ecologist sponsor does no have the expertise to code an algorithm but the students were able to train her to use the algorithm.*

The context of the interdisciplinary projects is critical to the overall impact of the experience. The projects were created to address real needs of the sponsors, who are local business owners, government employees, and researchers in Israel. By bringing problem solving out of the lab and into the world, the variables multiply and the stakes are higher, but the opportunity for impact is greater. The learning experience gained by the undergraduates is a good example of **project-based learning**. The project example mentioned above highlights that the merging of diverse expert perspectives and solution strategies was successful beyond what any of the individuals could accomplish with their own disciplinary knowledge. By guiding the undergraduates through this experience, Meier had hands-on experience teaching convergence methodologies.

When asked to reflect on their **role** in the experience, she responded with the following:

> *My role was to 1) teach the undergraduates how they can better communicate with each other, with us as the advisors, and with their sponsors; I reviewed their presentations and reports, providing useful written feedback. 2) help the students identify strengths and weakness within the team so they can delegate tasks; in some cases I assumed the role of mediator during conversations regarding team dynamics 3) lead them through difficult problem solving situations, facing adversity with agility when things don't go according to plan 4) instill the value of the sponsor as an expert, meant to work in collaboration with the student team to ensure the student project fits within the system of the sponsor's organization or business.*

These roles demonstrate the rich **learning by teaching** experience she had in teaching the convergence methodologies of communication, collaboration, problem solving, and systems thinking.

When asked to reflect on the **conclusion** of the experience, she responded with the following:

> *By the end of the Project Period, each of the student groups gave a final presentation of their finished projects to their sponsors, the class, our Israeli host organization, and their family members. Through these presentations they*

demonstrated the skills they acquired during this fourteen-week experiential learning process. The growth we saw in the students from day 1 of the Preparation Period to the last day in Israel was immense.

During my time in Israel, I was able to visit two major universities, the Weizmann Institute of Science and Ben Gurion University. I organized meetings with a number of professors from mechanical engineering, human computer interaction, physical therapy, and medical robotics. It was valuable to share my research, hear about their research, and observe the dynamics of their labs with how they conducted convergent research projects.

There are many benefits from connecting with international researchers in one's field, the most important being collaboration opportunities, networking, and dissemination of research. This is an example of how graduate students can practice their own communication skills.

When asked to reflect on the **impact** of the experience, Meier responded with the following:

This experience was incredibly useful in learning, practicing, promoting, and teaching convergence methodologies in the context of PBL. I have continued to seek experiences to hone these skills further. I created an interdisciplinary project team for a senior capstone design project (MQP) relating to my own medical robotics research. I purposefully designed a team and project that requires knowledge of robotics, biomedical engineering, computer science, and language. As I lead this team through their year-long project, I have been incorporating assignments based on convergence methodologies such as identifying cross-discipline collaboration opportunities, ethical considerations, written and oral communication, and user-centric design.

Following my time in Israel, I presented my experience to my fellowship group within the WPI FORW-RD program and shared everything I learned about mentorship, leadership, problem solving, systems thinking, and communication. My participation in this experience and STEM outreach lead me to win a leadership award. I was able to use my new confidence in convergence research and communicating across disciplines to present my medical robotics research at two neuroscience conferences, one of them being the 2023 Brain & Human Body Modeling (BHBM) where I won 2nd place in the student competition. My involvement in the program was valuable to the site Director and the WPI Global School as evidenced by an invitation to return as an adjunct faculty advisor the following year.

Meier's achievements and self-driven initiatives since completing the experience are valuable outcomes, indicating the impact and retention of skills obtained from her experience.

This testimony provides valuable insights regarding the student perspective on the proposed program, demonstrating what it might look like for future graduate student participants. In our future work we plan to further investigate the impact of the proposed program with extensive assessment through engagement with other stakeholders on their experience, as previously outlined by Section 4.

6 Conclusion

As industry calls for collaborative experts and society calls for experts in problem solving, we can use themes of convergence research to elevate STEM graduate education. Employers are looking for leaders with skills in problem solving, systems thinking, communication and collaboration. Programs built using the proposed ConGrad education framework such as the proposed program, can provide graduate students with foundational knowledge of convergence methodologies, opportunities for real-world experiences to implement them, and a chance to teach the same skills to their peers or juniors.

Acknowledgments

This material is based upon work partially supported by the National Science Foundation (NSF) under Grant No. DGE-1922761. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF. We would like to acknowledge the WPI Women's Impact Network (WIN) Impact Grants - 2023 Supporting WPI Women in STEM Education Research.

We acknowledge Erin Solovey and Isa Bar-On as faculty mentors for Tess B. Meier during the pilot experience in Israel and for their support of the presented project. We acknowledge Benjamin Pollard for his input in the later stages of framing and documenting the project in this paper.

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