Work in Progress: An Integrated Approach to Engineering Design Across the Curriculum

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Abstract

Meeting real world challenges requires engineers with diverse experiences and skills who can function effectively on multidisciplinary teams. Educators have long strived to prepare students by providing relevant experience in undergraduate engineering programs. Motivated by the increasing complexity of modern problems, as highlighted in documents like *The Engineer of 2020*, there has been a growing movement to develop engineering programs specifically designed with integrative and interdisciplinary approaches to engineering education. Owing to the relative newness of these types of programs, there are ongoing conversations on the best practices for developing curriculum that balances breadth and depth as well as overcoming logistical challenges of accreditation and determining where and how to administer such programs within an institution. Further, it is vital for the growing community of integrated engineering programs to evaluate if these programs meet the stated goals. In this work in progress manuscript, we describe the experience and lessons learned from developing and launching one such program, The Engineering Design Program at the University of Alabama at Birmingham. The program includes a Bachelor of Science in Engineering Design degree, which began in 2020 and was ABET accredited in 2025. A minor in Engineering Design and Innovation was added in 2023. To take full advantage of the dedicated engineering design faculty, the program also includes "Project Lab," a non-credit bearing course open to all engineering students where students work in teams to solve a client problem. Our aim is that this description of our work to date is helpful to other institutions that may be exploring starting an integrated engineering program, as well as continue to spur discussion on how best to evaluate the outcomes of these programs.

Tags

engineering design, innovation, integrated engineering, teaming pedagogy & leadership development, teaching curriculum & pedagogy

Integrated Engineering

Real world engineering challenges have long required multidisciplinary teams and approaches. In recent decades, technologies and the problems they address have continued to get more complex. As noted in reports such as *The Engineer of 2020*, educators and industry are actively exploring how to best prepare rising engineers for the modern world [1], [2]. While programs across all disciplines have continuously worked to iterate their curriculum to address these challenges, there has also been a growing movement to develop integrated engineering programs which are specifically designed around multidisciplinary or interdisciplinary approaches [3], [4]. Owing to the variety of names of these programs and recent growth, it is difficult to quantify the exact number of programs in this category. To estimate the prevalence of these programs, we used the ABET Accredited Programs Search Tool to identify the US programs accredited using the "Engineering, General Engineering, Engineering Physics, and Engineering Science" and

"General Criteria Only" criteria under the ABET Engineering Accreditation Commission (EAC) [5]. Based on the program names, we separated out programs with a specific focus such as energy engineering, mechatronics, or nanoengineering, and categorized the remaining programs as listed in Table 1.

The majority of programs found were named "engineering." We noted that within this category, the majority were from institutions that only offered a single ABET accredited BS in Engineering. These are typically smaller institutions without individual engineering departments dedicated to different majors. In all other categories, nearly all programs were from institutions with two or more or ABET accredited programs. Using 2004, the year *The Engineer of 2020* was published, as a dividing line, we note an increase in programs of all categories relative to the growth of ABET EAC accredited programs overall. This increase is especially apparent in General Engineering, Integrated or Inter-/Multidisciplinary Engineering, and Engineering Design by 2023. While not necessarily causal, the rise in the alternative programs correlates with this increased interest in preparing students for a more complex world.

Table 1: General Engineering Program Criteria Only ABET Accredited Bachelor's Degree Programs in the US

	2004	**2023**
Engineering, Single Program*	17	60
Engineering*	10	38
Engineering Physics	11	21
Engineering Science	7	11
General Engineering	0	6
Integrated, or Inter-/Multidisciplinary Engineering	1	9
Engineering Design	0	4
Total General Criteria Only	46	149
Total ABET EAC Accredited Programs in the US	1613	2520

Engineering, Single Program* refers to degree programs named "Engineering" at institutions that offer a single ABET Accredited Engineering Bachelor's Degree. Engineering* refers to degree programs named "Engineering" at institutions that offer two or more ABET Accredited Engineering Bachelor's Degree. Total ABET EAC Accredited Programs in the US is provided for reference. Data retrieved from [5], February 2026.

Further examining the curriculum of these diverse programs to determine if or how they integrate different fields and build multidisciplinary skills, is an interesting subject for future work, as is evaluating student outcomes. Given the relative newness and low numbers of these programs, our aim in sharing this work in progress is to contribute to the ongoing effort to explore best practices in developing curriculum, share lessons learned overcoming logistical challenges of accreditation and determining where and how to administer such programs within an institution, and prompt conversation on the best ways to evaluate the effectiveness of these programs.

Program Motivation

Across these programs there are different approaches to building a multidisciplinary skillset. One approach that many undergraduate programs take to integrate ideas either within or across a field

is design and design project-based coursework. The ability to apply engineering design principles to produce working solutions is a crucial student outcome for all engineering disciplines as evidenced by its inclusion an ABET required student outcome for all accredited undergraduate engineering programs [6]. Traditionally, these principles are primarily covered in a capstone design course in the final year of study. Along with teaching engineering design, capstone courses aim to integrate many of the concepts and components of the entire degree's curriculum, while in the process satisfying several other ABET required student outcomes. When executed well, these capstone experiences do indeed introduce design principles that allow students to hone technical skills in a more real-world based application [7]. However, consolidating such a breadth of material into a single 1- or 2-semester course may come at the expense of a deep understanding of design thinking [8]. Further, these major-specific capstone courses tend to have students from a single major, while in the professional world teams are likely to be interdisciplinary. Working on real world projects also often calls for non-technical skills such as teamwork, project management, and leadership, adding additional competencies to try to fit into a single capstone course. Motivated by the benefits that adding additional design-based coursework could provide to engineering students, as well as the inherent multidisciplinary nature of many of these types of projects, the University of Alabama at Birmingham (UAB) School of Engineering established a new, integrated engineering program with engineering design as the organizing theme.

Program Description

The Engineering Design Program at UAB offers a Bachelor of Science degree, a minor, and extracurricular programming. The Bachelor of Science in Engineering Design (BSED) degree was approved by the State Commission on Higher Education and The Board of Trustees of The University of Alabama System in February 2020 and launched the following Fall. The program earned ABET accreditation in 2025. The minor in Engineering Design and Innovation was approved by the State and UAB in 2022. The core of both the major and minor is a three-semester engineering design and innovation sequence: EGR 117 – Design Thinking, EGR 217 – Prototyping, and EGR 317 – Project Implementation (Table 2). Students in the major must also complete at least one minor in another engineering field and the two senior design courses related to their engineering minor, resulting in 5 total semesters of design centered project work. After EGR 117, all courses include a semester or year-long real-world client-provided projects. These clients, who are typically members of local companies, state agencies, not-for-profit organizations, or healthcare providers, provide teams with a problem description and meet several times each semester to offer feedback on the team's design iterations. Each course culminates in a final design and prototypes presentation to the project client, the class, and interested members of the community, often including faculty and advisory board members. In addition to repeated opportunities to design and test solutions to client problems, each course requires that students develop teamwork, problem-solving, critical thinking, client management, time management, and project management skills. The design courses also aim to motivate the development of strong research skills and the ability to analyze and evaluate information from an expert through integration of library resources and required meetings in collaboration with the UAB's STEM librarian.

Table 2: Summary of Core Engineering Design Course Content

Course	Summary of Content
EGR 117 - Design Thinking	Student teams apply a human-centered design process as they iterate a student ideated product over the semester. The project must be substantial and benefit people while balancing real-world constraints. Students are also introduced to the UAB STEM librarian, who familiarizes the students with key research resources available for their projects. Over the semester, students make three presentations of their project to the class where peers, faculty, and staff in attendance provide verbal and written feedback of strengths of the project/presentation and elements that need improvements from the perspective of a potential user and of an investor. Students must incorporate feedback along with ongoing research and prototyping towards developing a marketable product and strong project pitch at the end of the semester. Course learning includes hands-on exercises and challenges to develop teamwork, empathy, and prototyping skills. Through structured assignments, students learn teamwork, project management, research, and conflict resolution skills.
EGR 217 - Prototyping	Students learn a broad range of simple and advanced prototyping techniques to test their ideas and designs against user and client needs. The course relies heavily on The School of Engineering Design x Prototyping Lab, which is equipped with an array of 3D printers, laser cutters, a CNC mill, a waterjet cutter, microprocessor controllers and electronics components, as well a plentiful supply of cardboard, foamcore, popsicle sticks, tape, glue straws, and other items for early ideation and prototyping. A semester-long client-led project is the backbone of the course. Students learn to keep a detailed design notebook, prepare and deliver presentations and reports to constituents (peers, clients, users, faculty, industry, etc.). Midway through the semester, each nust schedule a consultation with the UAB STEM librarian to reinforce the use of reference materials related to engineering design and standards, prior art, regulatory requirements, and other information that directly impacts their design process. The team must also create advanced prototypes that demonstrate key design features document how this librarian-assisted research impacted their project design and evaluation.
EGR 317 - Project Implementation	The course is centered around a semester-long design project for a real-world client, which may be a continuation of a project started in EGR 217. EGR 317 includes four professional development modules: business tools, intellectual property management, engineering ethics and professionalism, and standards and risk assessment/risk management. Students learn to use basic project management tools (project charter, statement of work, work breakdown structure, Gantt chart, and business model canvas) to organize and clarify their design project. The intellectual property module culminates in a simulated patent application on an inventive concept for the semester project, presented to and reviewed by USPTO patent officers. Ethics, risk, and standards modules include case analyses and in-class discussions of topics relevant to their project. We again collaborate with UAB Libraries faculty to teach acceptable, ethical use of artificial intelligence as the learning mode for the ethics and professionalism module.

While the Engineering Design Program is centered around the BSED degree, the staffing and infrastructure of the program supports the Engineering Design and Innovation minor and Project Lab to benefit interested students outside of the degree by providing design-based curriculum and experiences to other engineers at varying levels of time-commitment. The 18-credit hour minor is designed to be accessible to both engineers and non-engineering students. In addition to the core engineering design competencies provided in the core 3-course sequence, the minor emphasizes the creative aspects of design by requiring three creativity and art studio courses. Options include courses in creativity and imagination, drawing, sculpting, and graphic design, among others. Allowing non-engineering students to complete the minor further creates interdisciplinary opportunities with students outside of the School of Engineering.

Independent of the major or minor, the Engineering Design Program also provides access to Project Lab, which all engineering students are eligible to participate in. In Project Lab, students join formalized teams to design a solution to a client-provided problem. The team is responsible for all aspects of project management, design, and fabrication. Though there is no required didactic component Project Lab, both engineering faculty and more senior students provide guidance in design thinking and other competencies covered in the core courses. With no prerequisites or other barriers to participation, any engineering student can join these design projects and thereby self-select opportunities to develop hands-on problem-solving skills as early as their first semester in the School of Engineering. Students have the option to complete Project Lab has as a credit bearing course, similar to undergraduate research or independent study programs for up to 3 semesters which are accepted for elective credit in the BSED curriculum as well as several other engineering degrees.

Program Details and Fulfillment of ABET Requirements

The BSED curriculum was designed to provide students with maximum flexibility to develop an engineering degree that aligns with their career interests and aspirations while still fulfilling the rigorous requirements of an ABET-accredited engineering degree. The program requires 128 semester hours of coursework which includes 21 hours of general education core courses, 34 hours of math and basic sciences (including calculus, differential equations, calculus-based physics, and general chemistry), and 53 hours of engineering coursework distributed as shown in Table 3. This leaves 18 hours to be used for elective courses either in or out of the chosen engineering minor. BSED students may choose an engineering minor from the list below. Of note, there are additional, more specialized engineering minor options in areas for which a major is not offered, such as neuroengineering, software engineering, environmental engineering, and engineering world health. This further supports the goal of flexibility to support students in personalizing their program to their unique needs. With this above-average level of elective credit flexibility, numerous BSED students have opted to earn a second minor on top of their engineering minor in areas such as business administration, physics, and art studio.

Table 3: Required Engineering Content in the Engineering Design Core

Engineering Fundamentals (23 hours)	Engineering Design and Innovation Breadth (15 hours)	Engineering Depth (Minor Options, 15+ hours)
Intro to Engineering	EGR 117 Design Thinking	Applied Mechanics
Computer Aided Graphics & Design	EGR 217 Prototyping	Biomedical Engineering
Computer Methods in Engineering (Programming)	EGR 317 Project Implementation	Civil Engineering
Statics	EGR 498 Senior Design I*	Electrical and Computer Engineering
Dynamics	EGR 499 Senior Design II*,§	Engineering World Health
Mechanics of Solids		Environmental Engineering
Engineering Materials		Materials Engineering
Electrical Systems		ME - Mechanical Systems
		ME - Thermal Systems
		Neuroengineering
		Software Engineering

* Engineering Design majors take either the BME, CE, ECE, ME, or MSE capstone design sequence. §Since Civil Engineering only offers a single-semester capstone design course, Engineering Design majors must complete one approved CE 4XX design elective in lieu of EGR 498.

BSED is a stand-along degree program not housed in any of UAB's five engineering departments. The BSED program leverages the existing engineering classes offered in the other engineering departments. With the exception of the three Engineering Design program-specific courses (EGR 117, EGR 217 and EGR 317), Engineering Design students take the required engineering fundamentals and engineering minor courses offered by faculty across engineering. In this manner, Engineering Design students are taught by discipline-specific domain experts and learn with peers in different majors. A significant benefit of this distributed model is that the Engineering Design program needs only a small number of faculty for program educational delivery and administration. Currently, the Director of Engineering Design and an Engineering Design Instructor can teach the four sections of the Engineering Design courses (EGR 117 fall & spring, EGR 217 fall and EGR 317 spring) and manage all aspects of program administration (academic and professional advising, advertising and outreach, recruiting). The Engineering Design program does not offer a separate capstone design sequence. Rather Engineering Design students take the capstone design course(s) in the department that most closely aligns with their engineering minor. A significant benefit of this distributed model of program administration and educational delivery is that the Engineering Design students are integrated into design teams with students from other majors in a capstone design course taught by faculty in Biomedical Engineering (BME), Electrical and Computer Engineering (ECE), Civil Engineering (CE), or Mechanical and Materials Engineering (ME/MSE). Of note, Materials and Mechanical Engineering (MME) is a joint department that teaches a combined capstone course for ME and MSE students. Thus, Engineering Design students are typically on a design team with students from at least one other major. Feedback from the capstone design instructors indicates that while all students contribute to the engineering design analysis and prototype development required to deliver an acceptable final engineering design, the Engineering Design students typically assume team leader and project manager roles.

Having engineering design students take the existing core engineering and the discipline-specific courses for their engineering minor allowed the development of an Engineering Design Program that meets ABET Program and General Engineering criteria with a Director of Engineering Design and an Engineering Design Instructor managing the program and teaching the three engineering design-specific courses. The flexible nature of the degree presented unique challenges to fulfilling all criteria and required outcomes. As outlined in Table 4, all criterion 3 outcomes are covered in the three core courses in the Engineering Design sequence (EGR 117, 217, and 317). Both EGR 117 and 217 have assignments explicitly created to ensure students meet the technical learning objectives to solve complex engineering problems by applying principles of engineering, science, and mathematics (outcome 1) and to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions (outcome 2). Further, when presented in 317, these assignments are provided as clear continuations and of the 217 version, allowing students to incorporate feedback, iterate, and improve on these skills.

As discussed, the Engineering Design program does not offer a separate capstone design sequence. Rather Engineering Design students enroll in the capstone design sequence of the department (BME, CE, EE, ME/MSE) most closely related to their engineering minor. This fulfills the Criterion 5d requirement of a culminating major engineering design experience.

While many of the Criterion 3 outcomes are covered in these capstone courses, the BSED curriculum does not rely on those courses for these outcomes. This allows for the instructors of those courses to choose the outcomes to focus on most appropriate for that discipline without adversely affecting the overall experience for BSED students or the ABET accreditation status.

Table 4: Mapping of ABET Criterion 3 Student Outcomes to BSED Courses

Required Engineering Courses / **Student Outcome**	1. Solve complex engineering problems	2. Apply engineering design	3. Communicate effectively	4. Ethical/professional responsibilities	5. Function effectively on a team	6. Experiments, data analysis, engineering	7. Acquire new knowledge
EGR 117 Engineering Design I: Design Thinking	X	XX	X		XX		X
EGR 217 Engineering Design II: Prototyping	XX	XX	XX		XX	XX	X
EGR 317 Engineering Design III: Project Implementation	XX	XX	XX	XX	XX	XX	XX
EGR 498 Capstone Design I	XX	X	X	X	X	X	X
EGR 499 Capstone Design II	XX	X	X	X	X	X	X

A marking of XX indicates that the Student Outcome is strongly addressed in the course and achievement of the student learning outcome is assessed in the indicated class, whereas a marking of X indicates the Student Outcome is reasonably addressed.

Outcomes and Discussion

Interdisciplinary Experiences

A goal of BSED program is to educate engineers to meet the needs of a rapidly changing world through an emphasis on engineering design principles and inter-/multidisciplinary experiences. Evaluating the success of outcomes related to providing interdisciplinary experiences is the subject of future work. We can however, at this stage in the life of the program, evaluate if the experiences are occurring. When BSED students proceed into the capstone design sequence of the department closely related to their engineering minor, they work on more discipline specific projects on a team with students from other majors (BME, CE, ECE, ME and/or MSE). Delivering interdisciplinary classes in this way is premised on the hypothesis that the BSED program will attract a diverse student population with respect to the minor they choose. As shown in Table 5, this has been generally successful. The plurality of students have selected the Mechanical Engineering - Mechanical Systems (ME-MS) or Materials Engineering (MSE) minor, but there is a robust distribution across other engineering minors. Of note, at UAB, the mechanical and materials engineering majors participate in a single combined two-semester capstone design sequence which allows for senior design teams with students from up to three different majors in the capstone course. Engineering Design students enter their senior design experience having previously completed three semester-long team design projects, two requiring that they work directly with an external client. Thus, the BSED students often have more advanced project management, team building, and leadership skills than students from other School of Engineering programs. In senior design, the BSED students must navigate partnership

with peers who may have deeper technical skills owing to their more traditional engineering education. Such experience better simulates real world professional settings wherein teams must balance technical, communication, and leadership skills between members to be successful. In future work, we plan to evaluate how this dynamic affects both the Engineering Design students, and those on the teams from the other majors.

Along with intermixing with other engineering majors during capstone, the core courses themselves are interdisciplinary by nature by virtue of BSED students choosing different engineering minors and the courses being open to non-BSED students. As students proceed through the curriculum, they take their core courses with students from a variety of other UAB programs who have different interests and have completed different discipline-specific coursework.

Table 5: Distribution of Minors in Engineering Fields by Year

Grad Year	Minor							Sum
	BME	CE	EE	ME-MS	MSE	NE	Software	
2023			1		1	1		3
2024			1	3	3			7
2025	1	1	1	2	3			8
2026	1	1		6		1	1	10
SUM	2	2	3	11	7	2	1	28

BME = Biomedical Engineering, CE = Civil Engineering, EE = Electrical Engineering, ME-MS = Mechanical Engineering – Mechanical Systems, MSE = Materials Engineering, NE = Neuroengineering, Software = Software Engineering

Additionally, 3 students have completed the minor, with 6 more currently enrolled, further intermixing students within the core courses. Over 100 students have participated in Project Lab since 2015 with nearly all teams having mixed majors and class levels. Additionally, we have made intentional efforts to expanding access to design education across UAB's curriculum by opening the design courses to other majors and getting University approval for EGR 117 to fulfill a University Core Curriculum requirement of "Communication in the Modern World." This has expanded the diversity of the EGR 117 classes with engineers and non-engineers collaborating on projects and learning design thinking together.

Experiential Learning, Employment

One objective of the program is that students either establish careers in engineering or other professional fields in which they apply their critical thinking and problem-solving skills, earn or be enrolled in a graduate or professional degree program, or both. At the time of writing, 21 of the 26 students (approximately 81%) from the BSED program's first 4 cohorts (including May 2026) have achieved this at graduation. The Engineering Design Program also strongly encourages experiential learning in the form of cooperative education, internships, honors research, professional society project competitions (ASME BAJA, AIAA Design, Build, Fly, ASCE 3D Printing Competition, SWE Toy Modification for Persons with Disabilities, IEEE

SoutheastCon Hardware Competition, and others) and faculty mentoring. In the first 4 cohorts of the BSED program, 19 of 26 students (approximately 73%) had at least one co-op, internship, or research experience before graduation.

Student Experience

Objective evaluation of the program will be the subject for ongoing and future work. However, we have completed exit interviews for most program graduates (21 of 26) during their final semester, from which we can derive insight on student experience and suggestions for improvement. Owing to the low numbers of participants at this stage and lack of a pre-established survey for these interviews, we present anecdotal observations from written records of these interviews. Moving forward with the program, we will establish a consistent questionnaire from which responses can be coded and analyzed more thoroughly.

Multiple students praised the level of hands-on learning they received through client-based projects, the emphasis on teamwork and leadership development, and the flexibility of the curriculum. Program graduates felt well prepared for careers in industry or graduate studies with many noting that the going through repeated design cycles made senior design feel manageable. Multiple students indicated that the skills developed in design thinking, problem solving, empathy, user-centered design, project management, and communication will benefit their career. In future work, we plan the evaluate both the perception and implementation of design thinking in BSED students over their curriculum and compared to traditional students, potentially by implementing established methods [9], [10].

Regarding technical proficiencies, students in interviews noted that they gained skills in areas of CAD, prototyping, coding, and simulation software. However, multiple students cited these technical areas as those needing deeper development. Potential suggestions from these students included building in more CAD certification programs and more detailed electronic design or coding courses. Several students also suggested that year-long (vs. semester long) design projects (in EGR 217 and EGR 317) could be more meaningful and successful. Students also expressed a desire for stronger connections between Engineering Design and their chosen minors. These suggestions are consistent with the challenges of multidisciplinary programs such as this which must balance breadth and depth. As we improve the program, we will aim address these suggestions through both curriculum updates and updates to how we advise students.

Conclusions and Future Work

As measured by accreditation and job placement, the launch and initial 6 years of the Engineering Design Program at UAB have been successful. Participation rates in experiential learning activities while in school (internships, co-ops, research etc.) as well as placement upon graduation are high. Exit interviews early in the program providelimited anecdotal data about student experience and their perspectives on the program. As we noted in the discussion, now that the program is proceeding into a phase of growth and continuous improvement, the next

focus will be to perform scholarly work to more objectively evaluate if the objectives are the program are being met. We have recently begun a collaboration with School of Education and Human Sciences to evaluate how each EGR 117 cohort develops design thinking skills. In this endeavor, we plan to use validated instruments to assess design thinking [11] to determine how well Engineering Design students understand engineering design principles, how this develops over the course of their time in the program, and how it compares to engineering students in other degree programs at the UAB. Finally, we have keen interest in understanding the experiences of BSED students in their capstone design teams with their peers from the other engineering programs offered within the School of Engineering. We intend to survey senior design students and instructors to collect information about their perception and experiences of BSED students in capstone and their peers in teams with and without BSED students. We will also compare the outcomes of senior design teams with and without a BSED student with a special interest in evaluating whether BSED students fill more leadership-, management-, or communication-oriented roles and whether that comes at the expense of gaining technical experience during the senior project.

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