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Complementary and Contrasting Perspectives: Collaborative Teaching across Engineering, Computer Science, and the Liberal Arts

Dr. Carolyn M Rodak, Union College
Dr. Luke Dosiek, Union College
Andrew Burkett, Union College
Christine Henseler, Union College
Christopher Chandler, Union College
Dr. Nick Webb, Union College

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Abstract

The global challenges of today require creative interdisciplinary solutions that span engineering, science, social science, and the humanities. Therefore, our graduates need to be prepared to engage in multidisciplinary collaborative problem solving. At Union College three multidisciplinary team-taught courses were designed as part of the Templeton Institute (TI) mission to provide students with courses that integrate engineering and computer science with the liberal arts. The courses included an introductory course in Science, Technology, and Society (STS), Humanity-Centered Design (HCD), and Data Sonification. All three courses carried additional attributes such as general education credit and/or contributions to major or minor requirements. The introductory STS course was offered in the Fall terms of 2023 and 2024, and the HCD course was offered in the Fall term of 2024. The course on Data Sonification will be offered for the first time during the Spring term of 2025. The STS and HCD courses resulted in a diverse cohort of students in terms of discipline and class year. Both courses expanded student ways of thinking and created self-agency as seen in student course evaluations. The team-taught, multidisciplinary approach used in each course also provided faculty with professional development through the advancement and transfer of unique pedagogical approaches that may not traditionally be used in one's field. In addition, faculty built connections between traditionally siloed departments. One such instance resulted in intentional curricular alignment between Environmental Engineering and Spanish and Hispanic Studies to promote major/minor innovations and study abroad options. Faculty involved in the TI courses were supported through a small stipend and full teaching credit for each team-taught course. For initiatives such as this to be successful, such courses require sufficient leadership, vision, and pedagogical curiosity in addition to faculty support in terms of time and finances.

Introduction: Engineering and the Liberal Arts

There is little argument that solutions to today's complex problems require creative, collaborative, and inclusive solutions, yet meaningful integration of engineering and liberal arts education remains minimal [1], [2]. The engineering curriculum is often described as rigid and can be unforgiving when students deviate from prescribed paths loaded with science, mathematics, professional, and engineering course work. For example, the Accreditation Board for Engineering and Technology (ABET) [3], provides detailed guidance on the engineering curriculum, requiring a minimum of 30 credit hours in mathematics and basic sciences and 45 credit hours in engineering topics, technical content, and design. This means that approximately 60% of the 120-130 credit hours of engineering curriculum is already dedicated to prescribed STEM coursework. In addition, each discipline may have further accreditation requirements, increasing the curricular rigidity and decreasing the opportunity for engineering students to explore the humanities or other non-STEM fields. Engineering courses are designed to build on prior mathematics, science, and engineering coursework, which creates a series of rigid prerequisites that also act as barriers for students outside of engineering who may be interested in taking an engineering course. Because of this, courses beyond the introductory engineering curriculum remain essentially inaccessible to non-engineers, further expanding the divide between engineering, the liberal arts, and the humanities.

Numerous colleges and universities have implemented a required general education curriculum for all students that typically consists of a wide range of lower-level courses from varying liberal arts disciplines. Students are then required to take a certain number of these courses, typically representing about one third of the degree, spread across a predetermined number of contributing disciplines or themes. The goal of the general education requirement is to graduate well-rounded students and responsible citizens [4]. Although the general education curriculum creates opportunities for students to learn a variety of topics, it does not necessarily integrate disciplines together such as engineering and the liberal arts. Thompson et al. [4] found that although 69% of students surveyed could articulate the purpose of general education requirements in creating well-rounded global citizens, 71% agreed or strongly agreed with the statement that they would prefer to take additional courses related to their major instead of taking an equivalent number of general education courses. This disconnect indicates a lack of connection for students between the general education curriculum and the major courses [4]. Essentially, the completion of coursework outside the major does not necessarily translate to an ability to understand multidisciplinary perspectives or address the complex global problems of today and tomorrow.

Creating a Culture of Collaboration

As conceived, most general education curricula do not include courses within professional degrees such as engineering. This configuration of general education requirements creates a one-way street and often places the design and implementation of the curriculum on the liberal arts. Regardless of one's perspective of whether engineering *could* be considered a liberal art [2], this configuration results in engineering faculty with minimal ownership of the curriculum and limited collaboration and integration between engineering and the liberal arts.

Some general education curricula do include contributions from all faculty within a given institution. For example, Union College (Schenectady, New York) utilizes a general education curriculum focused on "Complex Questions," which are thematically split between two areas of inquiry: "Global Challenges" (GC) and "Justice, Equity, Identity, and Difference" (JEID). There are eight "Perspectives" categories within both areas of inquiry: (1) "Creative Works/Arts and Design" (CAD), (2) "Cultural and Historical Foundations" (CHF), (3) "Data and Quantitative Reasoning" (DQR), (4) "Engineering, Technology, and Society" (ETS), (5) "Literatures" (LIT), (6) "Natural and Physical Sciences" (NPS), (7) "Social Analysis, Politics, and Ethics" (SPE), and (8) "World Languages" (WOL). Although engineering faculty could contribute to any perspective, their courses typically fall within the ETS perspective. As Union College increases the offerings within this new general education curriculum, all students will need to take courses from all eight “Perspectives.” This inclusion of engineering within Union’s general education curriculum is a step toward both creating a culture of faculty collaboration and generating a multidisciplinary student experience. However, as mentioned above, the simple existence of coursework outside the major does not necessarily generate value and interdisciplinary connection from the students’ perspectives of their learning and majors.

In an effort to promote more interdisciplinary experiences for students, some engineering programs have begun to incorporate traditional general education concepts and perspectives within new engineering courses, such as the “Impacts of Engineering” at the University of Wisconsin-Stout, which integrates “topics such as ethics, social justice, and social responsibility into engineering education at a polytechnic institution” [5] and the “Sustainability Practicum” course at the University of Utah, which includes a multidisciplinary approach to project-based teaching and learning [6]. Some have looked to smaller-scale solutions, creating interdisciplinary modules for existing courses, while others have taken a wider approach of redesigning the curriculum [7]. But as Potter et al. [8] note, the implementation of interdisciplinary education is complex and will be unique to an institution: “Issues around faculty teaching loads, research expectations, course ownership, dual course listings[,] and the siloed nature of faculty departments have allowed for the development of separate, unique departmental cultures and have created artificial walls dividing the disciplines on most university campuses and making it difficult to offer an integrated curriculum.”

One answer to this siloing of academics is the creation of interdisciplinary majors that span a wide range of disciplines, such as Science, Technology, and Society (STS), which often brings together faculty research and teaching interests from vastly different disciplines and areas of expertise. As a field that traces its historical roots to roughly the mid-twentieth century, STS quite famously synthesizes, on the one hand, philosophical and theoretical approaches to technoscience’s complex roles played in human cultures and societies with, on the other hand, rigorous hands-on applications of science and engineering methods and practices. In this context, STS represents a strong example of an inherently interdisciplinary field of study that joins together departments and disciplines that are rarely recognized as crucially in conversation. For example, at Union College teaching faculty in STS include representatives from a range of disciplines including English, Classics, History, Political Science, Geosciences, Engineering, Sociology, Physics and Astronomy, Mathematics, Computer Science, Religious Studies, and Psychology. The fostering of such a multidisciplinary field embodies an important institutional step toward the cultivation of a culture of collaboration for a given college or university.

Integration of concepts from different disciplines in education can happen through a range of approaches fuzzily divided into multidisciplinary, interdisciplinary, and transdisciplinary teaching (MITT). Multidisciplinary teaching often includes people from different disciplines working together and drawing on their own disciplinary knowledge to "enrich and expand the original boundaried inquiry. Synthesis is not its goal" [1], whereas interdisciplinary teaching pulls different disciplinary perspectives together to synthesize and deepen knowledge and skills [9]. To reach transdisciplinary teaching and learning, students must collaborate beyond the boundaries of their respective disciplines on projects and problems in the real world [10]. MITT has been shown to have several benefits that lead to significant student learning including, but not limited to, the following: enhanced foundational knowledge of disciplines, understanding of how and when to apply skills, connection of ideas and approaches, integrated knowledge, and learning how to learn, which together lead to metacognition and enhanced critical thinking [9]. MITT, which specifically incorporates team-based activities, also provides students with the opportunity to work in multidisciplinary teams, a practice that is essential in many disciplines, including engineering [9], [10], [11].

Team teaching is one mechanism to provide students with multidisciplinary perspectives in an effort to promote interdisciplinary thinking [6]. Methods range from "tag-team" approaches, where faculty are responsible for specific class periods or modules, to fully collaborative teams, where each faculty member is present at each class period. Although team teaching of this nature is time intensive, especially when fully collaborative, it has been found to be a rewarding experience that can enhance an educator's own professional development and promote pedagogical transfer through the sharing of best practices and skills during the teaming process [7], [11], [12]. Of course, for these benefits to manifest, teams must function effectively; faculty must share a passion for the topic and their discipline, be willing to share control of a given course, and, ideally, have experience working together. From an administrative perspective, it is also critical to have an appropriate mechanism for sharing credit and finances among contributing disciplines [9]. When these conditions are met, fully collaborative and multidisciplinary team teaching can generate interdisciplinary and transdisciplinary thinking while providing a more inclusive experience for faculty and students, given the inherent heterogeneity in background, experience, interests, and learning styles [9].

Process for Course Selection

In general, any faculty member may design and propose multidisciplinary, collaborative, and/or team-taught courses. However, the implementation of new courses within existing teaching loads, expectations, and curricula can be difficult, bringing about concerns of time management, compensation, and loss of autonomy in the case of team-taught courses [7]. At Union College, the Templeton Institute (TI) serves as a strategic mechanism for creating a culture of collaboration and discussion through the development of multidisciplinary courses that combine engineering and computer science with the traditional liberal arts. The support of multidisciplinary course development is one way that the TI achieves its mission to "catalyze learning through a dynamic environment that fosters collaboration within and across engineering, computer science, and traditional liberal arts disciplines. Its mission is to enable connections, experimentation, innovation, and discovery through integrative coursework, projects, and research." Faculty members who develop and teach courses selected as TI courses receive a variety of incentives, such as small stipends for new courses or modifications to existing courses, financial support for external speakers, and, if the course is team-taught, full teaching credit for each faculty member for the first iteration that the course is offered.

The process for selection as a TI course is competitive. A call for proposals goes out in October each year for potential multidisciplinary courses for the following academic year. Proposals are then due by the middle of January. The proposed course must align with the TI mission and address contemporary and emerging societal challenges. The proposals require a tentative syllabus that clearly reflects the mission of the TI as well as details of plans for longevity of the course and expectations regarding any course prerequisites. Submissions are reviewed and evaluated by the Templeton Institute Steering Committee (TISC), a group of faculty members from various disciplines across campus. In addition to addressing the required TI content, elements of successful proposals have included projects, speakers, and field trips. Courses that connect to the general education curriculum and/or are team-taught are strongly encouraged and receive higher priority in the selection process. The selection of a course does not circumvent Union College's procedural norms, and all TI courses must go through the standard course approval process and be scheduled strategically in consultation with departmental chairs and program directors. Faculty are asked to have these conversations with administrators prior to submitting a proposal.

This process, with minor revisions each year, has resulted in the selection of one TI course in Academic Year (AY) 2023-2024 and two new TI courses in AY 2024-2025 (Table 1). Though not required, all three courses selected during the first two years were multidisciplinary and collaborative team-taught courses. Recognizing the significant undertaking of designing a new course, the TI expanded its options during its AY 2025-2026 call to include small stipend incentives for the creation and implementation of small multidisciplinary course modules. The remainder of the paper will focus on the content and feedback from the AY 2023-2024 and AY 2024-2025 TI courses, along with student and faculty perspectives.

Table 1: Templeton Institute (TI) Courses

Course Name	Term	Faculty Departments Represented
Introduction to Science, Technology, and Society	Fall 2023 Fall 2024	English, Classics, History, and Computer Science Guest Lecture: Engineering
Humanity-Centered Design: Ecodesign your Life	Fall 2024	Civil and Environmental Engineering, German Studies, Spanish and Hispanic Studies

What Does Data Sound Like?	Spring 2025	Electrical and Computer Engineering, Music

Course 1: STS-101, "Introduction to Science, Technology, and Society"
STS-101 is a team-taught course that introduces students to the range of methodologies, epistemologies, topics, and concerns central to the field of Science, Technology, and Society (STS). How do scientific concepts develop, take root, and evolve? What range of roles do scientists and engineers play as they interact and intersect with broader societies? How might scientific practice and theory affect public planning and discourse? What are the social, political, historical, anthropological, moral, religious, philosophical, and ethical dimensions of technoscience's complex roles in human cultures and societies? These are some of the fundamental questions that we explore in this survey course, which is a team-taught class offered by four or more college faculty members. To help our students narrow in on these broad questions and open up their responses to both historical and contemporary real-world scenarios related to them, we have structured this course around four major modules offered by faculty from various backgrounds and forms of expertise in the field, with each module focusing on specific case studies that address a range of global challenges as well as the historical, philosophical, material, and theoretical contexts that have characterized the trajectories of their various forms of emergence.

Students gain an historical perspective on contemporary beliefs and practices related to STS and can push back on perceived truths. We also explore how technological and scientific developments are culturally embedded and have varied impacts on different societies, communities, and individuals. Students analyze the origins of technological solutions, how they work, and how they interact with human societies, shape scientific methods, and influence human interactions with the environment. We think critically about the impacts of technoscience on human societies by discussing theories that highlight the dialectical co-dependency of humans and the objects they create with ever expanding technologies. Finally, students understand the engineering design process and intentional and unintentional consequences of such topics and areas as Artificial Intelligence (AI) with hands-on exercises.

Starting in Fall term 2023, this course began focusing on case studies involving the longer historical arc of twentieth and twenty-first century developments in the history of computer science that gave rise to breakthroughs (conceptually *and* materially, speaking) in the field of AI, which culminates in Module IV, "Histories of Computer Science and Artificial Intelligence." To ground and contextualize further this crucial module of the course, offered toward the syllabus's conclusion, we open the class by offering a variety of perspectives that address experimental pedagogical approaches to the history and philosophy of forms of technoscientific emergence and development through, for instance, Module I, "Science Studies Methods and Knowledges," which centers on the work of Bruno Latour, Thomas S. Kuhn, Donna Haraway, Susan Leigh Star, Helen Longino, and other intellectuals foundational for the field of STS. Module II, "Histories of Technology and Medicine in the Global South," offers a re-reading of crucial texts in STS from the perspective of the Global South, with an emphasis on the Indian subcontinent, and aids in broadening the sweep of the course's historical and geographical approaches to these and related topics outside of and beyond Western traditions and patterns of thought. Module III, "Science, Technology, and the Past as Mediated through Human Entanglement with Objects," both strengthens and deepens this global approach through course materials focusing on theories of scientific and technological objectivity issuing from the Classical age to our own. We also hosted faculty as term guest speakers and course visitors, who offered week-long explorations of course issues at the intersection of engineering and the liberal arts, thus allowing the students and faculty of this course to reflect on, reconsider, and newly apply the concepts and approaches central to our syllabus to beyond-the-classroom activities through campus-wide STS lectures (Figure 1).

Figure 1: (Left) Fall 2023 STS campus-wide lecture on "Feminist Technology" with Biomedical Engineering faculty member, Professor Jennifer Currey. (Right) Fall 2024 STS campus-wide lecture on "Exploring the Black Box of Design" with Civil and Environmental Engineering faculty member, Professor Carolyn Rodak.

Through key texts, case studies, and approaches, we examine contemporary and emerging societal issues presented by developments in technology and science, while also probing the historical, philosophical, material, and theoretical backgrounds and trajectories of such global challenges. STS-101 is thus aligned with the mission of the TI to foster "collaboration within and across engineering, computer science, and traditional liberal arts disciplines." STS-101 offers modules and guest lectures taught by computer scientists, engineers, humanists, and social scientists, and the Fall term 2023 and Fall term 2024 iterations of this course were staffed by faculty from the departments of English, Classics, History, and Computer Science. During the Fall term 2023 offering of the course, a faculty member from Electrical, Computer, and Biomedical Engineering (ECBE) acted as guest lecturer and Fall term speaker, while a faculty member from Civil and Environmental Engineering (CEE) served in this role during Fall term 2024.

The learning objectives and goals of this course include the following: (1) To be introduced to and to study in depth the range of methods, theories, and concepts fundamental to the field of STS from a range of faculty perspectives. (2) To explore key STS texts by writing argumentative essays and completing project-based assignments that engage in basic ways with secondary criticism, theory, and/or history, etc. (3) To practice course discussion skills in the classroom through a seminar-style format. (4) To address contemporary and emerging societal challenges presented by a range of developments in various forms and fields of technology and science, while also probing the historical, philosophical, material, and theoretical backgrounds and trajectories of such global challenges. (5) To give a formal presentation on and write/create a final paper/project at the end of the term that explores objectives 1, 2, and/or 4 above. Students are also required to complete four projects (e.g., research papers, nontraditional projects, etc.) of varying lengths (e.g., four-to-five-page papers) and types throughout the course of the term. One paper/project is completed following each of the course's four major modules.

STS-101 is now offered every Fall term with rotating faculty from the STS Interdisciplinary Studies (IS) program. We plan to retain a thematic approach to STS topics each year and to ensure placeholder positions for modules to be offered in computer science and/or engineering areas of study and expertise, as relevant. Each year, students witness interdisciplinary conversations between faculty in their classes, since in each class, at least two faculty are present, and there are designated days in which all faculty members are present in each of the lectures. Additionally, STS-101 now qualifies for Union College's revised general education program as a "Global Challenge" (GC) course representing two "Perspectives" categories: "Engineering, Technology, and Society" (ETS) and "Cultural and Historical Foundations" (CHF). As the entry-level course in our IS program, STS-101 has no prerequisites or other required forms of academic background or experience for students wishing to enroll in the class. The course is appropriate for all levels of students (i.e., from first-year to senior students), and it serves as our common core course required by all majors and minors in our STS program.

Course 2: ESC/ISC-221, "Humanity-Centered Design: Ecodesign your Life"

"Humanity-Centered Design: Ecodesign your Life" is a fully collaborative, team-taught course conceived in response to an initial desire to collaborate between faculty in Modern Languages (MLL) and Civil and Environmental Engineering (CEE) and a shared interest in reading and discussing the book, *Design for a Better World: Meaningful, Sustainable, Humanity Centered* (2023) by Don Norman [13]. The course evolved through discussion to become a locally-sourced and humanity-centered general education course, which enables all students to broaden their understanding of *design* from multiple disciplines and diverse perspectives with a focus on our own lives, experiences, and stories of people, communities, and ecosystems. Students are encouraged to learn principles of Humanity-Centered Design (HCD) and recognize their own place within complex systems as well as their potential and agency as co-designers of their own interconnected lives. The course thrives through student-centered projects and stories, where discovery and conversation drive learning. The course includes guest speakers and field trips, where students observe and engage with businesses adopting the HCD approach.

Through an emphasis on HCD, design justice, sustainability, and other critical literature, the course seeks to redefine the engineering design process by expanding students' "design" mindsets through a focus on humanity-centeredness and on human behavior, psychology, communication, and connection, with an emphasis on storytelling to give voice to the unheard. Students explore how the engineering and humanity-driven processes influence each other and can be integrated into their own educational paths. To attract a wide range of students, the course is cross listed in Engineering Science (ESC) and Interdisciplinary Programs (ISC) to improve visibility and discoverability of the class in the Union College catalog [6]. The course is also designed to meet general education requirements related to "Engineering, Technology, and Society" (ETS), and it counts as elective courses for the interdisciplinary programs of "Gender, Sexuality, and Women's Studies" (GSWS) and "Environmental Science, Policy, and Engineering" (ESPE). Overall, these efforts appear to have been successful in attracting a wide range of students and creating a diverse cohort in its first offering in Fall term 2024.

The general structure of the course included discussions, hands-on activities, field trips, and speakers. There was significant engagement outside the classroom through readings and discussion boards. Each week, the students read a required text, selected two readings from a cultivated listing of texts, prepared a written response based on their readings, posed a discussion question to the class, and responded to at least two discussion questions from their peers. In addition, the course included a term-long design project of their own choosing. At several points within the course, students had dedicated time to discuss their projects with the faculty. Students were initially apprehensive about the lack of constraints on their project topics, with many identifying the selection of their topic as the most challenging aspect of the course. However, by the end of the course an overwhelming number of students identified that the ability to choose a project aligned with their personal values and interests as one of the strengths of the course.

Each week the course explores a different question related to HCD and students' roles and forms of agency in their own lives. The first of three units focuses on the values of creativity, community, and connection. It begins with the question: "Are you a designer?" In the first week, we engage students in a conversation about what design is and why we consider ourselves designers. We also explore the impacts of poor design and consider how to affect change and implement better solutions. What role does design play in the places we inhabit and the world we build? What does that mean for one's life, education, and career? We parlay this topic into a focus during the second week on interconnected systems, asking the students: "How Connected

Are You?” As a class, we explore system theories and our own interconnectedness as humans, communities, and ecosystems. Students explore the people, communities, and ecosystems connected to their lives through an in-class activity in which they create a life map. In the final week of the first unit, we challenge students to consider that almost everything is artificial. The class explores how history and design have influenced our artificial ways of life. In our first iteration, students were presented with two seemingly contrary future visions: one from the American Society of Civil Engineers (ASCE) presented in the 2024 film *Cities of the Future* [14], followed by an open discussion with a guest speaker from Rancho Mastatal, a sustainable living and education center in Costa Rica. At the end of this first unit, the students had defined their values and their roles as designers but were left to ponder the following question: if technology and human behavior got us into this situation, can it also get us out?

The second unit focuses on the values of growth, nature, and diversity and is defined around four key questions: (1) “How do you measure what is important?”; (2) “How can design be made more just?”; (3) “What do you leave behind in the ‘Age of Waste’”?; and (4) “How can we move from humans to humanity?” This middle unit reinforces the power of storytelling and the purpose of measurement, its limitations, and how to use measurements that are important to people to communicate in meaningful ways. Students explore the connections between storytelling and design justice and how the design process, though often well intentioned, can support the status quo and silence marginalized communities. In our first iteration, we welcomed speakers from the “Good Work Institute,” a worker self-directed nonprofit organization, which exists to build and amplify the collective power of people to reject systems of oppression and extraction and to create regenerative, just, and life-affirming communities. The concepts of design justice are then expanded to focus on sustainability through the “Three P’s” of “People, Profit, and Planet” and the United Nation’s (UN) sustainable development goals. Following this discussion, students traveled to the Good Work Institute to explore first-hand how we can move from humans to humanity.

The final unit focuses on applying course concepts to students’ own lives and experiences under the values of contribution, respect, and vision. We discuss why change is so difficult and how we can use design to challenge and change our world. In our first iteration of the course, this unit included personalized discussions, including individualized educational priorities, a question-and-answer session with Don Norman via Zoom (Figure 2), and the presentation of their individual design projects. The design projects generated in the first offering of this course included a wide range of topics including tangible designs, campus-community related projects, and literature-based study techniques.

Figure 2: “Humanity-Centered Design” question-and-answer session via Zoom with Don Norman.

Course 3: AMU/ECE-246, “What Does Data Sound Like?”

AMU/ECE-246 is a forthcoming course that will be offered for the first time in Spring term 2025. It was designed as part of Union College’s Music Technology minor that is administered by both the Music (AMU) and Electrical, Computer, and Biomedical Engineering (ECBE) departments. The course will be cross-listed and team-taught with one faculty member from each department in a fully collaborative format. In addition to being a TI course, it will carry general education credits under the “Global Challenges” (GC) area of inquiry, offering students the option to count it as either a “Creative Works/Arts and Design” (CAD) or “Engineering, Technology, and Society” (ETS) course.

This course is an introduction to the field of data sonification, a creative and innovative approach to understanding and communicating by translating data into sound. Data sonification goes beyond traditional data visualization methods, offering unique insights and perspectives on datasets from a variety of sources. Students will explore a broad spectrum of interdisciplinary applications, ranging from the practical (e.g., Geiger counters for radiation detection or machines monitoring vital signs for healthcare patients) to the technical (e.g., scientific research in fields like electrical engineering, astronomy, and physics) to the creative (e.g., musicians creating new music or sound art from patterns and structures found in data). This course encompasses theoretical foundations, practical techniques, and hands-on experiences with software and hardware tools for scientific and creative projects. Through a combination of lectures, guest speakers, discussions, and interactive labs, students will gain a deep understanding of the principles behind data sonification and its diverse applications in the modern world.

Throughout the term students will explore data sonification concepts and examples of its historical significance across disciplines. They will learn techniques to translate diverse data types into audible representations, manipulating parameters like pitch, timbre, and rhythm. Students will examine real-world uses of data sonification in healthcare, environmental monitoring, and industry through case studies, and they will gain insights into the use of data sonification in scientific research. At the same time, they will discuss and consider ethical issues related to data sonification, including artificial intelligence, privacy, bias, and responsible use in various contexts. Students will evaluate existing data sonification projects critically, propose improvements, and develop effective communication skills for presenting complex information. They will explore the creative potential of data sonification in fields like music composition and sound art through hands-on experiments and will collaborate with their peers to create meaningful data sonifications of their own using datasets (e.g., the UN list of global issues; datasets of their own choosing). By the end of the course, the students should be able to answer the following key questions:

- What is data?
- How do we obtain it?
- What does it mean to process it?
- How do we process it?
- What information can we gather?
- What is data sonification?
- What is audification?
- What is the history of data sonification?
- How do we generate sound?
- How do we map data to sound?
- Which types of data are appropriate for which musical parameters?
- What information can be in sound?
- What are the modern tools we can use for data sonification?
- How do we define what music is?
- How do we analyze music?
- What information does music contain?
- How do we make music from data?
- Can we “hear” the data in music and sound art?

The students will be assessed with several low-stakes assignments plus three projects. In the first project, students will design a device that transforms data into sound. Focusing on practical, real-world applications, students will identify a specific problem or need and conceptualize a device that provides auditory feedback. Their designs may address diverse fields, such as monitoring environmental changes or enhancing healthcare diagnostics, encouraging students to explore the societal impacts and benefits of auditory data representation. The project will challenge students to integrate technical knowledge with inventive thinking, fostering skills in design, problem-solving, and the application of sonification technology to address tangible, societal challenges.

In the second project, students will collect diverse datasets and map them to various parameters of sound. Through hands-on exploration, students will experiment with translating quantitative information into audible representations, examining how different mappings can highlight patterns or insights within the data. For instance, students might use changes in pitch to represent temperature fluctuations or manipulate rhythm to reflect traffic-flow data. This process invites them to think critically about how sound can effectively communicate information while remaining engaging to listeners. The project encourages creative expression as students begin to discover novel ways to convey data through sound. By the project’s conclusion, students will not only have honed their data collection and sonification skills but also will have gained a deeper understanding of the nuanced relationship between information and auditory perception.

The culminating project will challenge students to synthesize everything they have learned in the course by creating a piece of music or a sound installation using datasets. Drawing on their understanding of sound parameters, musical concepts, and data-translation techniques, students will create something that blends information and art. This project invites students to think beyond technical execution, challenging them to explore the artistic and narrative dimensions of their work. They will also consider the listener's experience and experiment with ways to make complex information accessible and audible through sound. Whether designing an immersive soundscape that brings climate change data to life or creating a work that sonifies patterns in astronomical data, students will be encouraged to push the boundaries of creativity. By transforming raw data into an immersive auditory experience, students will gain a deeper appreciation for the power of sound as a medium for communication, expression, and discovery. The final project is not only an exercise in technical and artistic synthesis but also a celebration of the interdisciplinary possibilities at the intersection of liberal arts and engineering.

Student Perspectives

As briefly mentioned in the sections above, the TI courses have attracted a diverse range of students in terms of majors (Figure 3), minors, and class years. Of the 62 students taking a TI course in the first 18 months of implementation, 12 (21%) were first-years, 23 (37%) were sophomores, 18 (29%) were juniors, and 8 (13%) were seniors. It is worth noting that these courses are not advertised to students as TI courses or in any special manner inconsistent with current practices on campus. The courses attracted an exciting mix of students representing the interdisciplinary interests of Union College and the efforts of the faculty within these courses to design unique, multidisciplinary classes of wide interest. The distribution in class years also demonstrates that students are interested in taking interdisciplinary courses before and after they have declared their majors.

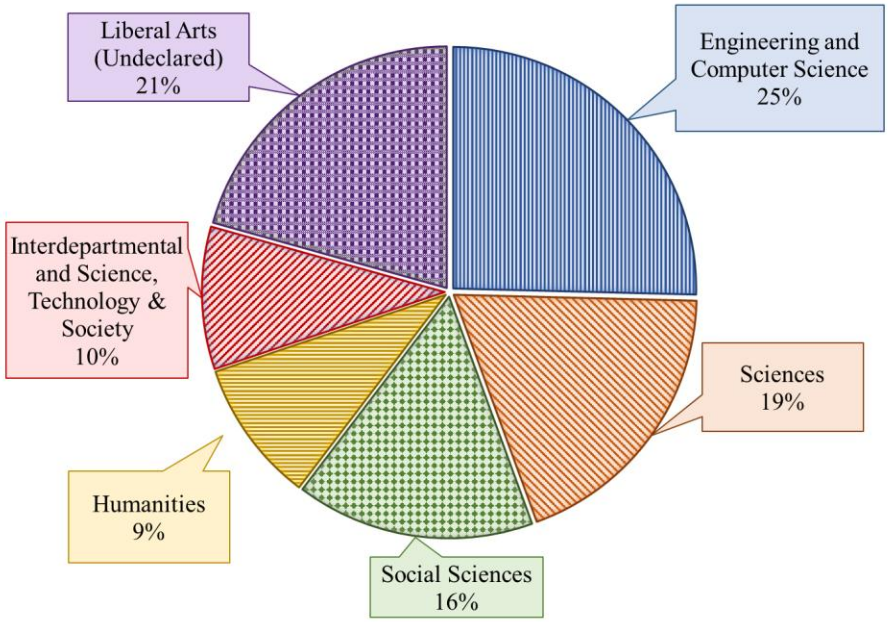

Figure 3: Distribution of Union College student majors enrolled in Templeton Institute (TI) courses during academic years 2023-2024 and 2024-2025.

The TI courses offered underwent course evaluations consistent with Union College's practices. Students receive a survey for each faculty member in the course, and much of the quantitative content is instructor specific and not directly relevant to this discussion. More applicable are the qualitative responses of students taking a TI course and the themes emerging from them.

One concern of a team-taught course is the coordination, time, and cohesiveness of the faculty. While one comment alluded to the presence of occasional disconnects due to a course being offered for the first time, many comments highlighted the advantage of having a team of faculty on the course:

- "For the first time teaching this course, all three instructors did really well in meshing their different backgrounds together to create a well-rounded and cohesive course to include humanity and engineer[ing] while ingraining multiple life lessons."
- "I really like being able to take this course with all three instructors as they helped support each other and created a very welcoming as well as multifaceted environment."
- "Each instructor brought a different perspective to the class, yet all were passionate, engaging, and understanding of their students. They all had such interesting presentations that helped the class feel very welcoming and enjoyable to be in."

These comments also indicate student recognition of the multidisciplinarity of these team-taught courses. Students also address how their thinking changed based on the content presented by the faculty in each course:

- “Many of the topics discussed in class were ones I had never considered before. They ranged from ideas in sustainability, storytelling, and leadership.”
- “This class taught me to think differently about design.”
- “I now have a different perspective of life’s structures and human interactions with the environment.”
- “The two projects and assignments we did allowed me to build my own definition of design.”

Finally, students also identified connections between the presented content and their everyday lives and personal passions, especially within the written evaluations of the HCD course:

- “Everyone is [*sic*] the class worked on different final projects about design and integrated what we learned in class.”
- “Each week’s topics were extremely relevant to personal interests as well as to everyday life and how we interact with everything.”
- “In every class, we learned something different that could spark inspiration on our projects.”
- “I was always intrigued or surprised by something I read or saw.”

Additionally, an informal optional follow-up survey was designed to solicit responses specific to TI courses in the Fall term of 2024 (Table 2). We intend to use this survey (with minor modifications) more formally in the future to solicit responses from students. The survey was optional and only received three responses, likely due to its distribution after the term had ended and students had traveled home for break. In the future, it will be disseminated prior to the end of classes. The three responses were multidisciplinary and from students self-identified in (1) “Humanities,” (2) “Engineering,” and (3) “Science.” The responses highlight curiosity, the topic, and the general education requirement as important components for why the students chose to take the course. In addition, on average the students saw how the course integrated engineering and the liberal arts through the content and design project. Students left with an appreciation for the integration of disciplines and a recognition not to limit themselves within their own disciplines.

Table 2: Informal Follow-Up Survey of TI Courses
Q1) Why did you take this course? [check all that apply] *Curiosity, ESPE credit, Faculty reputation, GenEd credit, Topic, Other*
1. GenEd credit, Topic (HCD) 2. Curiosity, GenEd credit 3. Curiosity, Faculty reputation

Q2) One of the goals of the Templeton Institute is the integration of different fields and perspectives. To what extent did you see and understand this course as bringing together engineering / computer science and the liberal arts? *No integration [1] [2] [3] [4] [5] Clearly integrated*
1. 5 2. 4 3. 3
Q3) Please provide one example of how this course integrated concepts or perspectives from engineering / computer science and the liberal arts.
1. Though the overall topic of the class was designs and how those are engineered, the main theme was also focusing on how those are human impacted and driven. 2. It taught how to better apply the humanities into making new things, either with technology or without. Each week, we read over documents that were used to help provide us with the principles on which we made our design. It was great because we all came from different majors, and this process was different for everyone. 3. Our design projects were wide open, and a lot of people designed physical components that required both engineering and humanity[-]centered thinking which are two things that rarely go hand in hand.
Q4) What was the most valuable concept/perspective you took away from this course?
1. Never just look at something for how it is but do the deeper connecting of why it is like that and know that it could always be improved. 2. I learned how to let integration of fields take place, guiding how I decided on my project. 3. Not limiting one's self from the supposed confines of your discipline.
Q5) In what ways (positive and/or negative) did this course differ from courses in your major?
1. It was really great in helping view the world differently not only in learning how we have created Everything around us but that we are also the masters of our own lives and can change things accordingly. 2. It was extremely enjoyable, and felt like it emphasized the human and discussion of individual passions. 3. It was an extremely flexible and varied course in that no two classes were the same and there was no strict syllabus or grading system. I would say this had a positive effect because it allowed me to loosen up a bit, which is something that a lot of college classes do not provide much wiggle room for.

Faculty Perspectives

The faculty involved with TI courses were provided with several prompts regarding their experience and perspective. The first was about the value and interplay between humanistic and/or social scientific perspectives, methods, topics, or concerns and those of engineering and/or computer science within the courses as designed. Faculty teaching TI courses were asked to consider, on the one hand, how humanistic and/or social scientific perspectives, methods, topics, or concerns were understood or recognized, in a given TI course, as adding value to or reshaping the perspectives, methods, topics, or concerns of engineering and/or computer science. On the other hand, and vice versa, these faculty were asked to consider and report on how engineering and/or computer science perspectives, methods, topics, or concerns were understood or recognized, in a given course, as adding value to and reshaping the perspectives, methods, topics, or concerns of the humanities and/or social sciences.

Within STS-101, faculty feel it is increasingly important that students can contextualize, for example, the development of a technology such as AI within a wider societal framework in order to consider the full range of impacts that technology can have on individuals, cultures, and societies. Understanding that the development of technology is often an evolutionary process can give agency to students from all backgrounds to realize that they have input to offer at many points in that development cycle. Perhaps most fundamentally, the STS-101 faculty group came to recognize that an important part of their role as educators in such a multidisciplinary course was both to show and to explain to students how a range of global challenges facing society (e.g., AI, legacies of colonialism, climate change, resource management, etc.) are not the domain of a single department or discipline and that no one field or area of research expertise may issue a priority claim to answering such global questions or concerns. Rather, it is only through the shared dialogue and critical conversation that occurs by bringing faculty and students from a diverse set of departments and disciplines together that we may adequately articulate strategies for beginning to address such topics. This process often requires a search for a shared vocabulary and set of methodologies with which to launch a course, and STS-101 opens by helping both students and faculty in the group to settle on and prioritize a set of humanistically and social-scientifically inflected theories, philosophies, and methodologies for recognizing and understanding better how scientists and engineers intersect and interact with broader cultures and societies. If this opening module of the course relies on the humanities and social sciences to frame such methods and approaches, later units of the course delve into engineering and computer science topics in ways that showcase the technical realities and hands-on nature of work in these disciplines while prompting faculty offering these sections to recontextualize these areas in ways that fundamentally probe the often inherently social, cultural, and humanistic bases of engineering and computer science. For example, the most recent version of this course offered a guest module by an engineer who not only taught the practical realities of the engineering design cycle but also framed this lecture and discussion through principles of design justice, which resonated with and opened new questions for other modules across the course seeking to emphasize the social scientific and humanistic dimensions of technoscience.

The HCD course emphasized that design is an intentional process that has uniquely shaped our lives in seen and unseen ways. Design is not owned by any one discipline but instead belongs to all. What is produced through design influences and is influenced by our community and ecosystem in expected and unexpected ways. Therefore, we chose to highlight the perspectives and value of the humanities, sustainability, and the stories of our communities, in particular those marginalized and/or silenced, while exploring the role of design in the large and small. Throughout the HCD course, we emphasized the role of self-agency and students as designers of their own lives, communities, and societies. All three instructors feel there are minor modifications to be made for the second offering of the course, but overall, the course succeeded in prompting students to begin to integrate their values and disciplines within design. As one student wrote in their final project reflection:

> The one thing I will carry with me throughout the rest of my life is that I have the power to use who I am, what I value, my experiences, and issues I care about to design something, whether big or small, that can make a difference.

Faculty were also asked to consider how designing and implementing a TI course impacted them on an individual level and at an institutional level. At the individual level, faculty responses included a theme of pedagogical creativity, refinement, and transfer within multidisciplinary team teaching reinforcing the findings from current literature [7], [12]. One faculty member stated that designing the team-taught course “allowed us to think of our teaching methods creatively,” and another stated that fully collaborative team teaching allowed them to “see a wide range of pedagogical techniques and approaches … I have already started implementing some of these ideas in my current courses.”

Many faculty emphasized the importance of providing students and faculty with team-taught multidisciplinary course experiences. These courses provide faculty and students in computer science and engineering with a mechanism to interact and speak directly in meaningful ways with their counterparts in the liberal arts and vice versa. It is also important for students to see faculty working outside their silos and collaborating on courses, given that students will likely need to demonstrate these skills after graduation. As one faculty member wrote,

> Students who are in engineering and sciences are curious about contextualizing their disciplines, and a focus on the relationship between science and society helps them do that. In my module, students focused on the development of science and technology under colonialism, and across other forms of intersections of gender and class. This exposed students to a more empathetic and humanistic approach to science and technology, and it gave them tools to evaluate their ideas of technology from a global perspective.

The connections made within the teams have also resulted in collaborations outside the classroom. For example, when engineering students start to consider minors, they are often guided toward STEM fields, where the "double counting" of STEM courses help fit STEM minors into the engineering curriculum more easily. After working together on the HCD course, two professors began working on developing and communicating a path for students to pursue a major/minor combination of Environmental Engineering and Spanish and Hispanic Studies, which included a term abroad. After determining the viability of the idea, they submitted an external proposal in an effort to find additional funding to support and grow this new multidisciplinary connection. The proposal is currently under review, but regardless of the outcome, the faculty intend to continue to explore this new connection.

Conclusions and Recommendations

It is clear that to solve the complex problems of tomorrow, we need to employ creative, collaborative, and diverse solutions. Therefore, our educational practices must adapt to train students to think critically while opening their minds to interdisciplinary and transdisciplinary solutions. In this paper we presented three multidisciplinary, team-taught courses in "Science, Technology, and Society," "Humanity-Centered Design," and "Data Sonification." The courses attracted a wide range of students from different majors, minors, and class years, resulting in a multidisciplinary student experience. Students indicated that there was value in having multiple faculty perspectives in the classroom and highlighted the courses as relevant and interesting. Many referenced a change in thinking in their responses to formal and informal course evaluations and surveys.

The faculty involved also benefited from the multidisciplinary, team-teaching environment. Not only in the expansion of understanding other disciplines but also in design, refinement, and translation of pedagogical techniques from the diverse disciplines present, with one calling the experience "transformative." The collaborations built also resulted in intentional, multidisciplinary curricular advancements between Environmental Engineering and Spanish and Hispanic Studies, resulting in a proposal (currently under review) for external funding to support and expand the effort.

Collaborations between engineering and the liberal arts do not just magically happen at liberal arts institutions. Efforts such as this require leadership, vision, pedagogy, and support [10]. Even at schools like Union College, where students have the opportunity to combine engineering and the liberal arts, such combinations are quite rare. Often the strict course structure and extensive prerequisites of engineering disciplines make it challenging for non-engineering students to access classes of interest. Similarly, the heavy course load faced by engineering students doesn't facilitate their exploration of opportunities in outside disciplines. Some schools including ours allow students to pursue joint or combined-degree structures. In reality, however, over the past fifteen years only one single combination of an engineering discipline and a more traditional liberal arts discipline has been seen at our institution, whereas typically 5% of the student body as a whole is engaged in these kinds of combined degrees. This only amplifies the need for faculty to work together in novel ways to ensure that a wide range of students are exposed to ideas from across the disciplines.

Successful multidisciplinary, interdisciplinary, and transdisciplinary teaching (MITT) requires leadership, vision, pedagogy, and support. Based on the data presented here, a few recommendations for future iterations at Union College as well as applications at other institutions include the following:

- *A wide range of options for faculty to become involved in MITT.* Team teaching is not for everyone and is time consuming, particularly when a new course is involved. Having options for single-instructor courses and smaller-scale course modifications/modules allows everyone to participate at the level that works best for them. For those interested in team teaching, a database of interested faculty members would be beneficial to help connect interested parties.
- *Appropriate financial and administrative support for faculty involved in MITT.* As mentioned, MITT takes time and effort that would otherwise be used elsewhere by faculty members. The amount of support should correspond to the scope of the proposed activity/course.
- *Communicate the pedagogical goals and benefits of MITT.* Not all faculty are aware of best practices and the benefits of MITT or team teaching. Communicating this to faculty can increase acceptance and adoption of new pedagogical techniques. In addition, a targeted, standardized method for collecting data about student learning and experiences in TI courses beyond the standard course evaluation tool is recommended. This will support consistent data-driven messaging regarding the effectiveness of such courses.

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