Work in Progress: Liberal Arts Help Engineering Students Change the World

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Dr. Alison Wood is an assistant professor of Environmental Engineering at Olin College of Engineering. She is a distinguished researcher in the fields of both water and sanitation, as well as a researcher and practitioner in using interdisciplinary thinking and approaches to solving environmental and sustainability problems. Dr. Wood is also pursuing her interests in the areas of equity and justice through education and engagement with context and values.

In addition to her teaching and advising duties at Olin, Dr. Wood serves as the Director of the Babson-Olin-Wellesley Three College Sustainability Certificate Program, the Director of Olin's Grand Challenge Scholars Program, on the Catalyst Board of the open source journal Murmurations, as a member of Olin's Sustainability Steering Committee, and as a member of Olin's Context and Ethics in Engineering Education Working Group.

After graduating from Harvard University with a B.A. in Dramatic Literature, Dr. Wood worked professionally in theater and wrote and recorded two musical albums. She then returned to school to study engineering, earning a B.S. in Civil Engineering from Rutgers University. Dr. Wood then went on to earn a Master of Science in Engineering in Environmental and Water Resources Engineering and a Ph.D. in Civil Engineering from The University of Texas at Austin, while working with the Austin chapter of Engineers Without Borders as a volunteer and project lead for a project in Peru.

She has published and presented on incentivizing decentralized sanitation and wastewater treatment, on sustainability of coastal community water and sanitation service options, as well as on integrating liberal arts and STEM education, currently through the vehicle of the Grand Challenges Scholars Program. She has co-designed workshops oriented toward educational change for Olin's Summer Institute and the joint Olin College-Emerson College event: Remaking Education.

Her love of learning was first fostered by an unusual elementary school education that was deeply interdisciplinary with a substantial arts curriculum, which has informed all her subsequent thinking about the potential for education to transcend conventional models.

Dr. Robert Martello, Franklin W. Olin College of Engineering

Robert Martello, Associate Professor of the History of Technology (Ph.D., MIT, 2001) has led Olin College's Arts, Humanities, and Social Science curricular development since 2001. Dr. Martello has developed a number of Olin courses that use self directed learning techniques to integrate humanities and social science content with technical concepts and competencies. He published several papers and delivered presentations investigating the relationship between interdisciplinary integration, self-directed learning techniques, and student motivation. Dr. Martello's history of technology research centers on the connections between technological development, managerial and entrepreneurial skills, and environmental resource use in early American industrialization. His book Midnight Ride, Industrial Dawn: Paul Revere and the Rise of American Enterprise, was published by the Johns Hopkins University Press in fall 2010.

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Abstract

As part of the ongoing work described in "Work in Progress: Transformation through Liberal Arts-Focused Grand Challenges Scholars Programs" (from the ASEE 2019 Annual Conference and Exposition), a professor of environmental engineering and a professor of the history of science and technology collaborated to add a new liberal arts course to the engineering curriculum at Olin College of Engineering in spring 2019. That work suggested that students learn new ways of thinking, knowing, doing, and being through participation in a transformative liberal-arts infused Grand Challenges Scholars Program. This project-based course was created with learning objectives of *communication*, *critical thinking and reflection, identity development*, and *embracing many ways of knowing and being*. Learning experiences provided scaffolding for students to identify and prioritize the impacts they hope to make in the world; explore paths for making these impacts possible; and begin to share these experiences, values, and ambitions with various audiences. The course asked students to engage with questions such as: *As individuals and engineers, how should we pose ethical questions and prepare to advocate for the values that we hold dear*? *How might we start to understand and react to larger global problems, causes, challenges, and opportunities that surround us*? *Who am I and what is my place in the world*?

The course was a new, experimental offering. The two instructors heavily involved students in shaping the design of the course both in the planning process prior to the start of the semester, as well as through detailed feedback activities during the semester. This paper will explain the goals of the course and will offer an analysis of student responses to the learning experience--which were overwhelmingly positive--based on various feedback mechanisms. Drawing upon the analysis of these data and on the experience of co-creating and co-teaching this course, we have also compiled lessons learned about how to design such a course and the most successful techniques used to achieve desired student outcomes. We conclude with next steps for revising and expanding these learning experiences, which are being implemented in 2020. This entire analysis is embedded in a larger ongoing study of how a liberal arts-focused Grand Challenges Scholars Program can successfully provide transformative learning experiences for students. The experience related herein serves as an illustration of how liberal arts content and methods can be deployed within an engineering curriculum to help students better position their course of study and their professional ambitions within a larger personal narrative and a sense of purpose in the wider world.

Introduction and Background

In 2008, the National Academy of Engineering published a report on the Grand Challenges for Engineering in the 21st Century, setting out an ambitious agenda for the profession for the coming decades [1]. The following year, the Grand Challenges Scholars Program (GCSP) was created by two engineering deans and an engineering college president--and endorsed by the National Academy--as a way to help undergraduate engineering students prepare to tackle these challenges [2]. The program is centered on five competencies considered crucial to complement a conventional undergraduate engineering degree: talent competency (mentored research or creative experience), multidisciplinary competency, viable business or entrepreneurship competency, multicultural competency, and social consciousness competency [2]. Every school with a GCSP designs its own program of coursework and co-curricular activities to support student development of these competencies, and some of these programs have focused on the ways these competencies align with a liberal arts education by building their GCSPs on a foundation of liberal arts and STEM integration [3].

Olin College of Engineering is one such school. Since its founding in 1997, Olin has valued liberal education and the integration of liberal arts with the study of engineering [4]. Olin is a tiny undergraduate college that offers only engineering majors. The gender-balanced student body numbers approximately 350 and the approximately 45 full time faculty work without departments or tenure. The school was founded "to be an important and constant contributor to the advancement of engineering education in America and throughout the world and, through its graduates, to do good for humankind" [5]. Much of the curriculum is hands-on and project based; many of the courses are co-taught by interdisciplinary teams and much of the content is integrated across disciplines. Olin also emphasizes teamwork, design, and student autonomy, positioning students as co-creators of their own educational experiences. In addition, all students complete an Arts, Humanities, Social Sciences concentration alongside their engineering major, and essential outcomes of a liberal education, per the Association of American Colleges and Universities, are integrated throughout the curriculum [6], [7].

Olin President Richard K. Miller brought this philosophy to GCSP as one of the three founders of the nationwide program. Olin was one of the first institutions with a GCSP, and was the only school to adopt the premise that all students would achieve the basic GCSP competencies simply by completing the standard undergraduate curriculum. Since 2017, a new faculty GCSP director has embraced the opportunity to redesign Olin's program to provide additional scaffolding for students to explicitly integrate the GCSP competencies, aspirations, and learning outcomes across their educational experiences. Objectives of Olin's GCSP redesign included helping students articulate their personal and professional values, offering support for reflection on their past experiences with the intention of preparing for purpose-driven future work, and providing

additional opportunities to develop the multicultural and social consciousness competencies of the national program.

The redesign process lasted approximately one year, and involved faculty members, students, and alumni. One of the major outcomes of the revamped program was a clearer articulation of Olin's specific approach and goals, as articulated in the new mission statement: *Olin's GCSP helps students leverage their educational experiences and participation in the Olin community to galvanize lifelong learning and community participation*. The program overview also lists the guiding principles of Olin's "GCSP 2.0"--developing the self ("I"), developing Olin ("we"), and developing the world ("all of us") [8]. As with the first incarnation of Olin's GCSP, students are expected to gain significant experience in the GCSP competencies throughout their undergraduate education. However, where "GCSP 1.0" used an independently written, in-depth senior reflection paper as the mechanism for students to connect their Olin educational experiences to the GCSP competencies and forward-looking aspirations, the GCSP redesign introduced a semester-long course to achieve these and other goals.

The designers and instructors of Olin's first GCSP course believe that the course itself, as well as the co-design process used to develop and then revise the course, offer valuable lessons not only to other institutions interested in establishing or revisiting their own GCSPs, but also to a wider group of educators who might wish to design new student-centered interdisciplinary courses.

Change the World: Olin's First GCSP Course

Olin's GCSP redesign culminated in the creation of a new course, Change the World: Personal Values, Global Impacts, and Making an Olin GCSP. It was co-designed by Assistant Professor of Environmental Engineering Alison Wood (who is also Olin's GCSP Director) and Professor of the History of Science and Technology Robert Martello to serve as the cornerstone of the program. The main goal of the course is to provide structured support for a culminating reflective synthesis. As mentioned above, in the early years of Olin's GCSP, graduating seniors accomplished their reflection through mentored writing outside of any course, which worked well for students in the early years of the program but less so in 2017. The Change the World course was conceived as an opportunity to teach the skills and scaffold the process of introspection. The target audience for this course is undergraduate engineering students who have some practice in dissecting the successes and failures of finished projects but often little or no practice in reflecting on themselves. The course also includes content, activities, and assessments that address two GCSP competencies (multicultural and social consciousness) present in Olin's larger curriculum but less prominent (and less developed) in the typical undergraduate experience than the talent, multidisciplinary, and entrepreneurship competencies.

The primary learning objectives of Change the World are critical thinking and reflection, identity development, communication (all drawn from Olin's Learning Outcomes [9]), and pluralism (embracing many ways of knowing and being, inspired by [10]). The course helps students identify the personal values that have informed their educational choices, situate their learning in cultural and systemic context, apply formal ethical frameworks to their implicit decision making processes, and project their current values and decision making processes onto future endeavors and impacts that they hope to achieve. While other Olin courses frequently ask students to consider the context and consequences of a specific technical project, Change the World focuses on the student as a person and a practitioner, not only on the narrowly scoped work at hand [11].

As Roche asserts [12], "a college education is very much about...understanding...what kind of person one is and what kind of person one wants to become." Mitcham expands upon the importance and efficacy of humanities, arts, and social sciences in "successfully engaging the ultimate Grand Challenge of self-knowledge, that is, of thinking reflectively and critically about the kind of world we wish to design, construct, and inhabit in and through our technologies" [13]. As Farrington concludes [14], key outcomes such as identity development rely on exposure to new experiences, such as "engaging in new ways of thinking" and "active reflection on oneself and one's relationship with others." Change the World is intended to foster these mindsets and provide these experiences for Olin students, using a variety of content and approaches drawn from the liberal arts, implemented in a hands-on classroom experience.

The semester-long course includes projects as well as a series of workshops, readings, discussions, and other smaller assignments, which introduce students to subjects such as ethical frameworks and case studies, paradigm theory, systems thinking, social justice, and many others. These smaller assignments develop skills in areas such as critical reading, reflective practices on personal values and identity, ethical decision making and self-empowerment, and communication for different audiences in different media. These content and skill areas are intended to provide a basic foundation in existing work on these topics (e.g., [15]-[19]) and foster in-depth discussions in class. Workshops and activities facilitate reflection, which is a critical tool of self-development and transformational learning [20].

One of the projects--the short "Building an Olin GCSP" project--asks students to suggest additions or revisions to either the course itself or the larger GCSP at Olin. These suggestions are critically evaluated by the instructors and inform ongoing revisions of the class and the program: students are told that their proposals might be implemented in the following year, which gives them a sense of partnership in the learning process. In another project, teams of students research locations around the world that are markedly different from their own contexts; they learn what they can about these places and present the results on posters for their classmates and the larger school community. However, in addition to sharing what they learned about the foreign location

and its context, they also explore what they learn about themselves from their research: students identify ways that the project has challenged their own paradigms and write about how they expand or shift their personal worldviews to accommodate what they've learned.

The major project that underlies the whole semester is the "Personal Vision and Mission Statement (Snapshot, Age ___)," known as the PVM. The PVM asks students to grapple with the question "who am I and what is my place in the world?" Responses take the form of both a written analytical and reflective component and a creative component in which students may use any medium of their choosing to articulate their current thinking about those questions. We emphasize the *current* aspect of the project, as we strive to help students separate from anxieties about defining their entire life paths. The learning objectives for this project include identity development, identification and communication of personal values and goals, use of communication as a tool for iterative personal development, understanding of one's self as an actor in an ethical (or unethical) system, and enacting and building habits of critical thinking and critical reflection. Homework assignments and in-class activities throughout the semester help students build pieces of this project along the way and search for connections and deeper insights over a longer period of time. The final products of this project (typically the creative components) are shared with the wider Olin community at a public showcase at the end of the academic year. This PVM has replaced the standalone personal reflection that previously served as the culmination of GCSP for Olin's students; completing the project is the primary requirement for graduating from Olin as a Grand Challenges Scholar.

The spring 2019 end of semester student course evaluations for Change the World were extremely strong, and formal and informal student feedback throughout the class were also positive, with comments received such as "I'm excited to be reflecting together as a class," "It has been very interesting and compelling to be able to choose some of the things we are learning," and specifically in reference to the Building an Olin GCSP project, "I like the newest project we are working on. It seems valuable and helpful." The instructors also agreed that the course was a success, as evidenced by their assessments of individual student achievement of learning outcomes and their observations of the highly constructive and engaged class dynamics. The instructors are conducting a research project to better understand the specific reasons for positive outcomes, and this work is in its early stages. While definitive conclusions or analysis cannot be offered at this time, observations and evidence suggest that the first implementation of this course benefited from features such as the interdisciplinary approach, the creation of a space in which ordinarily hard-pressed engineering students could reflect upon their broader learning experiences and aspirations, the inclusion of open-ended projects that offered opportunities to explore the larger societal implications of engineering, and the inclusion of students as partners in the planning and implementation of the course. End of semester feedback reinforced these perceptions, with comments such as "I really enjoyed this course because of how it was a space

of exploration and self-discovery" and "I really appreciated how I was able to tailor the assignments to my own interests or votes of what would be effective." We believe the role of students in co-creating the course will be of particular interest to other institutions who might already be familiar with some of the other pedagogical approaches used in the course.

Co-creation and Feedback

A long period of ideation and design preceded the first offering of Change the World and the inclusiveness and scope of this process inspired a number of creative course elements and ongoing improvements. In 2017, Alison Wood became the new director of Olin's GCSP in the midst of an institutional collaboration with several schools just launching or preparing to launch their own programs. Supported by this collaboration and the strong foundation of Olin's existing program, Dr. Wood took the opportunity to reconsider the many ways that GCSP might be most impactful and satisfying for Olin students, who were beginning to express a lack of interest in completing the senior reflection: they seemed to be internalizing the message that Olin's curriculum already provided most of the value of the program and therefore they chose not to take on a challenging personal writing project in the midst of their senior year. The students who did complete the reflection, though, consistently asserted how valuable the experience was. As Dr. Wood received these messages, she conceived of a GCSP course that would provide more structure for students in this experience and perhaps more clearly communicate the additional value provided by engaging with GCSP in addition to completing the Olin curriculum.

To better understand the needs of the community and the culture within which this program is embedded, Dr. Wood gathered seven faculty and staff colleagues to participate in a one-day workshop that generated ideas for a revamped Olin GCSP. The concept of a course emerged independently from this session. To bring the ideas to fruition, Dr. Wood enlisted fellow faculty member Robert Martello. The course would be designed in fall 2018 and offered for the first time in spring 2019.

Through fall 2018, as course planning began, Dr. Wood also continued her work with the student steering committee that helps run Olin's GCSP. Normal committee activities include organizing informal "Interesting Conversations" between students and individual faculty and staff members, running a book group, and planning the annual soirée celebrating the graduating Grand Challenges Scholars each spring. Weekly committee meetings offered opportunities to share course ideas and plans with the students, who provided feedback and suggested new ideas of their own. Student committee members proposed and vetted specific readings and course topics, and weighed in on proposals for class discussion formats and techniques. The instructors recorded key messages from the steering committee meetings and feedback for use both in improving the course as it was running and for continuing to develop the next iteration of the

course. Examples included specific suggestions for revising the PVM project description to make it clearer and more approachable for students, reminders for the instructors to frequently and explicitly communicate the objectives of class activities to students, and ideas about timing and framing the course projects to increase student engagement.

In-depth feedback was also collected from all students enrolled in the class. Three times during the semester, feedback surveys were deployed asking students to respond to four open-ended questions: (1) What has been working well for you? Think about what has introduced you to new ideas, gotten you excited, been fun or engaging, or anything else you think has been really great. (2) What has not been working so well? Be specific if possible, for example share things that were confusing or disjointed. Help us understand why the thing didn't work for you. (3) What's something you wish we had done? Think about specific assignments or activities that would have enhanced your experience that you'd like us to do in the future. (4) What else would you like us to know?

The instructors always acknowledged the feedback in class after receiving it and explained whether and how the input would be used. Some responses to these four questions informed the shaping of the course almost immediately. For example, the instructors introduced more variation in the size of discussion groups from day to day because some students asked for more large groups and some asked for more small groups. In other cases, student feedback was not actionable (or the instructors didn’t choose to act) in the short term, and the instructors informed the class that some version of their ideas would be incorporated into the next iteration of the course in spring 2020: for example, some students found certain one-off sessions led by guest instructors to be engaging but not clearly related to the rest of the course content, so cohesion across all sessions was prioritized for 2020.

As discussed previously, students had an additional opportunity to suggest changes to the course and to the broader GCSP through one of the course projects that asked them to submit a proposal for a new course element or a new GCSP element. These ideas received peer feedback from other students in the class, and critical feedback from both instructors prior to the final submission. A key change made based on a student submission was restructuring a small class project into a set of assignments and class discussions early in the semester, followed by a newly designed ramp-up to the PVM project (which appears to be working well in 2020).

Preparation for the second version of Change the World began in fall 2019 with a thorough review of the feedback and observations collected during spring 2019. The instructors used this input to guide iterative revision of the course. Feedback was solicited from the student steering committee as part of this iterative process, and feedback is being gathered once again from students enrolled in the course to continue informing a cycle of constant improvement.

Lessons Learned and Next Steps

As mentioned above, version two of the Change the World course is taking place in spring 2020. To better understand the larger outcomes of the course and of Olin's GCSP program, an educational research study is being launched to investigate the impact of the program on current and past Olin students. Data collection and analysis of student experiences and learning outcomes have not formally begun. But even at this early, "work in progress" stage, the instructors have made a number of observations regarding the "cost" (defined broadly), impact, and effectiveness of both the course itself as well as the co-design process used to plan and revise the course. Our early observations are consistent with results observed in education research literature and incorporate student feedback received.

The use of student feedback during the course proved extremely valuable even though the use of feedback requires significant time and effort. Students are more inclined to offer thoughtfully considered feedback when they believe it is being used in a constructive manner, which requires some form of instructor acknowledgement and response to the feedback even when it will not all be acted upon. Student feedback can be confusing, contradictory, and unpredictable, further requiring instructor effort to make sense of it, perhaps through clarifying follow up questions or a class discussion. In spite of this time commitment, there is no doubt that student feedback had a significant positive impact on the course. The instructors determined that students respond best to requests for feedback when the request is made in a focused and actionable manner that also offers a more open-ended opportunity for broader commentary. Interestingly, even though student feedback was primarily solicited with the goal of improving the implementation of the course, we believe, in line with Bovill [21], that students appreciated the opportunity to weigh in on their learning experience, and they appear to have benefited from the feedback process through increased investment in the course and perhaps a heightened awareness of what was most effective in terms of their own learning: comments from students included "thank you for your constant encouragement, your positive energy, your obvious respect in our feedback," and "The clarity in timelines and responsiveness to feedback has been great."

In addition to in-class feedback, the course also profoundly benefited from the inclusion of students in the co-design and planning process. Whether the students were taking the course or were on the steering committee, they brought a valuable perspective to course planning and helped the instructors anticipate issues, consider different options, and test certain assumptions, assignments, or messages in advance. For example, student input helped create clarity in how course and assignment objectives were communicated, so those in the course could better understand the reasons behind and connections between their assignments and activities. If the goal is to support student learning, hearing directly from students about what helped, in addition

to observing what was most successful, is critical to create an experience that will best meet student needs. The instructors feel that the time they devoted to the co-design process was well spent, an upfront investment that greatly improved the course and saved time (and avoided problems) later.

This course also illustrated the benefits of interdisciplinary courses, a topic that has received recent attention from the National Academies [22] and the Association of American Colleges and Universities (e.g., [23]-[25]). Interdisciplinary integration is a complex, time-consuming pedagogical approach that requires careful planning and the willingness of instructors to stretch their disciplinary comfort zones. Students in Change the World required extra time and careful support to navigate such a learning environment because the course concepts, activities in and out of class, and even the learning goals and metrics of success crossed disciplinary and pedagogical boundaries and defied many of their prior expectations. After moving past the uncertainty and unfamiliarity of the integrated approach, students frequently realized they were able to bring a wide array of their existing skills and attitudes into the integrated course, often with valuable outcomes. The interdisciplinary approach allowed the class to explore complex real-world problems that could never fit into the space of a single discipline (for example, discussions of organizational approaches to address global climate issues, or in-depth studies of challenges facing different regions of the world), and also allowed students to consider new applications for skills and concepts they learned earlier. Instructor collaboration through co-teaching also leads to professional development for faculty: in this case, Dr. Wood had a valuable opportunity to learn from Dr. Martello's experience and skill in leading a humanities-based discussion class.

Finally, we observed in student feedback during and after the semester that the "change the world" framing of the learning objective was highly valued by most students. As noted previously, students expressed great appreciation for the way this class opened a space for personal reflection and ethically-focused conversations on larger contextual issues than typically arose in technical courses (from a student: "Discussions!!! holy guacamole they're great"), and the stresses and complications of 21st century society made them almost desperately aware of their need to process the rapid changes taking place in our world, and how they wanted to engage with these changes professionally and personally. Students reported the continuation of class conversations with a broader circle of friends outside of the course, and some of the public presentations of student work attracted a wide range of community members who were also excited to see this type of thinking developed on the campus.

Next steps for this course, and for Olin's broader GCSP program, will largely follow two paths. The instructors are continuing to gather student feedback throughout version two of the Change the World course to aid in its continuing improvement, and the next phase of this discussion will

involve faculty members apart from the teaching team who are interested in supporting GCSP. The instructors will consider alterations to the design of the course, specifically looking at reactions to changes made to certain projects and classroom activities in response to the feedback from version one, but also reconsidering the broader learning objectives and methods used to achieve them. In addition, because of the pandemic of 2020, additional structural and content changes are currently being piloted in an effort to best serve students given the challenging learning circumstances and the new context in which they are exploring their identities, values, and roles in their larger communities.

The instructors also plan to initiate more intensive research regarding GCSP outcomes later this year. A concerted data gathering effort will draw upon feedback from the course but also from surveys that will be administered to a broad range of students and alumni, including students who did not take the course or participate in the GCSP program, as well as students who graduated many years earlier. The research project will attempt to determine whether the GCSP learning outcomes were achieved during students' time at Olin or after graduation, and whether a significant correlation exists between particular course aspects and the desired outcomes.

We hope to use lessons learned from both the Change the World course and the co-design process that shaped it to inform and inspire others who hope to revise their technical courses and include interdisciplinary content and activities. Although the specific form of change efforts must fundamentally depend upon the goals and context at each institution, our experiences to date have convinced us of the profound benefits that result when instructors work alongside students draw upon liberal arts skills to empower engineering undergraduates and galvanize them to take value-driven actions in their lives and careers.

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