# Equity, Rigor, and Access: The New ERA of Engineering

**Benjamin Richmond, The University of Arizona**

Ben serves as the Manager of Undergraduate Education Initiatives in the University of Arizona's Division of Undergraduate Education in the Office of the Provost. He earned his BS in Public Health and MPH from the University of Arizona and is currently pursuing a PhD in Higher Education. Ben's research interest is in understanding the social and cultural barriers students face in pursuing higher education and developing higher education pathways for students. With this research focus, Ben has devolved programs that target students throughout their academic journey and use culturally anchored curriculum to increase students' knowledge and skills, improve students' self-efficacy in pursuing higher education, increase sense of belonging on a university campus, and help students navigate campus systems.

**Prof. Gregory L. Heileman, The University of Arizona**

Gregory (Greg) L. Heileman currently serves as the Associate Vice Provost for Academic Administration and Professor of Electrical and Computer Engineering at the University of Arizona, where he is responsible for facilitating collaboration across campus t

**Kian G. Alavy, University of Arizona**

Kian Alavy is Director of Strategic Planning and Initiatives for the Division of Undergraduate Education and a doctoral student in Higher Education at the University of Arizona. Kian is interested in the history and evolution of undergraduate education offices at research universities in the United States, particularly their current nationwide organization around high-impact practices (HIPs). He earned his MA in Middle Eastern and North African Studies at the University of Arizona and his BA in History from the University of Minnesota.

# Equity, Rigor, and Access: The New ERA of Engineering (Work in Progress)


## Abstract

In this paper we describe our work in progress paper Equity, Rigor, and Access: The New ERA of Engineering. This project is a multi-university collaborative that includes partners from The University of Arizona, Georgia Institute of Technology, and The University of California Sandiego, and aims to promote equitable attainment of engineering degrees by utilizing data-driven interventions across multiple universities. Engineering education has long struggled with barriers to equity, particularly among marginalized, low-income, and first-generation students. By leveraging student performance data, curricular structures, and demographic information, this collaborative will create targeted interventions that improve retention, academic success, and degree completion in engineering.

Guided by Kotter's Change Model (KCM), the project takes a structured approach to institutional transformation. By following Kotter's eight steps, this effort drives momentum, and fosters change in engineering education. Using KCM ensures that each phase of the initiative, from planning to execution, is supported by strong leadership and clear communication, which are critical for overcoming resistance and maintaining progress.

The project is structured around three primary goals: (1) establish a sustainable network for collaboration among faculty and institutions, (2) create a replicable model for interventions and learning strategies to address multi-disciplinary academic preparation barriers to pursuing engineering degrees, and (3) improve the equitable attainment of engineering degrees. To achieve these goals, four specialized working groups have been established including Data and Dashboards, Math Preparation, Faculty Development, and Funding. Each group is tasked with addressing critical aspects of student support, faculty training, and institutional collaboration.

The Data and Dashboards group is charged with developing real-time data dashboards that disaggregate student performance by key demographics, offering actionable insights into course-level outcomes. This will enable faculty to make informed decisions on curriculum adjustments and teaching methods. Simultaneously, the Math Preparation group works to design interventions to support students who are not calculus ready. These interventions aim to level the playing field for students, providing them with the necessary skills to succeed in core engineering courses. The Faculty Development group provides professional development resources and works with faculty to interpret student data effectively and apply evidence-based teaching strategies to foster a more inclusive learning environment. In parallel, the Funding group is responsible for identifying and securing financial resources to support ongoing project efforts, ensuring the initiative's long-term sustainability.

Through this multifaceted approach, Equity, Rigor, and Access: The New ERA of Engineering aims to reshape engineering education by fostering an environment where all students have equitable opportunities to succeed and thrive in their pursuit of an engineering degree. By focusing on institutional and structural changes, the project ensures long-term impact and sustainability, creating a transformative blueprint for the future of engineering education.

## Introduction

This work in progress paper addresses the unique critical challenges facing undergraduate engineering education and offers an innovative approach in working together to confront institutional structures and practices that reproduce systemic inequities. These challenges include low retention and graduation among underrepresented groups, increased and significant variance in curricular structure complexity across institutions leading to increased time to degree, and a lack of tailored support for students who do not begin their higher education journey in at least the calculus level. These challenges hinder equitable access to engineering degrees and fail to reflect the diversity needed in the STEM workforce.

One of the primary challenges facing undergraduate engineering education is low retention and graduation rates among underrepresent groups [1]. Looking at undergraduate engineering degrees between the years of 2000 to 2019, 12.8% of degrees were awarded to Hispanic or Latino/a students [2]. African American students made up 4.3% of undergraduate engineering degrees, and women made up just under 23% of all engineering degrees [2].

One factor that may be causing low retention and graduation rates is curricular complexity. Curricular complexity is a measure of how easily a student may progress through a curriculum towards graduation [3]. The two primary properties that determine a curriculum's structural complexity is the delay factor and the blocking factor [4]. The blocking factor refers to the extent one course in a curriculum blocks a student's ability to take other courses in a curriculum [4]. The delay factor is the measurement of the extent a student is delayed if a course in the sequence is not completed on time [4]. One variable that has a critical impact on structural complexity in curriculum is prerequisites. The more prerequisites a curriculum has, the greater the curriculum's structural complexity is [4]. This results in a student having a greater chance to be delayed in their degree completion as there are a higher number of courses blocking a student from progressing through a curriculum [4].

The more complex a curriculum pathway is, the less likely it is that a student would graduate on time [3], [5], [6]. Engineering complexity scores vary greatly by institution and are often the most complex disciplines in higher education. This complexity can increase the time it takes students to complete their degrees, increasing the cost of that degree [7]. This issue tends to affect students from underrepresented populations the most creating structural inequities.

Lastly, many students begin college not ready to take calculus. This problem is exacerbated by the lasting impacts of the COVID pandemic on high school education. At the same time many engineering curricula are designed assuming students will begin at the calculus level. This assumption is to the detriment of students as they will almost certainly be delayed on their engineering education journey.

This paper will describe an ongoing multi-institutional collaborative project that has developed over time. The "Equity, Rigor, and Access: The New ERA of Engineering" project aims to address disparities in undergraduate engineering education by leveraging data-driven approaches to enhance student outcomes, align curricula with diverse needs, and empower faculty to implement inclusive practices. Ultimately this project can serve as a replicable model for multi-institutional collaboration, be a source of scalable and transferable interventions to improve

STEM education and generate resources and best practices for national dissemination to foster systemic change.

This project aims to use curricular structure and curricular complexity data to identify the most efficient places and ways to develop interventions. By knowing where students may need the most support, we will be able to develop targeted and tailored interventions. Specifically this project aims to (1) develop and sustain a collaborative community of practice among engineering faculty at multiple universities to share best practices and innovative solutions for equitable student success, (2) create a replicable model for interventions and learning strategies to address multi-disciplinary academic preparation barriers to pursuing engineering degrees, and (3) improve equitable attainment of engineering degrees through data-informed, faculty-led initiatives, including real-time dashboards to make data-informed curricular decisions.

## Theoretical Framework

This project uses Kotter's Change Model (KCM) to guide its design and implementation, as we aim to create change within institutional structures. KCM highlights eight steps for change which include developing a sense of urgency, creating a powerful coalition, building a vision and strategy, communicating that vision, removing obstacles, creating short term wins, consolidating gains, and implementing change [8]. This project has grown and developed over time and is currently between the steps of removing obstacles and creating short-term wins.

## Methodology and Data Analysis

Building on the progress of efforts over time, this section will describe how we have used KCM to form a powerful multi-institutional guiding coalition and develop a vision and strategy. As this collaborative advances, we will describe how KCM shapes our approach to creating short term wins, consolidating our gains, and creating change at the institutional level.

### Creating Urgency

The first step in this process was to identify and understand the urgency of the problem at hand. This problem, described above, is that engineering degrees have the most complex curricular structures in higher education leading to longer time to degree and higher cost of degree, which disproportionately affects students from underrepresented backgrounds. This systemic inequity leads to engineering disciplines being one of the least diverse fields in higher education leading to a workforce that lacks diversity. While this problem exists at institutions across the country, this problem was identified and consistent among the three partner institutions, bringing them together to try to find a way to address it.

### Forming a Powerful Coalition

Following KCM, the next step of the project was to form a powerful guiding coalition. Initially this coalition was made up of administrators from each of the partner institutions, and in this coalition, partners were able to collect common data from their institution to identify equity gaps. This data included curricular structure and complexity, student performance, and demographic data. Student data was then disaggregated by race, ethnicity, first generation status and Pell

recipient status. It is important to note that we used Pell recipient status as a proxy for low-income. The student performance data collected is described in Table 1 [8, Tab. 2].

During the process of collecting the data, the guiding coalition recognized that change was only possible if change was led by the faculty at each of the partner institutions. Therefore, the guiding coalition formed faculty learning communities to analyze the data, situate the data within context, and begin identifying where targeted interventions could take place. To begin this process, the guiding coalition approached faculty chairs from Aerospace Engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Industrial Engineering, and Mechanical Engineering. These disciplines were chosen as they were the common disciplines across all three institutions. Faculty chairs then recruited faculty from their disciplines to participate.

**Table 1: Student Performance Data Points Collected**

- Four- and six-year graduation rate in each engineering discipline at each university
- Four- and six-year graduation rate in all other colleges at each University (Business, Science, Social and Behavioral Science etc.)
- Average grades for each engineering course. Specifically, the classes that students performed the worst measure by classes who had the most students receiving a D or E for students who already had two D's or E's
- Time to degree for each discipline at each university broken down by AP credits brought in from high school (0-9, 9-12, etc.).

*Each data set was then disaggregated by race, ethnicity, first generation status, and Pell recipient status.

Develop a Vision and Strategy

Once faculty were recruited, they first participated in a one-hour workshop that focused on how to analyze student performance data using an equity lens. Faculty then came together internally to review data specific to their own institutions and discuss the data in a discussion led by a trained learning community facilitator. After the first internal meeting took place, the faculty communities and guiding coalition met for a two-day workshop in person. A total of 34 faculty and staff attended the two-day workshop. During this workshop faculty were able to discuss the data as a large group and in discipline specific breakouts.

This in person gathering led to great discussion of the data, but also identified a need to come together to develop a vision and strategy on how all three institutions can work together to develop interventions and create change. This led to a three-day in-person gathering of intensive discussions. In these discussions 17 partners were able to identify and share problems, interventions, and solutions they have at their own institutions as well as begin discussions on how this growing coalition can move forward.

This second in person gathering led to identifying three main themes for interventions. The first common theme identified by the coalition was a need to meet students where they are in math preparation. Most engineering programs are designed assuming that students begin their higher

education journey calculus ready. However, this is not the case, and faculty identified that as students who completed high school during the COVID pandemic are entering college, even less students are calculus ready. Because of this, there is a need to find ways to meet students where they are at and develop interventions and efficient curricular pathways for students who are not calculus ready.

The second and third theme related to finding ways to make the data we collected accessible to faculty. The solution the group came up with is to design dashboards that are user friendly and easy for faculty to use. These dashboards would provide real time student performance data disaggregated by key demographics, offering actionable insights into course-level outcomes. This will enable faculty to make informed decisions on curriculum adjustments and teaching methods. However, having access to this data led to the third theme in faculty professional development. This includes training on how to interpret this type of data with an equity lens and other training such as how to revamp their curriculum to be more accessible to students.

These three themes served as the basis for the structure of the formal collaborative group that was then developed. This group has four working groups that work towards creating change at their institutions. The first working group is the Math Preparation Working Group, focused on sharing and developing strategies for targeted math readiness interventions. The second group is the Data and Dashboards group, focused on developing dashboards that can be easily accessed and used by faculty. The third working is the Faculty Development Working Group, focused on developing training and professional development opportunities for engineering faculty. A fourth working group, the Funding Working Group, was established to identify and pursue funding opportunities to support the other three groups.

One other theme that emerged was a discussion around rigor. Specifically, questions around what rigor is, the importance of rigor and its influence on the perception of quality and prestige of engineering programs, if rigor is problematic, and how we can increase equity and access without sacrificing the quality of the program. While a conclusion was not reached it was clear that the collaborative aimed to redefine rigor in a way that was inclusive, increased access to engineering, and did not sacrifice quality.

Moving forward with Kotter's Change Model

The next steps in the KCM includes removing obstacles, creating short term wins, consolidating gains, and implementing change [8]. Removing obstacles remains an ongoing phase. To begin, the heavy lift of data collection was taken on by institutional research offices. Then faculty buy-in was secured by working with faculty chairs at each institution. As the collaborative moves forward, other obstacles such as funding will need to be addressed.

By forming this collaborative, the next steps in following KCM can be achieved. Using thematic working groups, short term wins will be identified and implemented. By meeting regularly, faculty and collaborative members will be able to share and develop strategies and best practices to consolidate gains. Lastly, by being faculty led and informed, interventions identified and developed in the working groups will stand a better chance of success leading to institutional change.

## Discussion

Using Kotter's Change Model as a guide, this project aims to improve the equitable attainment of engineering degrees through data driven interventions across multiple universities. This project identified an urgent need in that curricular complexity in engineering degrees is leading to increased time to degree and increased cost of degree, which disproportionately affects underrepresented students. To address this urgent need a guiding coalition was formed and made up of administrators and faculty to develop a vision and strategy and ultimately develop faculty led interventions for institutional change. The primary outcome of the project to date is a network of collaboration made up of Math, Data and Dashboards, Faculty Development, and Funding workgroups.

While a final determination on how the collaborative views the idea of rigor was not made, it brings up an important point for discussion as the collaborative moves forward. Defined, rigor means something that is extremely thorough, exhaustive, or strictly adhered to. Many have made arguments that rigor is problematic. For example it could mean that engineering education is inflexible to a fault, not open to innovation, unwilling to welcome other ways of knowing, and ultimately detrimental to equity in access to engineering education [10], [11], [12]. Some have argued that we should move away from using rigor altogether [10]. Ultimately, while the collaborative has not reached a consensus, it is clear there is a need to become innovative in how we approach engineering education in order to increase equity and access, while also ensuring the quality of teaching and learning.

Throughout its implementation, this project has faced many successes and challenges. First, this project was started by administrators from the three partner institutions including the vice provost, vice chancellor, dean, and faculty chair levels. This buy-in from administration greatly helped to ensure institutional support of the project and helped to show that addressing systemic issues in engineering is a priority. One of the initial challenges to this project, however, was gaining faculty buy-in. This is because faculty already have overloaded schedules and have personal investment in the curriculum they have developed, therefore may not be as motivated to change what they have already created. Gaining buy-in from faculty chairs greatly helped in recruiting faculty to participate.

Ultimately this project aims to serve as a replicable model for multi-institutional collaboration. We found that it was critical to gain buy-in at all levels to ensure the project was a priority and that it would move forward. It was most critical that faculty bought into the project. This is because at the end of the day, change in how engineering is taught cannot happen without the faculty. For universities that are interested in engaging in similar work, we recommend finding ways to incentivize faculty participation as faculty already have overflowing workloads. This may be through finding funding to hire project coordinators or graduate assistants to lighten workloads or decreasing their teaching obligations to accommodate the additional workload.

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