Full Paper: Engineering Catalyst – An Alternate Supported Path to the Same Destination

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Engineering Catalyst – An Alternate Path to the Same Destination

Engineering Catalyst is a new program to support engineering and computer science students who enter the University of Oklahoma with a pre-calculus or college algebra math placement. With a strategic goal to increase B.S. engineering graduates by about 30% by 2029, the Engineering Pathways team at the University of Oklahoma (OU) designed and launched a new first-year engineering transition program in 2022. In early brainstorming in 2021, the name Engineering Catalyst was chosen to represent the vision of the program – providing students entering our college in pre-calculus or college algebra a supported path to their engineering or science degree. The program is an adaptation of national models for "gold/red shirt" programs and a first-year research program for mid-tier incoming students, guided by significant features of our local context. Here we describe the motivation and structure for this hybrid model first-year plus support program and an informal assessment of our first year.

Background and Local Context

Since first learning of Jackie Sullivan's plan to launch a program she called *Goldshirt* at University of Colorado-Boulder, an engineering education team at OU started trying to figure out how we could do something similar for our institution [1]. Our local context resulted in a capacity-limited, economic, and political environment that prohibited a similar launch at our state institution. The *Goldshirt* program and later adaptations such as the Washington STARS invite participation by students who are highly motivated for an engineering degree yet had less access to STEM curriculum than their peers or who identify in communities underrepresented in engineering or computing. The programs are modeled on athletic "redshirt" seasons where an incoming athlete has high motivation and potential, while needing additional strength or skill development. These developmental year programs focus on building supportive faculty- and peer-mentored cohorts; strong math, science, and academic skill foundations; and self-management and leadership competencies [2].

About seven years ago, we learned of University of Maryland-College Park FIRE, the First-Year Innovation and Research Experience program that supports entering students in research and innovation clusters during their first three semesters of college [3]. This program invites participants from the middle-tier of the entering class. The students have a semester of learning basic research skills and about different multidisciplinary research streams (topic areas), before selecting one of those streams. In the stream, they work in teams to define a research question or hypothesis and begin the work. Some students may be awarded summer internships and/or continue the projects into their third semester.

When a new dean was hired in 2020, the new leadership team and others in the college began revising the most recent strategic plan and developing action plans for growing and improving all aspects of our college. Figure 1 illustrates the college's current strategic goals: reach AAU-level performance in research and innovation, provide access to an engineering education for all students in our state, and increase the number of graduates to support our state's economy. The third goal to increase engineering B.S. graduates from around 600 to over 800 has drawn attention from university leadership as well as the state legislature. The new Engineering

Pathways (EP) program plays a significant role in the second and third goals, with Engineering Catalyst as a cornerstone program to meet the goals.

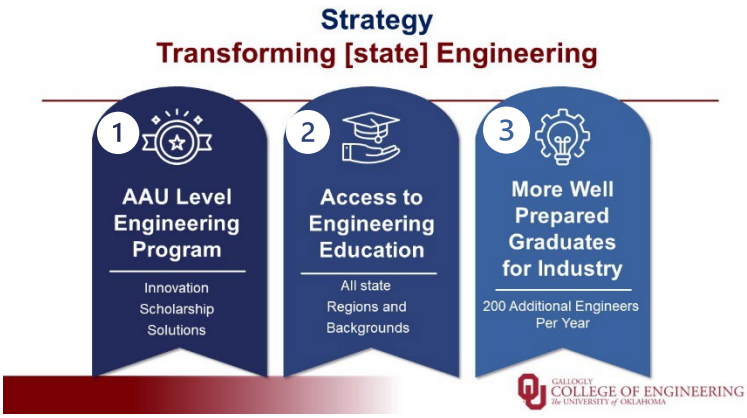

Figure 1. Graphical representation of the OU College of Engineering Strategic Goals for 2020-2025.

Increasing our number of graduates by 30% will require growth in recruiting and achieving more equitable access to engineering, as well as improving our retention to graduation. To address Goal Two of access and recruiting, the EP outreach and recruiting team is building more connections and partnerships across the state with public, private, and career tech high schools as well as clearer 2+2 or 2+3 programs with community colleges. We are heavily investing in visiting prospective college students in their home communities, especially communities that are overlooked or underserved for STEM recruiting. Our applications are up about 30%, but that so far has resulted in a growth of only about 10% in our entering class, with small changes in the demographics of the class. About 25% of a typical incoming class identifies as a first-generation student. Our university has test optional admissions, but about 60% of 2022 incoming students reported either ACT or SAT exam scores, with a median ACT (or converted SAT) math score of 26. Our incoming engineering classes are comprised of about 40% students who identify with a racial or ethnic minority community and about 5% international students. Half of the 477 public high schools in OK have a graduating class less than 40 students. To realize "All Access" from schools or regions without good STEM preparatory high schools requires that we invest more in outreach to those schools, and also in transition programs into college.

Our growth target of 200 additional engineering graduates by 2029 cannot be achieved by just recruiting more students; the goal necessitates improving our retention to graduation rate. Our college has open admissions for our degree programs. If a student is admissible to the university, then they may declare any engineering or engineering science major in our college. Our university's most recent data indicates an 83% acceptance rate for all applicants, which is mirrored in our entering engineering students. From 2021 (2015 cohort) data, only about 50% of first-time, full-time students graduated from their original major (6-year rate), though that fraction has trended upward over the previous eight years. The six-year graduation rate for entry-as-X-engineer to a degree from any STEM major is about 70%. This policy of open admission to the college of engineering is an important contextual factor for our retention programs.

Like many higher education institutions, especially in states with low K-12 achievement rankings, our engineering students largely enter unprepared for engineering calculus. At our institution, less than one-third of entering engineering students place into engineering calculus as

incoming first-time, full-time students. Our university offers a four-semester calculus sequence into which another 25% or so place, leaving about half of our incoming class enrolled in a preparatory math course. These numbers are approximations because 1) they change annually in a natural flux, and 2) they are influenced by a placement system that has had several variations over the last seven years.

The Program: Engineering Catalyst

In developing action plans to work toward the strategic goals, we examined what Engineering Pathways could do to support awareness, recruiting, transition, and retention. In addition to other efforts, the team quickly resurrected our dream of launching a *Goldshirt*-like transition program for students at OU. As implied by the name, the Engineering Catalyst program provides students with a supported path to their college of engineering degree. While being inspired by the "redshirt" programs, our Engineering Catalyst program cannot adhere to the fundamental structure of a five-year program. We must integrate into the usual four-year degree plans and limit the number of additional credit hours that we can require. The key components of the "redshirt" programs that we adopted are problem-solving skills embedded with mathematics learning, academic success skill development, dedicated advising, and community building as a cohort and within engineering. These objectives are distributed across three courses for Catalyst scholars: Math Catalyst, Engineering Catalyst, and Research Catalyst. Additionally, students are offered two years of scholarship support if they are meeting program requirements.

When the *Goldshirt* and *STARS* programs were founded, one of their key features was supporting students who were not eligible to begin their undergraduate engineering program in calculus. We know that students who begin engineering in a mathematics course before calculus have a longer path and can be more likely to exit engineering [4]. Thus, we developed our Engineering Catalyst program for serving students matriculating into either college algebra or pre-calculus & trigonometry, with cohorts defined by that first math class.

Besides the obvious additional time to degree from beginning an engineering degree in calculus preparatory courses, our college's course sequencing and some limited offerings mean that any misstep in their science, mathematics, or engineering courses could extend a student's degree time beyond an additional year. These hurdles lower retention rates for students starting in earlier math class even more. Under these circumstances, we consider community and general academic skill building as essential elements of the Catalyst program.

Math Catalyst

Students will take a Math Catalyst course concurrently with their math classes through calculus one. Their needs in these courses are seen as two-fold. Primarily, Catalyst Scholars are building and reinforcing math and problem-solving skills, engineering identity, and emotional wellbeing in their transition to college-level mathematics and other STEM environments. Additionally, students in Math Catalyst might like to receive a good grade to start college strongly.

Many courses that these Catalyst Scholars have taken before or will take in their college career are lecture-based – watching someone else perform mathematics and problem solving for them, describing each step, variable and reflective process. This does not allow them to create necessary connections to their personal experiences [5] or work with each other to help create satisfying moments [6] – both contributors to successful learning [7]. Therefore, Math Catalyst is steeped in group work on solving engineering applications of mathematics they have seen before or are currently seeing in their mathematics course. Each class unit begins with a new engineering or science context, definitions, or reminders of mathematical concepts before the students work through problems and lab activities in that context. Students are often reminded of and encouraged to use a particular problem-solving model, based on IDEAL problem solving and a framework for ill-structured problem-solving [8], including (1) understanding the problem, (2) making a plan for solving the problem, (3) enacting their plan for solving the problem, and (4) reflecting on their entire solution to optimize performance. Some materials for these lessons have been built from scratch, inspired by the contexts of these students, their degree plans, and the content of other courses at the university. Other materials are borrowed and adapted for this population, most notably the lessons and simulated labs available from Wright State University's Engineering Mathematics course [9].

Due to the nature of the course, the overall course grading scheme does not include traditional quizzes or exams. Instead, the students focus on growth in learning the content. They are partially assessed through skills-based assignments – written homework, lab reports, and components of a semester project – allowing for reflection time and resubmissions throughout the semester. Students are not expected to have perfect understanding of the content in their first attempt at an assignment, but they are expected to take feedback and grow in their math skills throughout the semester. They are separately assessed on efforts-based assignments – active engagement in the course through class preparation, participation in their learning, and completion of a semester portfolio. In this way, we communicate to students that they are expected to engage in their learning process in a variety of ways, which support their learning in other classes as they build habits for the rest of their career. Successful completion of the course is done by students who have excellent scores in both skills- and efforts-based assignments.

Engineering Catalyst

Students enroll in an Engineering Catalyst course in each semester of their first year. The first semester courses focus on successfully transitioning to the university, academic skill development, campus resources, cohort building and advising for the near and long term. We have a dedicated member of the college advising team who meets with the students at least twice during the term. We also enroll students with academic life coaches if needed. The second semester courses focus on professional development: self-advocacy, career center resources, and team building. Throughout the year students work on developing and practicing self-reflection. Students in both semesters are also asked to identify, share, and activate their personal support systems and individual motivations for studying engineering.

Most of the work in these courses in our pilot implementation was assessed on thoughtful engagement with the topic. We also strived to be responsive to changing student needs during the

semester. This approach resulted in some unintended consequences, and we are working out remedies for the new cohorts. Students did not engage in positive habits (such as weekly planning) to the degree that was needed. We also realized that we needed to include more basic information, such as effective use of our learning management system. This curriculum is under revision.

Research Catalyst

The final course in the Catalyst sequence is based on the UM-CP FIRE program described earlier. As we enrolled our first cohort in fall 2022, we will first offer this course in fall 2023. Although this course roughly corresponds to the FIRE first-semester course, Catalyst students will take this course in fall of their second year. This course guides students to develop their understanding of the research process through the design, research, collaborative authorship, and iterative review-based refinement of research ideas. Students will find and analyze primary literature, think critically and creatively, author and communicate in a scholarly fashion, and work collaboratively to solve scientific and societal problems using technology, delegation, and productive team communication. They will continue developing transferable problem-solving skills, teamwork, and engineering competency initiated in the first year Engineering/Math Catalyst courses. Students will identify research topics in the college that interest them and relate to their engineering goals. Catalyst staff will facilitate a shadowing experience and identifying existing data and appropriate research questions or hypotheses that the students can test or analyze. These experiences culminate with a presentation of background literature and analyzed research data demonstrating a potential research agenda and preparation for impactful participation in a future research experience. Our intention is to help the students move into paid research assistantships within the college as they move out of Catalyst courses.

Early Results and Lessons Learned

Approval for the program was not secured until summer 2022, so our recruiting and enrollment was limited significantly. We had made an earlier decision to only enroll students in the pre-calculus and trigonometry course in our pilot cohort. Although we hope to be able to support 30 students in each math cohort each year, we began with only seventeen students in our initial scholar class. The support provided through the Catalyst program helped these students achieve an average "B" grade in that mathematics class in comparison to a "C" average for all engineering students in the course.

Two students have not been retained in the college: one left OU for personal reasons, and another has left engineering. The remaining fifteen of the seventeen students have maintained good academic standing in the college of engineering. This 88% first-year retention rate compares quite favorably with the college average of 68%.

It turns out that the flexibility to be responsive to student needs contributed to a perception that the Engineering Catalyst class was not a "real" class. Helping students dig themselves out of holes as the end of the first semester approached, we realized that more structure was needed. In end of year conversations, several students recognized that the structured requirements in the second term course would have been beneficial to have had from the beginning. Students also

requested time in the first semester devoted to "Adulting 101;" while we focused on academic transition, life transitions were significant challenges for the students. We are revising the course to add more structure and to align the grading process to that in Math Catalyst.

Despite our efforts to recruit and enroll students in the program prior to acceptance day, we have encountered institutional hurdles to that plan. With test optional admissions entering its fourth year, the proportion of students submitting scores is shrinking. The locally developed algorithm for math placement depends on those scores along with other data. Our invitations for the fall 2023 cohort went out to accepted students in February, but students could not learn their math placement until after they scheduled their initial enrollment appointment, which could not be scheduled until after they accepted admission and paid their deposit. Additionally, if the student applied test-optional, then they did not receive a "math offer" when scheduling their appointment. They will be required to take a formal assessment to determine their placement. It is July and we are still waiting for those math placement results for many students.

We hope that by sharing our story we can learn from others who have launched similar redshirt-like programs or inspire other colleges to create their own. We are eager to engage in conversations to improve our program as well. We gratefully acknowledge the UW STARS program for support for J.D. to attend the Redshirt Symposium in June 2022.

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