Designing a new holistic engineering program

Dr. Julia D Thompson, University of San Francisco

Julia Thompson is an Assistant Professor at University of San Francisco. She has a passion for integrating the soul's work into the engineering design process and technology. She is driven to help students, and people in general, look at technology as a pathway toward healing of earth and unjust social structure. Julia did her undergrad in chemical engineering at UC Berkeley and her PhD in engineering education at Purdue. Her research interests focus on how engineering design practices impact the relationships that engineering programs create with the community.

Dr. Amalia Kokkinaki, University of San Francisco

Dr. Kokkinaki is an Assistant Professor at the University of San Francisco, teaching in the Departments of Environmental Science and Engineering. Her research focuses in the areas of groundwater transport and remediation, environmental modeling and statistical methods for environmental monitoring and characterization. She teaches Environmental Chemistry, Environmental Data Analysis and environmental engineering courses.

Jes Parker, University of California, Berkeley
Hana M Böttger, University of San Francisco

Hana Böttger's interests lie at the intersection of structural materials engineering and architecture, and she created and has been directing the Architectural Engineering minor program within the Department of Art + Architecture at University of San Francisco. She joined the new Engineering program curriculum development efforts in 2015, became interim director in 2018, and is the first chairperson of the department.

Böttger has been a teacher for 20+ years. In her architecture and engineering courses at USF, she emphasizes low-carbon, environmentally sustainable approaches to designing for the built environment, and especially the effect of these decisions on under-served communities. She doesn't separate good design from seeking social justice.

Dr. N. Jeremy Kasdin, University of San Francisco

3rd Annual Conference of CoNECD

Collaborative Network for Engineering and Computing Diversity

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Designing a Holistic Engineering Program

Integrating diversity, inclusivity and equity through asset-based pedagogy, ongoing community-engagement experiences, and project-based learning

University of San Francisco
Department of Engineering

Julia D. Thompson
Amalia Kokkinaki
Jes Parker
Hana Böttger
Chris Brooks
N. Jeremy Kasdin

Goals: a USF education will…

- Educate future engineers within a **Jesuit liberal arts** tradition – to be problem-solvers for others
- **Value diverse perspectives** and actively recruit a diverse student body, faculty, and staff
- Provide **innovative, interdisciplinary, project-based** learning
- Build upon connections with the **industry and innovation of the San Francisco**

Program Educational Objectives

What kind of person is the graduate of your program? What are they able to do within 3-5 years after graduating?

- Demonstrate fluency with **design thinking, systems thinking, creative problem solving, and self-directed scholarship** as modes of approaching the engineering process.
- Implement a holistic approach to engineering which **values context, integrates multiple perspectives** through collaborative teamwork**, questions need, and considers impacts** on both individuals and society at large.
- **Lead responsibly** through a fusion of engineering **judgement, practice, and entrepreneurship**, while representing the engineer's critical role in projects, organizations, the environment, and society.
- Exhibit a professional and personal identity which upholds **values of social justice, environmental sustainability, and respectful service even under unknown and challenging conditions**.

The first cohort

We are proud of USF's commitment to diversity, and planned for this to be a cornerstone of our program.

USF is one of the most ethnically diverse schools in the nation.

We have a great deal to offer to the tech, design and engineering world.

Demographics of our first cohort:
30 students in total

15 men
14 women
1 non-binary

30% Hispanic
13.3% Black
20% Asian
13.3% two or more races
23.3% White

Admission Criteria

- Three years of high school math - to highest level offered at the school
- Three years of science, two of them with labs
- Passion activities
- Community engagement activities

First two years (cohort together):

- **Summer Zero** special program – all students for 6 weeks together on campus
- Engineering projects from Day 1
- Foundational math and science courses
- **Project courses** in spring – real projects with community partners
- International or domestic **immersion** in first or second summer

Environmental Engineering concentration

Sustainable Built Environments Engineering concentration

Electrical and Computer Engineering concentration

- Project courses are still together with cohort
- Liberal Arts core courses can be together
- Capstone project in final year together
- Professional practice & internships

Curriculum:

4 years

The Department of Engineering offers a single undergraduate program:

Bachelor of Science in Engineering

Students must select one of three concentration areas:

- Environmental Engineering
- Sustainable Built Environments
- Electrical & Computer Engineering

Most students additionally have room to pursue a minor program or electives in another field.

Curriculum: special features

In order to promote the success and persistence of traditionally underrepresented students, our curriculum is heavily based on pedagogical techniques shown to increase their engagement.

- Asset Based Learning
  - Provide opportunities for students to articulate the assets they arrive with, and embed the use of those assets in the lessons of engineering design

- Community Engagement
  - Students work with communities throughout the curriculum, integrating engineering skills within the complexities of communities.

- Project-Based Learning
  - Immediate application of new skills in foundational courses, as well as the series of project courses through the curriculum, in order to provide hands-on experience, inclusive of diverse learning styles and forms of deliverables.

Special features examples

In order to promote the success and persistence of traditionally underrepresented students, our curriculum is heavily based on pedagogical techniques shown to increase their engagement.

- Provost of Diversity and Inclusion
- Professional Development Opportunities for Faculty
- Class Projects
  - Co-designing games with elementary students
  - Water balance of organic farm
  - Projects Integrated with Physics Labs
- Personal Reflections to integrate life outside of engineering to work within engineering

Summer Zero

Summer Zero is a six-week summer program that prepares students for life as an engineering student and helps them transition successfully to college.

- Students learn their individual talents and assets
- Classes in Math, Programming, Writing
- Students engage in a summer long engineering project
- Field trips to local industry and laboratories
- Workshops on succeeding in college and navigating USF
- Social events and trips around the area
- Free time!

Summer Zero: effects & conclusions

Highly encouraging results were observed

- Students reported a significant increase in confidence in their writing, programming and math skills,
- 7 (of 14) students from precalculus to calculus I at the start of the fall semester.
- Students expressed a sense of inclusion and community:
    - "Summer Zero confirmed to me that I am ready and deserve to be in the engineering program. I felt like I would be at the bottom of the class before but now I feel ready."
    - "It's braced me for what is ahead and helped fill the silence and loneliness that the latter half of this year has thrown at me."
    - "Summer Zero has helped me to be more confident starting out my first semester in college."

Innovation Hive

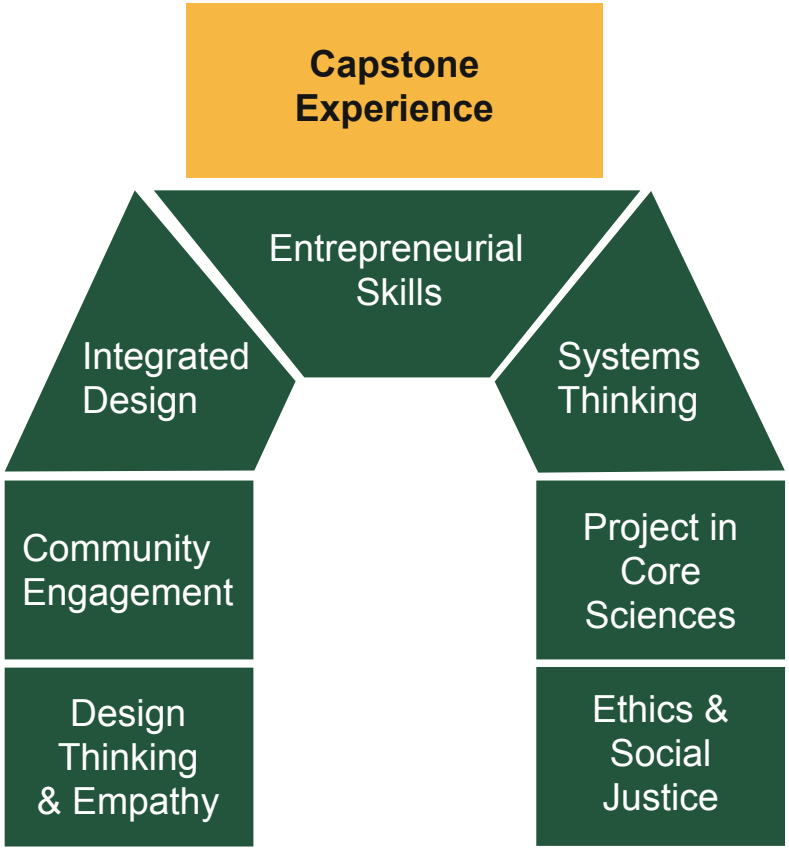
A university-wide initiative to increase collaboration, interdisciplinary work, and entrepreneurship on the USF campus.

Innovation Hive

Classroom, Student, and Engagement Spaces

- Space for engagement between USF and industry/community partners
- Open 24/7
- Bookable for seminars and classes, study, clubs, mentoring, tutoring and work space in evenings and weekends
- Host courses to provide tech skills for other programs from the rest of campus
- Host guest lectures, workshops, and events

Project Arch



Capstone

Year 4- year long investigation of a personal, community, or industry design or research project

Project & Design 3

Year 3- Taking engineering solutions to market

Project & Design 2

Year 2- Integration of technical knowledge into design for Communities (e.g. sensors for wetlands)

Immersion

Summer 1- Cultural Immersion with a community

Project & Design 1

Year 1- Social Justice, Environmental Sustainability, Conceptual Design, Community Engagement

Summer Zero

Summer 0- Design thinking, Empathy & Design, Team Work, Personal Identity as an Engineer

Project & Design 1

- **Engineering Problems -** What should engineers be working on?
- **Conceptual Design –** How do we create conceptual designs solutions?
- **Community Engagement Strategy –** What strategies and skills can we develop to work with communities?

Engineering Outreach Immersion

In the first or second summer, all students will be encouraged to attend a summer immersion course immediately following the spring semester. This course meets two of the university's graduation requirements - Cultural Diversity, and Community-Engaged Learning, as well as earning students a certificate in the principles of Permaculture.

- umbrella theme of permaculture - how to consider ecological, cultural and social factors when undertaking an engineering design process.
- hands-on project together with community members
- lessons and activities to learn about a place & its culture
- bonding experience reinforces greater mission of program


HAPPY FIRST WEEK OF CLASS
ENGINEERING CLASS OF 2024

Designing a Holistic Engineering Program

Below is an overview of the presentation, Designing a Holistic Engineering Program. This will be presented at the CoNECD conference in January 2021.

Slide 1 Cover slide

Welcome

Slide 2 Title of the talk

In Fall 2020, the University of San Francisco launched a new undergraduate Engineering program with a General Engineering major, designed to integrate access, inclusion, and diversity, with specific emphasis on the representation of women and students from underrepresented populations. To do this, the programmatic structure emphasizes asset-based pedagogy, ongoing community engagement, and project-based learning throughout the undergraduate experience.

In this presentation, we will review the curriculum and overall goals of the program.

Slide 3 Goals

Through the development of the program, and the specific courses, we have been guided by four goals:

1. To provide a Jesuit Liberal Arts Education, which is rooted in social justice and seeks to care for the mind, body, and spirit of each community member.
2. To value diverse perspectives - students, faculty, administrators, advisory board members, and guest speakers.
3. To create innovative, interdisciplinary, and project based learning environments throughout the curriculum
4. To prepare students with engineering practice, by building upon connections with industry professionals of our local community.

Program structure was created with an explicit commitment to evidence-based approaches in pedagogical research and the personal experiences of successful engineers from underrepresented backgrounds. In researching best practices, we research reports such as AAUW Solving the Equation (Corbett & Hill, 2015) and the NAE's The Engineer of 2020 (National Academy of Engineering, 2004). We also held workshops with women and people of color who hold senior leadership and engineering positions. Questions focused on identifying what drew them to engineering and what was essential in helping them to persist and succeed. Faculty also

attended a week-long workshop at Olin College aimed to promote project-based learning and transformative engineering education

Key themes that emerged from these experiences included: the importance of mentoring and engineering community development, both during and after graduation; the role of interdisciplinary education in engineering problems; and the value of diverse ways of learning and doing. These became guiding factors of program development.

Slide 4 Program Objectives

Our long term-vision, what we want the engineers to be like 3 to 5 years after graduation, bridges our university mission and the ABET student outcomes of the engineering program. These include:

- Demonstrate fluency with design thinking, systems thinking, creative problem solving, and self-directed scholarship as modes of approaching the engineering process.
- Implement a holistic approach to engineering which values context, integrates multiple perspectives through collaborative teamwork, questions needed, and considers impacts on both individuals and society at large.
- Lead responsibly through a fusion of engineering judgement, practice, and entrepreneurship, while representing the engineer's critical role in projects, organizations, the environment, and society.
- Exhibit a professional and personal identity which upholds values of social justice, environmental sustainability, and respectful service even under unknown and challenging conditions.

Guided by these principles, we set out to recruit a diverse first cohort that would contribute different assets, perspectives and priorities that will be instrumental as we implement and improve our curriculum in the coming years.

Slide 5 First Cohort

Our initial class includes 30 students. 14 women, 15 men, and one non-binary indiviudual. In terms of ethnicity and race, the students identify as 30% Hispanic, 13.3% Black, 20% Asian, 13.3% mixed-race, and 23.3% white, with all reported underrepresented minorities significantly above the national averages.

Recruiting materials for the first year were developed to showcase our commitment to inclusivity; the promotional imagery centrally features students of color and non-binary students. In our outreach, we emphasized that community engagement opportunities and consistent

project-based learning have been incorporated in the curriculum in order to create a more human-oriented engineering foundation.

Slide 6 Admission Criteria

Admission criteria were designed to ensure that the program is accessible to a wide range of students, while also ensuring that students can complete an accredited engineering curriculum within four years. While we require three years of math and science, the program design allows students to enter with precalculus and catch up in their mathematical skills while making progress towards their degree. In addition, by maintaining a cohort model for the first two years and only asking students to choose a concentration at the end of their second year, we can accept transfer students coming after one year.

Slide 7 Curriculum

Now we will dive into a bit of the nuts and bolts of the program. In terms of curriculum -for the first two years, the cohort is together. Key features include:

- Summer Zero special program – all students for 6 weeks together on campus
- Engineering projects from Day 1
- Foundational math and science courses
- Project courses in spring (all required) – real projects with community partners
- International or domestic immersion in first or second summer

We will go into specific elements of this experience in the next few slides.

All the concentrations are classified as General Engineering majors. After the first two years, students will choose one of three concentrations: environmental engineering, sustainable built environments engineering, or electrical and computer engineering. These concentrations build on the expertise and resources that already exist on campus.

Each year, the entire cohort will take an interdisciplinary project course that integrates the content that students are learning that year, and builds necessary skills in project management, communication skills, working in teams and working with communities or other stakeholders. Additionally, we have planned the curriculum for students to be able to travel abroad during the Fall of their Junior year, to work with communities in different cultures and settings, and expand their perspectives in engineering challenges in these different settings. We fully expect and assist students in the process of finding internships and part time positions at local companies and startups in their respective fields

Slide 8 Curriculum- Special Features

To further meet our goals of diversity, inclusivity, socially aware and empathetic engineers, we have committed to asset-based learning, community engagement and project-based learning. We are guided by these principles throughout the curriculum, from in class activities (including core sciences) and assignments to faculty professional development and assessment.

Slide 9 Special Features Examples

We have a few examples to illustrate the actions we have taken within curricular and professional development.

In terms of equity and inclusion, we invited the vice provost of diversity and inclusion to conduct a workshop with the students on microaggressions in summer zero. Additionally, within the first year project course, we held conversations of saviorism and had regular reflection assignments for them to integrate how topics of equity are important within their work as engineers and how they can regularly engage and reflect on equity within their work.

As faculty members, we take regular professional development opportunities to create a more inclusive space. Currently, the first author is exploring ways to integrate an anti-racist grading approach in the first year project course, with a faculty learning community on campus. The antiracist grading process, originally designed for writing, recognizes the different backgrounds of students and allows grading on completion and self-guided work.

The project courses are partnering with local afterschool programs, an organic farm, and a local native community to design projects in the first two years. In the afterschool program, university students will co-design games with elementary students. At the farm, the farm managers have asked us to explore the water balance - while students design water sensors and model the water system. This provides opportunities for students to do real-world projects, while also learning about social and environmental justice.

In our physics for engineers course, students have a combination of traditional labs and multi-week projects. During covid, all the students are given boxes with items to conduct the labs and projects. In the final 3 week project - students worked in groups to design 10 minute physics activities based on a concept introduced in lecture. Each group is given a different concept. Students wrote up the procedure for an activity, created a user survey, ran a user test with other students, updated their procedure, retested, updated their procedure again, and submitted their final documentation and report. The project activity was co-designed with faculty members in rhetoric and engineering. In this process, students get deeper familiarity with physics concepts, learn technical writing, experience user-testing as the designer and user - directly linking physics concepts to engineering design and testing.

Slide 10 Summer Zero

To ensure students have a smooth transition from high school to their engineering education, we have created Summer Zero. Summer Zero is a six-week summer program that prepares students for life as an engineering student, and helps them transition successfully to college. In summer zero, students engage in math, programming, writing and project classes. The program is led by key faculty members from engineering and related departments who teach the courses and serve as mentors. Activities are designed to help students understand each other's individual talents and assets, and prepare for success as they enter the program. They take math, programming and writing courses, and participate in an overarching design project with local community partners.

The entire incoming cohort is expected to attend Summer Zero, however, it is not required. Coursework is supplemented by workshops with a focus on community building, campus resources, and an introduction to the engineering profession. All program costs, including the courses, housing and meals on campus, are covered.

Slide 11 Summer Zero: Effects & Conclusion

For its first offering in 2020, the original Summer Zero program design was adjusted to a 4-week synchronously delivered remote version due to the pandemic - 3 weeks of course instruction followed by a week of workshops. Despite this change, a number of highly encouraging results were observed students. Students reported a significant increase in confidence in their writing, programming and math skills, resulting in the re-placement of 7 (of 14) students from precalculus to calculus I at the start of the fall semester. Additionally, students expressed feelings in connection within engineering.

Slide 12 Innovation Hive - Making Community

From the moment students begin their journey in Summer Zero, and through their four years, students can take advantage of our Innovation Hive to design, build and test their creations. The Innovation Hive is a hands-on learning space that is hosted by the Engineering Program and central to the project-based curriculum, while remaining open to any member of the university community.

Main objectives of the space include:

- Flexible, multipurpose space for students, faculty
- Set up for rapid brainstorming
- House computers, 3D printers, CNC routers, digital etchers, electronics benches, etc. for quickly fabricating prototypes and small devices
- Larger machining: lathe, drill press, table saw, etc.
- Testing equipment such as universal testing machine

Slide 13 Innovation Hive - Physical Space

The design process for the Innovation Hive included focus groups with student leaders recommended to program staff by the USF Office of Student Disability Services. Student focus groups discussed equipment use and space layout to consider the range of abilities represented by students on campus.

Features of the physical space include:

- Space for engagement between USF and industry/community partners
- Open 24/7
- Bookable for seminars and classes, study, clubs, mentoring, tutoring and work space in evenings and weekends
- Host courses to provide tech skills for other programs from the rest of campus
- Host guest lectures, workshops, and events

Slide 14 Project Arch

All engineering students are required to go through the project arch- a metaphor for the pathway into engineering. These are a series of required courses, consisting aimed at giving students an overall understanding of engineering technical foundations, integrated in socially relevant contexts.

The foundation of this arch education is ethical and social justice. The core science and math courses sit on top of this foundation, while also integrating project based experiences. In the third and fourth year, students are using the foundation concepts and applying to real world contexts. The Final capstone project is designed to be held and use all the course concepts, as students work with community and industry partners and work on real-world applications.

Slide 15 Project & Design I

An example of a foundational course in the project arch, is project and design 1. In the first section of the course, students:

- learn the history on engineering and technology- including who has historically made engineering decisions and who has been benefiting from engineering
- engage in readings and conversations about engineering and colonialism and saviorism.
- analyze, critique, and present on various engineering organisations and associated goals- such as engineers without borders and UN sustainability goals

In the second Section, students:

- identify problems they want to work towards,
- learn empathetic interviewing techniques

- interview potential users and experts
- create conceptual designs (not necessarily technological base)
- present on designs

In the final section, students

- identify personal values to guide their work as engineers
- write personal philosophies of engaging with communities.

Slide 16 Engineering Outreach and Immersion

All the project-based hands-on learning that the students experience through the project and design 1 course, connects and leads to a summer immersion course. This course is currently not required, but is highly encouraged.

Engineering Outreach Immersion provides an opportunity for students to engage in real-world design, planning and building projects with an underserved community, where collaborative design and innovation in technology and implementation are required to best serve the needs of the partnering community. Planned for 2 or 3 weeks during the summer session, the course combines student acquisition of contextual and cultural literacy with technical practice in the form of community-engaged learning. While destinations and partners may change over successive offerings, the primary elements will remain constant: a distinct cultural context, a relatively underserved community partner, background lectures and readings to understand the region, culture or other factors, and direct engagement with members of the community in their context.

Slide 17 Concluding Remarks (Zoom picture)

So that is an overview of some of the steps we are taking. We would deeply appreciate thoughts and feedback.

References

Corbett, C., & Hill, C. (2015). Solving the Equation: The Variables for Women's Success in Engineering and Computing. American Association of University Women. 1111 Sixteenth Street NW, Washington, DC 20036.

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