2023

Centering Meaning-Filled Design Within Engineering Education: Recommendations On How To Integrate Interdisciplinary Architectural Design Charrettes, Community Engagement, Sustainability Principles, And Adapted Agile Methodologies Into A Student-Centered, Project-Based Engineering Program

David D GILLETTE
California Polytechnic State University San Luis Obispo, United States of America, ddgillet@calpoly.edu

Michael HAUNGS
California Polytechnic State University San Luis Obispo, United States of America, mhaungs@calpoly.edu

Thomas FOWLER
California Polytechnic State University San Luis Obispo, United States of America, tfowler@calpoly.edu

Centering Meaning-Filled Design Within Engineering Education:
Recommendations on how to integrate interdisciplinary architectural design charrettes, community engagement, sustainability principles, and adapted Agile methodologies into a student-centered, project-based engineering program

Authors:
Dr. David Gillette
Co-Director Liberal Arts and Engineering Studies
California Polytechnic State University, San Luis Obispo, California, USA

Dr. Michael Haungs
Co-Director Liberal Arts and Engineering Studies
California Polytechnic State University, San Luis Obispo, California, USA

Professor Thomas Fowler IV
Graduate Program Director, Architecture
California Polytechnic State University, San Luis Obispo, California, USA

Abstract (249 words):
The Liberal Arts and Engineering Studies program (LAES) is a hybrid engineering and humanities degree housed in both the engineering and liberal arts colleges. LAES requires the same required math and science courses of standard engineering degrees, adding upper-level concentrations split equally between advanced engineering and humanities courses.

LAES was designed for retaining and recruiting a diversity of students in engineering, and to address recent innovations in industrial practice, technology design, and community-centered education. Through fifteen years of trial and error, the LAES program has developed a set of meaning-filled design guidelines for project work, combining engineering and humanistic problem solving with sustainable environmental practice integrated throughout every aspect of design, production, and use. In partnership with many departments across campus, especially Cal Poly's architecture program, LAES has worked on many projects that exist within the complex economic, political, social, spatial, and cultural needs of local communities.

LAES projects in collaboration with architecture students, have ranged from community housing construction with re-purposed shipping containers, to re-designing pedestrian neighborhood corridors, to the use of narrative-driven STEM education modules with underserved middle school students, to the design of immersive-reality explorations of artificial coral ecologies off the coast of California.

In this paper, we review what we have learned from our project work, with a focus on student learning assessment, leadership training, working across disciplines, and teamwork management, demonstrating how those practical academic concerns interact with the instruction of our design principles. We conclude by offering practical

recommendations for how other programs may use some of our design guidelines and project ideas within their own curriculums.

1 INTRODUCTION

1.1 Section 1 University & Program Context

The Liberal Arts and Engineering Studies degree at the California Polytechnic State University (Cal Poly) in San Luis Obispo is a hybrid BS program combining the study of engineering with the study of the arts and humanities. The program encourages students to see engineering, the sciences, and humanistic study as interconnected and as equally necessary for solving our planet's most important problems. LAES has the same entrance requirements as the College of Engineering at Cal Poly, thus requiring a strong grounding in physics and math, as well as the same writing, communications, history, culture, ethics, and reasoning requirements of the most demanding degrees in the College of Liberal Arts.

Based on continual student input and faculty guidance, the LAES Program has developed a number of popular hybrid concentrations that intermix engineering and liberal arts to create specializations in the study of sound and electronics; theater arts and computer game design; psychology and computer system development; art and aesthetics with industrial design; environmental stewardship with power systems management; community development with project design principles; and computer programming with technical communications. The LAES degree allows students to combine the most challenging aspects of the Colleges of Engineering and Liberal Arts at Cal Poly, while creating a hybrid study program that prepares them for their chosen career.

The LAES curriculum allows students to participate in multi-disciplinary development teams that work on real-world national and international technology and culture projects. To foster high-level leadership and communication skills, LAES student projects are always run in collaboration with other Cal Poly majors from Engineering, Liberal Arts, Architecture, and the Sciences, while working one-one-one with our program's commercial clients and partners from California and overseas. To further prepare students for the global marketplace and provide them with intercultural communication skills, the program strongly encourages students to spend at least one quarter studying or working abroad (LAES provides credit and partial funding for these trips).

LAES graduates have been highly successful in obtaining technical, design, and management careers in companies such as Warner Brothers Studios, Disney, Sony Pictures, Tesla, Apple, DTS, Universal Studios, Microsoft, as well as a wide range of high-tech and creative design companies throughout the world. The LAES degree has also served as the foundation for alumni who are currently pursuing graduate studies in MA, MS and PhD programs in psychology, engineering, social sciences, education, law, and business management.

1.2 Section 2 **Addressing Loss of Engineering Students**

The LAES program began as an attempt to stem the flow of Cal Poly students leaving the engineering college mid-way through their studies. At the time, well over 30% of the students who entered engineering as freshmen were changing to majors in the colleges of business, liberal arts, or science and math. Many of these dissatisfied engineering students chose to leave Cal Poly altogether, seeking engineering degrees at institutions that were less restrictive or in some way allowed for more productive integration with coursework from other disciplines. Engineering students who did not have the resources to start again at another institution or who could not afford to spend an additional two to three years to complete a new degree at Cal Poly decided to stay in engineering, resulting in lower grades, and overall dissatisfaction with the institution.

After a year-long, multi-level university proposal review process, the pilot LAES program was fully adopted into the Cal Poly curriculum as a BA program in 2013. The program continued to expand its number of students, roughly doubling in size between 2013-2018 (from 25 to 80 students). In 2017, in response to persistent student requests and requests from the employers of LAES graduates, the program changed from a BA to a BS degree to more properly represent the extensive scientific and technical aspects of this hybrid degree.

The creation of the LAES program, more cross-program collaboration between engineering programs, and a related, open-structure revision to the General Engineering program have often been credited with greatly reducing this loss in Engineering students at Cal Poly. In this paper, we examine some of the key features of the LAES program's design that we believe are central to helping retain and improve the overall academic and professional success of good, interdisciplinary Engineering students, while also adding a more community-focused, principle-driven aspect to Engineering study and practice. The full history of the program's development, along with a discussion of the organizational and divisional differences that had to be overcome the creation of this kind of hybrid program between two different colleges, can be found in this article:

'When the hurly-burly's done, of battles lost and won: How a Hybrid Program of Study Emerged from the Toil & Trouble of Stirring Liberal Arts into an Engineering Cauldron at a Public Polytechnic," Engineering Studies, 2014.

1.3 Section 2 **Project-Based Learning Trial, Error, Assessment & Review**

During the first few years of the LAES program's trial run, all the faculty, administrators, and students connected to the program engaged in much trial and error to determine the most effective methods for bringing together students with diverse LAES academic concentrations to work complex projects that needed to produce a set of useful deliverables for real-world clients. At the same time, the LAES program was also experimenting with how to partner with other academic programs for short- and long-term engagements on the same project, with design and development work that often spanned many quarters.

Throughout this process the program conducted many informal and formal assessment processes that ranged from student consultations and surveys on group work management and grading, to end-of-process review of project deliverables with project clients and LAES program academic advisors, to examining how some end products fell short of expectations and where others met expectations and goals or greatly exceeded them. These assessments all resulted in action items that were then integrated back into the program the following year to serve as additional points for continuing, long-range review, revision, and implementation.

Over the last ten years, these ongoing assessment processes have informed continual changes (large and small) in the program's core course structures, the selection of each year's project partners, the effective management of student teamwork, and the continual refinement of the grading process. The yearly internal (Cal Poly and CSU) assessment processes were then reviewed and amplified further as the program moved from the trial-run phase to full program phase as a BA, then through a comprehensive series of external reviews, and yet one more program review for the conversion of the program into a BS degree.

These three additional external program reviews (trial-run, BA, BS) involved analysis of changes in student demographics, academic achievements, writing assessment based on randomly selected student senior project essays and documents, student and project client surveys, surveys of potential and actual student employers, alumni surveys, and continual consultation with LAES student leaders to help develop new study concentrations for the degree. The external program reviews were conducted by program directors and academic administrators from other engineering programs around the country including the Massachusetts Institute of Technology (MIT), the Colorado School of Mines, Rensselaer Polytechnic Institute (RPI), Union College, among others.

All the review and assessment processes commented on the program's successful integration of community and client-center projects, charrette-inspired iterative design, and structure for our projects, and the effective use of agile and scrum methodologies in the management of our project-based learning capstone courses and for project/client work. Additionally, over the last ten years of the program's existence, we have integrated a few basic environmental sustainability principles into every project we undertake and have developed program specific meaning-filled design principles. We will now briefly discuss how we put these methodologies and principles to use with three projects chosen from the beginning, middle and current state of the program.

One of our main sources for pedagogical inspiration comes from Schon's work, "Educating the Reflective Practitioner" (1987) in which he says:

"Designing, both in its narrower architectural sense and in the broader sense in which all professional practice is *design-like*, must be learned by doing. Though students may learn about designing from lectures or readings, there is a substantial component of

design competence—indeed at the heart of it—that they cannot learn in this way. A *design-like* practice is learnable but it is not teachable by classroom methods. And when students are helped to learn design, the interventions most useful to them are more like coaching than teaching—as in a reflective practicum."

Schon continues by noting that "…professional education should be centered on enhancing the practitioner's ability for "reflection-in- action"—that is, learning by doing and developing the ability for continued learning and problem solving throughout the professional's career. If knowledge in the professions is advanced through this process of reflective practice, successful education of students learning the profession should be centered around opportunities to solve real problems involving multiple approaches and to repeat the process of trial, critique, and reflection often." (Schon 1991)

2 METHODOLOGY

2.1 Section 1 Community & Client-centered Projects

Over the ten-year span of the LAES program, we have worked on well over forty different projects, large and small, some running only a few months, others running for many years. These projects are all quite different from each other, often with very different clients and deliverables. However, they all share the same organizational, design and implementation principles.

We have chosen three projects to use as examples in this paper, all of which have and additional shared element of collaboration with the architecture program students and faculty at Cal Poly. These projects also are all centered around community education and civic engagement.

The **HO:ME** project (Housing Opportunities Through Modular Environments; 2009-2010) was a LAES design and development project in collaboration with the Cal Poly Architecture program, and the Housing Authority of San Luis Obispo (SLO). The project worked to design and then have approved for development, a transitional housing facility for the city of San Luis Obispo, built from repurposed shipping container materials, to assist residents transitioning from an unhoused situation into community supported housing situations managed by the SLO housing authority.

The **Two-Towns** project (2015-2017) was a LAES design, development, and user-testing project in collaboration with the Cal Poly Architecture program and various civic and business organizations for the city of Sacramento. This project worked to design, develop, and then test the efficacy of various ways to encourage more public use of a large pedestrian passageway connecting an older commercial part of downtown Sacramento with a newer entertainment complex. The project eventually focused on the use of augmented reality systems to help visitors explore and better understand the artwork and historical displays installed throughout the length of the passageway, thereby also learning more about the history of the structures, land, and communities of California's capital.

The **Ocean Sight One** project (2022-Ongoing) is a LAES design, development, and public education project in collaboration with the Cal Poly Architecture and Music programs and a marine research center at the University of California Santa Barbara (UCSB). This project is developing new forms of immersive visual and aural presentation to take citizens of California into the vibrant artificial coral reefs that have developed at the base of the oil rigs off the coast of Santa Barbara. These rigs are soon due to be decommissioned and, in some fashion, removed. The marine life at their base constitutes some of the most healthy and robust coral environments in the world, environments that many people want to preserve and expand upon.

Ocean Sight One aims to educate the California public about the history of these oil rigs, the complexities of the decommissioning process, the state's connection to this process, the importance of maintaining healthy coral reefs, and the inter-connections between the natural elements of these reefs and the built environments of the rigs which were created for industrial use. The project will develop, test, and then present in various public formats immersive 3D cinematic experiences, mobile virtual-reality, and augmented-reality interactive games, all built from underwater 360 high-quality video and audio captured from deep ocean dives around one of the central Santa Barbara oil rigs engaged in this process.

2.2 Section 2 Charrette-inspired Iterative Design & Whole-Systems Thinking

The use of the term word Charette is said to originate from the École des Beaux Arts in Paris during the 19th century, in which instructors circulated a cart (a "Charrette") through the studio, collecting final drawings while students frantically put finishing touches on their work. The work was quickly critiqued, and the process began again building from the positive elements of the most recent critique. A variation of this charrette form of rapid iterative design has long been a key part of Architecture practice and education, but in the last twenty years charrettes have become a part of many design disciplines. We have adopted the use of charrettes to initiate the work on many of our projects in LAES, especially when those projects connect to the Architecture program.

The iterative design methods and compressed design/review/revision structure guides all our work in the LAES program. For example, in collaboration with the Architecture program, for the Two Towns project we used a series of design charrettes with students and local community to develop the visual, interactive, and rhetorical approaches we would take with our design work for the city of Sacramento. The charrette briefs distributed to student teams at the start of the charrette required that all the charrette's design iterations (in accordance with the federal building guidelines from the Americans with Disabilities Act—ADA) account for accessibility issues in their designs (designing for visitor differences with hearing and seeing abilities, height, wheelchair use, language, and age).

This design requirement to account for public accessibility has become a central requirement for all LAES projects, teaching students to empathize with how different people and communities will engage with the technologies and systems they create. In

their accounting for ADA guidelines in all their work, engineering students must also research, discus and resolve in their final design issues of inclusion, diversity, equity, ethics, psychology, and civic governance alongside their concerns for safety, efficiency, and effective use of materials.

We have found that this whole-systems form of thinking requires the LAES students to make active use of their studies in liberal arts as much as their study in engineering and the sciences. This inter-linkages of concepts between disciplines through hands-on practice and team-centered discussion, we believe forms the core educational purpose of our de-centered capstone courses in which students teach themselves as much (if not more than) the program and our faculty teach them. (Muscatine 2009)

2.3 Section 3 **Agile & Scrum Production Methodology**

Agile is a methodology for software development that emphasizes flexibility and collaboration between cross-functional teams. (Beck et all 2022) It emphasizes iterative development, continuous feedback, and adapting to changes as they arise. Scrum is a specific framework for implementing Agile principle and values in product development. (Sutherland 2015) It defines specific roles, events, and artifacts that help teams work together efficiently and effectively. It involves a series of sprints, lasting two weeks each in our courses, during which the team focuses on a particular set of features or functionality deemed most important to the customer to grow the working product increment in a way that maximizes the return on investment. At the end of each sprint, the team presents its completed and tested work to all stakeholders who collectively decide which work items to keep, change, or remove. This activity is called a Sprint Review.

Our students use Scrum to complete work for our collaborators. Scrum keeps the student teams communicating and working together effectively while remaining consistently focused on customer satisfaction. The testing requirement of the Sprint Review improves the quality of student deliverables while its live demonstration of working functionality component drives customer feedback and involvement. The scope of work completed, thoroughness of testing, presentation quality, and rate the stakeholders approve of work provide regular opportunities for individual and team learning assessment to guide our course grading.

2.4 Section 4 **Project Integration of Environmental Sustainability Principles**

Many of our projects in LAES are not lavishly funded, and often function with almost no funding at all. Therefore, from necessity, the program focuses on frugality and recycling. As a result, the program has adopted a cradle-to-grave-to-cradle principle for all project purchasing and equipment use. But we also require students to demonstrate how they have used the cradle-to-grave-to-cradle principle with their project designs and recommendations for future iterations of their project solutions.

The overall goal of focusing on continual re-use and re-creation with our project and design materials is to, whenever possible, divert our materials from becoming an

immediate addition to the waste stream of the community. This was demonstrated in the HO:ME project by the very nature of the materials we were proposing to be used for the city's housing project—shipping containers which have become a blight for many countries where they are discarded into vast waste dumps once they are deemed no longer viable for use in containerized shipping.

HO:ME project students worked with the city of San Luis Obispo, to convince the local community that these re-purposed containers of steel and wood could provide effective, aesthetically complimentary material for construction at a much lower cost than working with less sustainably sourced building materials. Two Towns project made use of existing artwork and informational materials in the passageway, and a connection with the smartphones of visitors to not only create newly expressive and interactive "materials" for the space, but also to educate visitors about the history of these artists who created the work (the Royal Chicano Airforce). These artists designed their work to function at two levels: one level had a hidden cultural history embedded within each mural which was accessible to those who knew of the artists intention and symbology prior to viewing, and a second level designed to teach all visitors about the agricultural practices and migrant labor communities connected to the city of Sacramento.

While the Ocean Sight One project is still in early process, the entire focus of the project is on large-scale sustainability issues that involve the preservation of robust marine environments that are intimately connected with the repurposing of industrial construction and drilling materials. The media aspects of the project also work to make extensive use of prior-gathered site images, sound recordings, and site data for presentation in a new format designed to instruct larger state audiences about the sustainability decisions the state will be making on their behalf in the coming years.

2.5 Section 5 Project & Program Integration of Meaning-Filled Design Principles

As a result of ten years of work with charrettes and agile, in conjunction with creating products and solutions for different clients and communities we have arrived at a set of design principles that we call meaning-filled design. We require all students to address these principles, in some substantial way, with every part of work on an Agile development team, with their collaborative work in a charrette process, and with the development of their individual senior projects.

These design principles evolved from the actual construction and implementation of our projects in actual public locations, through interaction with visitors, audience members, and other people in a community. Actual use, by humans, of our design decisions in human communities immediately **gives meaning** to our project deliverables, inventions, and overall solutions, with all the complexities (ethical, moral, symbolic, communicative) that come with this use-generated semiosis. Therefore, when working in community-centered contexts, our students can not only design for technological and mechanical efficiency and effectiveness but must also design for **human-centered meaning** that arises from use. We say their work is meaning-filled, in that they are aware that through public use, every aspect of what they create will be invested with meaning as it enters its use community, therefore it is meaning filled.

These meaning-filled principles, at one time or another, serve as the basis for nearly all our program review processes and are key points for discussion with senior students as they develop their senior project, capstone projects.

These design principles are:

1) **Build for and with community**, appreciating and integrating local symbols, signs, stories, and history into your work.
2) **Extend empathy** throughout design by understanding and accommodating difference.
3) **Encourage critique** through open collaboration and iterative participatory revision.
4) **Embrace complexity** while working toward simplicity.
5) **Establish trust and transparency** through extensive user testing and critical engagement.
6) **Be inclusive** in all discussions, designs, implementations, and public use.

A full discussion of these design principles and their application in our program would require a much longer paper to cover in depth. We introduce these principles here for consideration by other engineering programs that may be asked to become more community-focused and inclusive in their pedagogy but lack curricular methods to address these concerns within a more traditional engineering curriculum.

Instead of trying to address these issues by simply requiring engineering students to take a course in ethics, or community development from other disciplines, we recommend that choosing community-based projects as the center-pieces of problem solving and design within a project-based learning engineering course, can be a way to bring to the fore concerns for empathy, inclusion, diversity, difference and communication while at the same time putting to use standard engineering problem solving for the technological and mechanical aspects of the solution. (Sneider and Zhu 2020)

The three projects referenced above (HO:ME, Two Towns, Ocean Sight One), required engineering expertise and problem solving to be effective, but that engineering work could not stand separate from the equally compelling liberal arts concerns dealing effectively and fairly with community histories, needs, and interests.

3 RESULTS

3.1 Section 1 Adapting to Diverse Student Needs & Diverse Demographics

Diverse projects working with diverse communities provide a diverse collection of students many ways to personally connect with the work at hand and allows them to connect what they are producing as students and learners with their lived experiences from outside academia and their roles as citizens in a global community. We believe the program's focus on diversity in every aspect of design, instruction, and community engagement has made the program welcoming to students who may have otherwise felt

their full set of interests and lived experiences were not considered relevant within an otherwise more traditional, fundamentals-only engineering curriculum. (Lehr and Haungs 2015)

When surveyed over the years, by external program reviewers and through internal program assessments, current and recently graduated students comment on how the integration of engineering and humanities disciplines made them better communicators, collaborators, and more active members of their community. These findings were summarized, in one external program assessment (2012) by the lead reviewer from MIT who noted:

“Our site visit…made it clear that student retention at Cal Poly was one of the most admirable achievements of the LAES program. LAES currently serves as a “retention net” (as distinct from a “safety net”) in serving to retain some of the brightest, creative, self-driven and entrepreneurially minded students who were formerly enrolled in an engineering degree program at Cal Poly…it should be noted that the program contributes not only to the general problem of retention, but to the specific problem of retaining women, minorities, and socioeconomically disadvantaged (and as it turns out, privileged) students who feel overly constrained by a traditional engineering degree program…(surveyed students) reported a separate passion, for music, for computer graphics, for law, for global economic development—areas of study that maps onto the disciplinary mix generally found within the College of Liberal Arts.”

3.2 Section 2 Learning Assessment Using Agile Adapted to an Educational Setting

The events and artifacts defined by the Scrum framework provide natural points in production to integrate academic grading, specifically Sprint Reviews. This has two main advantages: grading efficiency and increased student engagement. The grading process is more efficient because there is no need to introduce extraneous artifacts such as quizzes, exams, or written reports. We use a grading rubric that measures the following criteria of a Sprint Review: scope of completed work, work items accepted, testing, demonstration, professionalism, individual review, and publishing materials. The use of Sprint Reviews not only provides a consistent method to incorporate stakeholder feedback it also provides consistent feedback to each student regarding course performance.

The Scrum framework also increases student engagement. At the beginning of each Sprint, each team is empowered to select the scope of work they will complete during the sprint. They make these choices considering the skillsets of the team, available resources, and stakeholder requirements. This gives them direct influence over their own learning assessment while providing real world services to community partners. Our use of Scrum fits naturally into any course that strives to focus on project-based learning, such as in a cornerstone, capstone, or senior project experience. Scrum seamlessly provides team management, a clear production schedule, customer feedback, and opportunities for academic assessment that is widely used in industry.

Summary

While building a hybrid engineering and liberal arts program like LAES might not be possible at other institutions due to structural, political, and disciplinary impediments (Vanasupa et all 2012), we believe that many of the design and instructional principles we have developed and refined over the years can be adopted in piecemeal to help diversify, strengthen, and positively amplify attempts to better connect engineering education with the communities of students and civic/commercial organizations that it serves.

REFERENCES

1) David Gillette, Michael Haungs, Elizabeth Lowham, “When the hurly-burly’s done, of battles lost and won: How a Hybrid Program of Study Emerged from the Toil & Trouble of Stirring Liberal Arts into an Engineering Cauldron at a Public Polytechnic.” Engineering Studies: Journal of the International Network for Engineering Studies (INES) Vol. 6, No. 2, (August 2014): 108-129.
2) Donald A. Schon, *Educating the Reflective Practitioner: Toward a New Design for Teaching and Learning in the Professions* (Jossey-Bass; 1st edition,1991).
3) Charles Muscatine, *Fixing College Education: A New Curriculum for the Twenty-first Century* (University of Virginia Press, 2009).
4) Beck K., Beedle M., van Bennekum, A. Cockburn, A., Cunningham, W., & Sutherland, J. Manifesto for Agile Software Development. Agile Alliance (2022).
5) Jeff Sutherland, *Scrum: The Art of Doing Twice the Work in Half the Time,* Random House Business, (2015).
6) Roel Sneider, Qin Zhu, “Connecting to the Heart: Teaching Value-Based Professional Ethics,” *Science and Engineering Ethics* v. 26 (2020):2235-2254.
7) Jane Lehr, Michael Haungs, “Liberal Studies in Engineering Programs -- Creating Space for Emergent & Individualized Pathways to Success for Women in Computing Disciplines", American Society for Engineering Education (ASEE) Annual Conference Presentation, Seattle Washington, June 14-18, (2015).
8) Linda Vanasupa, Kathryn McCormick, Carolyn Stefanco, Roberta Herter, Margo McDonald, “Challenges in Transdisciplinary, Integrated Projects: Reflections on the Case of Faculty Members’ Failure to Collaborate,” *Innovations in Higher Education*, V37 (2012): 1710-184.