Ten Years of Continuous Improvement: A Retrospective Case Study

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Background

In recent years, a number of small liberal arts institutions have expanded to include engineering degrees. As one such institution teaches its tenth incoming class, the faculty are taking a look back at major changes that have occurred.

Purpose

We are writing this paper as both a record of our evolution and as a unique case that may provide insight for similar institutions' developing engineering programs. This program evaluation takes a look at important components of our development over the first ten years of the School of Engineering. In taking a look back, we are providing a foundation for future growth as well.

Methodology

This is a program evaluation using a retrospective case study methodology for collecting and analyzing data. We did not intentionally collect this data but are using existing data along with first-person perspectives from the faculty authors who have been a part of the changes to develop an understanding of program components that evolved over the first decade of the School of Engineering. Major changes across the entire program have been selected for this report; additional discussions of specific components such as values education and the first-year experience are presented in additional publications at this conference [1, 2, 3].

In case study research, a variety of data sources are used to develop an understanding of a case, which is a situation or event of interest. In a retrospective case study, a significant event or situation has occurred that is worthy of analysis and the timeline of events is reconstructed after the events have occurred using a variety of supporting data [4]. Longitudinal data, including first-person accounts and historical data, are collected without premeditation and are used to develop an understanding of the significant event or situation. These data sources are used to create a detailed description of the case and can include descriptions of the case from the researchers, interviews of those involved in the case, demographic and other numerical data to describe the case, and content or artifacts related to the case. Further analysis of these data can be done, including thematic or content analysis of qualitative data and statistical analysis of quantitative data to support the overall description of the case [5].

Data included in this study are first-person perspectives of the faculty authors, documents from meetings, institutional data, artifacts, and social media and press releases. At two faculty meetings, faculty were asked what major changes they perceived across the ten years of engineering. Some of these, including changes in first-year programming, concentration-specific programming, and integration of values education, have been presented in their own separate publications. Of the topics considered consistent across the entire program, comments were grouped into overall themes, and these themes were assigned to faculty who took reviewed data and documents related to these major changes. Due to page limits, three major curricular changes were chosen for inclusion in this case study. Supporting quantitative data is provided with minimal analysis, such as presenting percentages, and no additional qualitative analysis beyond building data into a narrative description has been completed.

Limitations

This paper is a retrospective case study of a specific program. We do not claim that this is generalizable research. However, some of the lessons that we have learned may be beneficial for other institutions as they build or adapt their programs. There are many small liberal arts institutions that are expanding their offerings through STEM and engineering majors. These schools in particular may find that our evolution provides insight into their development as well.

Context

The School of Engineering is housed within a small, rural, religiously-affiliated, liberal arts institution in the shadow of a large state school known for its engineering programs. The institution decided to start a School of Engineering to better serve its local community, in particular first-generation rural students who did not have the academic preparation for the nearby state school or who preferred a more hands-on education closer to home. In starting this program, multiple factors were considered including local opportunities for employment, interest of potential students, and synergy between offerings. The original plan was for a single engineering degree with four concentrations: chemical engineering with a pharmaceutical focus to connect with the pharmaceutical program at the institution and the large number of local pharmaceutical companies; mechanical engineering with a manufacturing focus as a concentration likely to draw a the largest student population and support local manufacturing industries; electrical engineering to also draw a large number of students and support the local automated manufacturing industries; and civil engineering to support local community works.

Table 1. Timeline of major events

2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
ME ChE	Annex 1	EE	Annex 2	Pandemic		ABET accreditation	CC Update	EMS	

ME – Mechanical engineering concentration, ChE – Chemical engineering concentration, EE – electrical engineering concentration, EMS – electromechanical systems engineering concentration, CC Update – community college transfer improvement

In the first year, both mechanical and chemical concentrations were offered. Two years later, the electrical engineering concentration began. The civil concentration has not yet been offered. The pandemic and smaller entering classes of students have caused the delay, making it unreasonable to hire additional faculty or purchase any additional lab equipment thus far. Instead, due in part to the continued rise of automated manufacturing and student interest in a combined electrical and mechanical degree program, an electromechanical systems concentration began in the seventh year of the program. This concentration combined classes from the two existing concentrations (electrical and mechanical) and added one new class. Interest and enrollment in this concentration has been high, allowing for a potential increase in student body with minimal institutional investment. Student enrollment is shown in Table 1 as percentages; actual values are not given to protect student anonymity given the small size of the institution as a whole and School of Engineering.

Table 2. Total engineering student population

	% in Engineering				% of Institution				
Year	ChE	ME	EE	EMS	ChE	ME	EE	EMS	All Engineering
1	16	84	-	-	0.3	1.6	-	-	2.0
2	17	83	-	-	0.5	2.2	-	-	2.6
3	16	75	9	-	0.6	3.0	0.4	-	3.9
4	15	72	12	-	0.8	3.8	0.6	-	5.2
5	13	68	18	-	0.7	3.5	0.9	-	5.1
6	16	62	22	-	0.9	3.3	1.1	-	5.3
7	11	70	19	-	0.5	3.5	0.9	-	5.0
8	9	68	23	-	0.5	3.6	1.2	-	5.3
9	13	59	27	1	0.7	3.4	1.6	0.1	5.9
10	13	51	25	11	0.8	3.1	1.6	0.7	6.1

Engineering student enrollment overall has remained fairly steady as the overall institution enrollment numbers have fallen. When the electromechanical systems concentration was implemented, faculty were concerned that students may be drawn from the electrical engineering concentration, which was already smaller than anticipated. Instead, the population of students in the mechanical engineering concentration has decreased somewhat. This is still a new concentration, so further evaluation will be needed to see what kind of an impact it has on the School of Engineering as a whole.

As the graduation date for the first class of engineering students approached, faculty and students alike were excited. This highly anticipated event would be accompanied by an application for ABET accreditation and a feeling of accomplishment for all. Unfortunately, the first class was expected to graduate in May of 2020. This put a damper on the proceedings and delayed accreditation an additional year due to the uncertainty around site visits. Accreditation was achieved, and as seen in Table 2, at least three percent of all institutional graduates have been from the School of Engineering.

Table 3. Engineering graduates

	% in Engineering				% of Institution				
Year	ChE	ME	EE	EMS	ChE	ME	EE	EMS	All Engineering
1	24	76	-	-	0.8	2.5	-	-	3.4
2	7	74	19	-	0.2	2.2	0.6	-	3.0
3	14	66	20	-	0.7	3.2	1.0	-	4.8
4	19	70	11	-	0.7	2.5	0.4	-	3.6
5	7	70	23	-	0.3	2.7	0.9	-	3.9
6	19	48	26	7	0.7	1.8	1.0	0.3	3.8

Facilities

The development of the first two buildings of the School of Engineering was reported on in detail in a prior publication [6]. In 2016, the School of Engineering refitted an older building to integrate classroom and lab spaces together in what the program calls the ClassLab format, along with several supporting spaces such as a makerspace, machine shop, and various study and community-focused rooms. In 2017, a metal shell building added ClassLab spaces for second and third-year general courses along with labs for degree concentrations. In 2019, a second and for-now final metal shell building was built with space for capstone projects work, the electrical engineering concentration, competition teams, and additional machine shop space.

Engineering was originally intended to be moved into a larger entirely new building made for the School by about 2021, but COVID and other funding challenges have delayed that transition for the foreseeable future. However, the 'temporary' spaces were set up with the possibility of such a delay in mind and are pleasant and fully-featured facilities. The primary difficulty with the arrangement is simply that members of the community and equipment are distributed across campus and can be physically remote from each other. It is more difficult to manage and oversee lab equipment, study spaces, storage, and other logistical issues with limited personnel when they are physically separate on campus, and students and faculty sometimes need to scramble to get from a class in one building to a class in another. These challenges are nothing new on many campuses and represent only a minor downside to the current configuration.

While the renovation and construction of the buildings represents significant change and growth over time for the School of Engineering, changes to the buildings once established have been limited. Some machine tools or pieces of scientific equipment have been moved around various shops or labs to best manage limited floorspace as new equipment is acquired, but in general the ClassLabs and supporting spaces are using the same layouts and furniture as when they were built. Since all work is at most ten years old and designed with uses closely matching current practice in mind, desire for renovations or changes is limited. Additionally, having purchased furniture intended for heavy use in institutional settings it has held up well and does not yet require replacement.

One unique challenge was the first electrical engineering space. The Circuits class was offered for the first time before electrical engineering faculty were hired for the electrical concentration. The faculty member in charge of the class was tasked with upgrading an existing classroom into a circuits lab. This renovation would likely require removing a row of seating, taking the largest classroom in the engineering building from 40 to a maximum of 30 participants, reducing the capacity of the space for extracurricular events. It would also require specifying equipment for an electrical engineering lab that may not be what the faculty hired for the electrical engineering concentration would appreciate. Instead of designing a lab, the faculty chose to use Digilent Analog Discovery kits for the course, allowing students to borrow their own equipment to use in the classroom and at home. This provided a number of benefits beyond seating capacity and keeping options available for future faculty hires; lab staffing and hours did not need to be considered, assignments could require students to build additional physical circuits on their own time, and the largest unexpected benefit to this choice was the transition to virtual education during the pandemic. Students were able to take their kits with them to complete hands-on assignments while in-person education was on pause.

Curriculum Changes

As with many engineering programs, the undergraduate engineering degree offered by the School of Engineering has a large number of credit hours, highly structured courses with a number of prerequisites, and can be very inflexible for students. At a small institution, an additional problem is that many courses are offered only once a semester or once a year, leading to greater inflexibility for student schedules. To consider where the curriculum could be more flexible, two faculty took part in a Curriculum Analytics Community offering through the Gardner Institute [7]. Curricular analyses undertaken with this support did not find any potential optimizations of the curriculum. One limiting factor is that the curriculum starts with precalculus, extending a prerequisite chain further than many other programs, but this characteristic of the program is essential for serving the local community.

Later, some changes were implemented to support student needs over the years, including reducing credit hours and revising courses within concentrations.

Credit Hours

There have been two major changes in the overall curriculum. One is that the Differential Equations course was changed to include Linear Algebra, making it more difficult for students to transfer in credit for this course. The second was changing the number of overall credit hours required for graduation from 136 to 132. This was debated for years, initially brought up in a faculty meeting in 2018. At first, it was tabled until after the initial ABET assessment so that there were no major changes from inception until the initial review. After accreditation was completed in 2022, delayed due to COVID, the question was reconsidered. Faculty in both the electrical and mechanical concentrations felt that students could drop a required science course, either Biology or Chemistry II, however the faculty in the chemical engineering concentration had a need for these science courses in their required Bioprocessing course. Eventually, it was decided that the chemical engineering concentration did not require Organic Chemistry II, dropping all concentrations down to 132 credits required for graduation starting in Fall 2024. The faculty would like to reduce the required credits further, however the yearly discussion always stalls when faculty cannot decide what courses to remove. The faculty recognize the typical goal of 120 credit hours and would like to reach 124 credit hours as most institutions with 120 required credit hours do not also require precalculus. Future discussions are assured.

Common Courses vs. Concentrations

There is one degree offered, a Bachelor of Science Engineering degree, with multiple concentrations. Faculty who teach in these concentrations typically do not have general engineering degrees, but majored in the area they teach in. This creates a tension between sharing courses across all concentrations to provide a breadth of knowledge for all students and wanting to provide more concentration-specific content for students. The electrical engineering faculty were the first to choose to separate some courses, taking the common Materials Science course out of the electrical concentration and replacing it with a special topics course that was intended to include some of the content these students would no longer take. Other courses like Heat Transfer and Thermodynamics have been changed over the years as the faculty in the mechanical and chemical concentrations debate what content should be in each course and which students should take them. Heat Transfer was originally not a shared course, then to unify the curriculum it was taught to students in both concentrations. Ultimately, it was determined that the content and timing was better taught in separate courses given the way heat transfer is discussed by each group. More details regarding this can be found in another publication [1].

Civil vs. Electromechanical Systems Concentration

In the initial planning for the School of Engineering, four concentrations were intended: mechanical, electrical, chemical, and civil engineering. The first three concentrations included the initial faculty hires and began enrolling students in the first three years. The final concentration was delayed due in part to the pandemic. The subsequent reduction in enrollment and resources delayed building a new engineering building and made hiring new faculty an unreasonable strain on the budget. During the first five years of the program, however, there was student interest in a combined electrical and mechanical program. This interest was echoed in discussions with industry partners and external and student advisory groups. In reviewing the curricula, we determined that we could develop a new electromechanical systems concentration that would combine courses from the electrical and mechanical concentrations while adding one new course, Actuators and Sensors. This concentration is in its third year, so its impact has not yet been fully understood.

Transfer Students

The School of Engineering program values community and attempts to build strong cohorts in the first-year program. A significant component of the introductory seminar class for engineers creates opportunities and expectations for students to get to know each other. The community is important for creating study groups and supporting future success. A first-year living and learning community was created in the program's 4th year to further build strong connections amongst students. The curriculum is designed to bring all students up to a common baseline in terms of problem solving, software tools, communication, and teaming abilities. The original curriculum design assumed that nearly all students entering the School of Engineering would be first time, full-time students. Transfer students were accommodated on a case-by-case basis, but the program was not specifically designed for them.

Our view on transfer students has evolved for several reasons, with the most obvious being a decline in undergraduate enrollment over the last nine years both in the engineering school and the rest of the university. Less obviously, we have recognized that our program is ideal for many community college (CC) transfers who value practical hands-on experiences and who have thrived in the small class environment of their local community college.

In 2023, the University as a whole began to review its transfer student processes in an effort to be more welcoming to community college students. Memoranda of understanding were signed with several nearby CC's that clarified the requirements for guaranteed admission and awarding of transfer credits. Most importantly, the transfer credit policy was updated. Formerly, courses from a 2-year institution were treated differently than those from a 4-year institution in three ways. First, the number of credits that could be accepted from a 2-year institution was lower than from a 4-year institution. Second, once a student had earned 64 credits, they could not transfer a course from a 2-year institution. Third, 2-year institution courses could not be transferred in as 300-400 level courses. The new policy sets one overall limit for transfer credits that does not discriminate against credits from 2-year institutions. It removes the 64 credit threshold; this allows students to take CC courses over the summer after their sophomore and junior years. Also, if a community college course is equivalent to a 300-400 level course, then it can be transferred in. Differential Equations is an example of such a course. Many CC's offer Differential Equations. However, because it has a 300 level course number, it was not previously accepted for transfer credit without a course substitution and signature of the engineering dean.

Besides university changes, the School has adjusted its practices to facilitate timely graduation of transfer students. When the program started in 2016, our web page showed a curricular plan for transfer students that was four years long. The reason for the 4 years was the pre-req sequence. The first-year engineering courses were pre-requisites for all of the 2nd year engineering courses. In advising, we recommended that transfer students take a minor so that they could remain full-time over the four years. Now, our web page shows 2-year graduation plans and the transfer courses that are needed. Advisors are well versed in creating 2-, 2.5-, and 3-year plans depending on the particular courses that are transferred in. Students with sufficient math and science credits take our first-year engineering courses concurrently with sophomore engineering courses. The sophomore course instructors have had to make some adjustments. For example, the first-year engineering courses teach software that may be used in a sophomore course. The sophomore course instructor may have to provide extra help or direct the student to self-study resources. Thus far, instructors and transfer students have been able to adapt well.

These changes in policy approach have led to greater numbers of transfer students and better retention of transfer students. "Transfer student" could be defined a few different ways. For example, it could be any student who transfers in more than 32 semester hours. Alternatively, it could be someone who has an Associates degree. In our context, we define transfer student as someone who has sufficient math and science credits to take sophomore engineering courses in their first year at our institution. These students would be able to graduate in 2-3 years. For the first 8 years of our program, the percentage of transfer students meeting this definition ranged from 4.9% to 15.6%. In 2025-26, the percentage is 22.8%. In the first two years of our program, 5 of 21 students left before graduating. In the last 7 years, just 2 of 47 have left before graduating.

Lessons Learned

This paper has provided a brief discussion into the main areas that drove change during the first ten years of a new engineering program. Some of the key findings have been synthesized here:

1. Flexibility is key. Through flexible facilities, including offering lab kits instead of laboratory space, we were able to navigate the pandemic and changing curricular needs from adding new concentrations. By increasing flexibility for transferring credits, we have increased the number of transfer students joining and graduating from the program.
2. Recognize and reconsider assumptions. The initial plans focused on first-time undergraduate students and expected to have four concentrations, civil, mechanical,

chemical, and electrical. Given the interest from potential community college transfer students and the post-pandemic needs for maximizing student attendance while minimizing resource usage, these initial plans were revised. Better pathways for transfer students were developed. Instead of offering a new civil engineering concentration, where additional classes, faculty, and potentially facilities would be required, we offered an electromechanical systems concentration, requiring no new faculty and only one new class. This was not originally expected, however after reviewing the needs of the community, the interest of students, and the required resources, we were able to offer a fourth concentration to meet many needs without straining our budget.

3. Remember the mission. We are here for our students. Making it easier for students to navigate their undergraduate education while still upholding the quality required for our degree is paramount. To support students, we have implement a new concentration, created easier pathways for transfer students, and reduced the number of credits required for graduation while keeping our requirements to enter the program lower than most engineering programs.
4. Transparency and accessibility are important. Many of these documents were available in the faculty document repository, allowing for searching through past meeting minutes, ABET documents, and other supporting files. Some documents were only available on faculty's private computers. This is important for protecting personal data, for example student FERPA or personal information related to studies. Having deidentified documents saved in an accessible location supports program evaluation, quality assurance, and retrospective research projects like this.

We will continue to implement these lessons and the others we have learned during our time as we look ahead to the next ten years.

Conclusions

When the faculty began to consider what to revisit in this retrospective study, they started considering course projects and student activities. Once we began writing, we recognized that the most important changes over time were not those done by individual faculty, but those that impacted faculty and students in larger groups. The changes seen in the first year, transitioning from introductory courses to a comprehensive first-year experience, are captured in a separate article [2]. The importance of character education through the core Values has also been discussed in a separate publication [3]. In considering the important changes over time, four main areas emerged: the addition of different concentrations, choices related to educational spaces, creating additional curricular flexibility, and providing better support for transfer students. We hope that our reflections on the development of our program provide some consideration for other new programs in small institutions and provide some insight into the needs and decisions of a small, rural, religiously-affiliated, liberal arts institution in the shadow of a large state school known for its engineering programs.

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