

Onboarding Engineering Graduate Students from Non-Engineering Undergraduate Majors

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Abstract

Various government agencies forecast a shortage of engineers caused by a combination of factors including an increase in job opportunities, attrition in the STEM pipeline, and exits from the labor force for various reasons. While efforts have been made by many institutions to address the high dropout rates in STEM fields at the undergraduate level, some are implementing measures to facilitate graduate education in engineering for students with non-engineering undergraduate backgrounds through the establishment of bridge programs. Although these initiatives are not the primary driver of the graduate student population, they have led to a rise in enrollment of students from non-engineering backgrounds in graduate engineering programs. At Grand Valley State University (GVSU), there has been a similar increase in applicants with undergraduate degrees in physical sciences (Math, Physics, or Chemistry), given their common interest in math, who would like to pursue a master's in engineering. Consequently, the Graduate Committee began looking into the feasibility of making the graduate engineering program more accessible to meet the growing demand for engineers in West Michigan. Notably, this initiative has enabled GVSU to partner with Historically Black Colleges/Universities (HBCUs) that do not have engineering degrees to provide pathways for graduates from these institutions to pursue a graduate degree in engineering at GVSU. This paper will outline the general program plan developed for the onboarding of students from non-engineering majors into the GVSU MSE program, along with insights from both students within HBCU pipeline and those outside of it.

Introduction

The median salary for an entry-level chemist is \$81,810, whereas for a chemical engineer, it is \$106,260 [1]. This 30% difference in yearly income holds more significant implications over one's lifetime. This marked difference in earning potential serves as a key factor influencing a shift in career trajectory, occurring either before or after undergraduate studies. Unfortunately, many students overlook crucial aspects such as job salary and availability when selecting their undergraduate major. While personal interest often guides this choice, studies reveal that familial and peer pressure also plays a substantial role [2,3], leading students to pursue majors that may not align with their passion or offer favorable job prospects and income. While more than 30% of undergraduate students regret their initial major choice and opt to switch majors at least once during their academic journey [4,5], a significant number refrain from doing so, primarily due to time and financial constraints [6]. For those who stick with their original major, around two-thirds of college graduates express regret regarding their chosen field of study [7]. Switching majors could result in additional semesters to graduation and increased costs due to tuition differentials and additional foundation credits required in the new major. Instead, a more viable option could be pursuing a graduate education in their desired field after completing their undergraduate degree. Apart from offering higher earning potential and a lower unemployment rate [8], a graduate degree provides the flexibility to transition into a new field [9]. Therefore, rather than switching undergraduate majors from chemistry to chemical engineering, a more

natural choice would be pursuing a graduate degree in engineering to maximize earning potential and employment opportunities.

According to the National Association of Colleges and Employers [10], a master's degree can lead to a 20% increase in earnings compared to a bachelor's degree. The national median salary, national projected growth rate, and state mean annual salary estimates for mechanical, electrical, biomedical, and computer engineering are given in Table 1 below. All engineering majors have a projected growth rate higher than the national average of 3%, indicating a healthy demand for degreed engineers.

Table 1: National and state employment outlook

Major	National Median Annual Salary [11]	National Projected Growth [11]	State Mean Annual Salary [12]
Mechanical Engineering	\$96,310	10%	\$76,401
Electrical Engineering	\$103,320	5%	\$78,142
Biomedical Engineering	\$99,550	5%	\$70,430
Computer Engineering	\$132,360	5%	\$93,353

The Congressional Research Service analysis of the Bureau of Labor Statistics predicts a shortage of engineers caused by a combination of surge in job opportunities, bleeding of the STEM pipeline, and exit from the labor force due to various reasons [13]. Recognizing this shortage, many universities are taking steps to make it more accessible for students with non-engineering backgrounds to pursue graduate education in engineering through the creation of bridge programs. Bridge programs are designed to facilitate the transition into engineering for students with non-engineering undergraduate backgrounds. For example, for over three decades, the LEAP (Late Entry Accelerated Program) by Boston University has been successfully transitioning students with undergraduate degrees in liberal arts to the graduate engineering program. This is achieved by placing the students in core undergraduate engineering courses required to achieve the necessary academic preparedness [14]. Other universities have also implemented similar programs [15, 16], leading to a rise in the enrollment of students from non-engineering backgrounds in graduate engineering programs.

At Grand Valley State University (GVSU), over the years, there has been a similar increase in applicants with undergraduate degrees in physical sciences (Math, Physics, or Chemistry), given their common interest in math, who would like to pursue a master's in engineering. In particular, the Biomedical Engineering graduate program draws interest from students in Biomedical Sciences, Cell and Molecular Biology, and Allied Health. So, the Graduate Committee started looking into the feasibility of making the graduate engineering program more accessible. This would not only allow us to meet the growing demand for engineers in West Michigan, but it would be well aligned with our program's student-centric focus. To prepare the students for the graduate-level engineering work, an exhaustive list of prerequisite undergraduate classes that students must take has been approved. While each applicant's curriculum is tailored, GVSU's School of Engineering developed a general plan to onboard students from a variety of non-engineering undergraduate backgrounds. Applicants are granted conditional admission to the graduate program predicated on completing the prerequisite classes with a B or better grade.

These plans allow the transition from a non-engineering undergraduate degree to the Master of Science in Engineering (MSE) degree by shortening the path for those students looking to change careers while still ensuring that they have the prerequisite knowledge to be successful. Notably, it also has allowed GVSU to partner with Historically Black Colleges/Universities (HBCUs) that do not have engineering degrees to provide pathways for graduates from those institutions to pursue a graduate degree in engineering.

This paper will provide details of the general program plan developed for the onboarding of students from non-engineering majors into GVSU's MSE program. MSE students have the option of selecting one of the following as their area of emphasis: biomedical; electrical and computer; mechanical; and design and manufacturing engineering. The undergraduate prerequisite coursework required to transition into the graduate program will be presented along with experiences of students from two different groups and recommendations to improve the program in the future.

Developing the General Program Plan

When developing an appropriate study plan, the Graduate Committee (GC) sought to address the following two concerns:

- 1) The rate-limiting step for undergraduate majors outside of engineering, along with limited technical knowledge and skills, has always been inadequate math and physics preparation. Consequently, the GC decided to focus extensively on applicants with non-engineering STEM undergraduate majors. These included, but were not restricted to, Mathematics, Statistics, Physics, Chemistry, Biology, Biomedical Sciences, Cell and Molecular Biology, and Computer Science.
- 2) This population of our MSE graduates would be at a disadvantage for future employment without a supporting undergraduate engineering degree. Therefore, the GC chose undergraduate courses with rigorous theory and substantial hands-on components to underscore practical and problem-solving skills.

The program plan for non-engineering STEM majors seeking an MSE degree in one of our four emphasis areas - Biomedical Engineering (Bioelectrical: BME-EE and Biomechanical: BME-ME), Electrical and Computer Engineering (ECE), Manufacturing and Design Engineering (MDE), and Mechanical Engineering (ME) - consists of two phases. The initial phase (see Table 2), mandatory for all non-engineering STEM majors, focuses on developing competency with common engineering tools and technical competency around physics and mathematics, the universal language among engineers.

The second phase involves specialization in topics (Table 3) related to electrical engineering (for students pursuing an MSE in ECE or BME-EE) or mechanical engineering (students pursuing an MSE in ME, MDE, or BME-EE). Therefore, depending on their preferences, students would undertake one of these discipline-specific pathways.

Together, the two phases require non-engineering STEM majors seeking a graduate engineering degree to take over 60 credits of undergraduate prerequisite classes to prepare them adequately for our MSE program. Usually, a student will take most of these undergraduate courses during

their first year at GVSU, with the remaining of them being taken simultaneously with a few graduate courses during their second year. The third and final year typically consists of only graduate courses.

Table 2: List of phase 1 courses to develop foundational competency in engineering.

Course	Credits	Competency
Calculus I	4	Technical theory
Calculus II	4	Technical theory
Calculus III	4	Technical theory
Linear Algebra and Diff Eq	4	Technical theory
Principles of Chem 1	4	Technical theory + Lab
Calc Based Physics 1	5	Technical theory + Lab
Calc based Physics 2	5	Technical theory + Lab
Intro to Engineering Graphics	1	Drawing and tolerancing
Applied Programming for Engineers	2	C programming
Intro to CAD/CAM	1	Solid Works
First Year Engineering Design	2	Design Process, design and build robots
Circuits I	4	Oscilloscopes, PSpice simulations
Microcontroller Programming and Applications	4	Embedded systems, hardware, timers, interrupts

Table 3: List of undergraduate courses for phase 2 based on specialization.

Electrical Specialization (for MSE in ECE or BME-EE)	Credits	Mechanical Specialization (for MSE in ME, MDE, or BME-ME)	Credits
Introduction to Digital System Design	3	Mechanics of Machines	4
Electrical Materials and Devices	4	Machine Design I	4
Signals and Systems	4	Dynamics	3
Circuits II	4	Material Science	4
Embedded Systems Design	4	Thermofluids	4
Electronic Circuits	4	Manufacturing Processes	4

Onboarding of Students

When students with non-engineering undergraduate majors are conditionally admitted to GVSU's MSE program, their academic history is reviewed. Their previous math and science courses are evaluated for alignment with the courses listed in Table 2. Only those foundational courses necessary to establish the prerequisite background for their eventual graduate-level coursework are assigned. Additionally, any upper-division undergraduate courses from Table 3, needed to support their MSE emphasis area coursework are identified.

While the specific undergraduate requirements vary by student, they typically amount to about 63 – 64 credits, approximately half the total credits required for a full Bachelor of Science in Engineering (BSE) degree at GVSU. Students from institutions with engineering technology

programs may have fewer undergraduate requirements before full admission into the MSE program.

Upon completion of prerequisite undergraduate courses with grades of B (GPA of 3.0 or higher), students can then progress into MSE courses. In some instances, if they are making satisfactory progress in their undergraduate coursework, they may concurrently enroll in a non-technical graduate course required for all MSE students, such as an engineering professionalism and ethics course. Taking this non-technical course can help fill students' schedules. However, their ability to take many MSE technical courses is limited due to prerequisite knowledge from required undergraduate courses.

This process has been in use for approximately 24 years, dating back to the inception of the graduate program at GVSU. It became more common with the introduction of the Biomedical Engineering (BME) emphasis within the MSE program in 2010, attracting students from majors such as biomedical sciences. In fact, some GVSU students commence their graduate journey during their undergraduate tenure to reduce time to completion. Up until the 2022 – 2023 academic year, over 30 students from non-engineering backgrounds have graduated with an MSE degree. In 2020, GVSU established the Historically Black College/University (HBCU) / Hispanic Serving Institution (HSI) consortium. Many students within this consortium expressed interest in pursuing graduate engineering studies. The consortium was conceived to complement rather than compete with the offerings of partner institutions, particularly those lacking engineering majors. As part of the HBCU/HSI consortium, three students were conditionally admitted into the MSE program during the 2021-22 academic year.

As the first cohort of HBCU students began taking the undergraduate prerequisite engineering courses essential for full admission into the MSE program, it became evident that transitioning between institutions posed an additional layer of challenge in acclimating to engineering studies. Measures to alleviate these difficulties were promptly considered, leading to the development of a week-long summer orientation course before the second cohort began in the Fall 2022 semester. Developed by faculty members from the School of Engineering, this orientation was accessible to all students joining GVSU through the HBCU/HSI consortium. The orientation aimed to familiarize students with campus offices and support services while providing hands-on experience with the Blackboard learning management system used at GVSU. Particularly for engineering students, it also serves as an introduction to some of the programs and software essential for their upcoming engineering foundation courses. This summer orientation initiative was swiftly implemented as a proactive measure by GVSU's School of Engineering to facilitate the transition of non-engineering majors into the engineering coursework to allow them to ultimately succeed in the MSE program. Anecdotally, the students in the second and third cohorts who attended the summer program experienced a smoother adjustment. However, to gain deeper insights into students' experiences and perceptions, a survey was administered to inform further improvements to the onboarding process.

Surveying the Students

A Survey was administered to gain insight into the students' perceptions across various aspects of the onboarding process into GVSU's School of Engineering. Given that the experiences of

students entering GVSU through the HBCU/HSI consortium would be used to shape agreements with new consortium members and update existing ones, two distinct groups were surveyed separately: those from the consortium and those who applied to the MSE program from non-engineering majors outside of the consortium, primarily from other disciplines at GVSU.

The surveys addressed several key areas, including the students' initial interest in studying engineering, their level of familiarity with the engineering profession and curriculum, and their perceptions of emotional, financial, and academic support received. Additionally, the surveys inquired about the impact of graduate assistant (GA) responsibilities on their confidence, their experiences with social adjustment to GVSU's graduate program, how they have been treated, and overall satisfaction. Respondents were also asked to highlight areas of difficulty and provide feedback on any aspects of their transition from a non-engineering major to the MSE program. The graduate engineering program at GVSU offers 18 different GA positions for graduate students during the academic semesters. These positions may be either a half-GA (the most common) or a full-GA. A half-GA for a semester entails working 10 hours per week and includes a compensation of 4.5 credits of tuition payment, along with a \$2,000 stipend. A full-GA doubles this compensation for 20 hours of work per week. The range of GA positions encompasses various responsibilities such as outreach with local high schools, involvement with First Robotics, assistance in the School of Engineering's machine shop and labs, participation in various projects, dedicated lab maintenance, grading for freshman courses, and support for the HBCU pipeline. Currently, students at GVSU from the HBCU consortium are engaged in GA roles related to freshman course grading, First Robotics, and support for the HBCU pipeline.

When students were recruited to participate in the survey, they were given the option to choose their preferred method: completing the survey in person with a faculty member overseeing it, participating via Zoom with a faculty member overseeing it, or receiving the survey via email, completing it, and returning it by email. Regardless of the chosen format, all participants were briefed on the purpose of the survey and how their responses would be used. A consent form was signed prior to completing the survey. The announcement email, consent form, and the survey itself were all approved by GVSU's Institutional Review Board (IRB).

A total of five students who arrived at GVSU through the HBCU/HSI consortium to pursue MSE completed the survey (nine of them were invited to participate), and the results are discussed below. For the other group who were not part of the consortium, a total of seven students were invited to participate in the survey, and four of them completed it. A limitation of this study is the small sample size; therefore, broad conclusions cannot be drawn from this study. However, it does help the authors understand certain factors affecting these students during their transition, which allows recommendations to be made to the Graduate Committee for implementation in the future.

Results and Discussion

Of the five students from the HBCU/HSI consortium, three of them have an undergraduate degree in mathematics while the other two have engineering technology backgrounds. For the non-HBCU students, two of them are from mathematics while one is from molecular biology, and one is from occupational health and safety management. The survey results from the

students who joined GVSU via the HBCU consortium revealed that the lowest ratings were in the areas of support for minority students and socially adjusting to GVSU, with average ratings of 2.2/5.0 and 2.0/5.0, respectively. Additionally, there were relatively low ratings for feeling academically and emotionally supported during their first semester at GVSU, scoring 2.4/5.0 and 2.6/5.0, respectively. For example, three students noted that integrating into their new environment was a challenge, i.e., low sense of belonging. While they arrived at GVSU as a cohort, one student indicated that they only had one class together (due to several sections being offered concurrently), resulting in limited cohort bonding. Furthermore, the HBCU students also faced challenges connecting with other classmates who had already formed study groups. GVSU is a predominantly white institution (PWI), and these results clearly indicate that more support structures are required to improve the sense of belonging, especially for minority students. This is reinforced by the fact that none of these concerns are present when examining the responses from students who are not part of the HBCU pipeline. The non-HBCU students felt emotionally supported (4.0/5.0); academically supported (4.3/5.0); that GVSU had adequate infrastructure support (4.0/5.0); and that they received sufficient personal guidance in socially adjusting to graduate school (3.5/5.0).

Moving forward, the GC proposes the following: (i) Structure the curriculum such that students from the consortium take as many foundational classes as possible together; (ii) Ensure that the faculty mentor assigned to the student shares the same specialization; (iii) Hold a faculty mentor training session to inform mentors about existing resources and develop empathy towards their mentees; (iv) During the summer orientation, connect the consortium students with student tutors in the foundational courses; and (v) Organize more frequent cohort activities to foster a stronger sense of belonging within the academic community.

Both groups of students felt financially supported during their first semester at GVSU. The HBCU group reported an average rating of 4.6/5.0, while the non-HBCU group had an average of 3.8/5.0. Furthermore, there was a strong sentiment that attending GVSU was a life-changing experience regardless of their academic performance, with an average rating of 3.8/5.0 (HBCU) and 4.0/5.0 (non-HBCU). The high rating for feeling financially supported likely stemmed from all students (except 1 from non-HBCU group) receiving graduate assistantships. When asked if their graduate assistant (GA) duties negatively impacted their confidence, the average rating was 1.8/5.0 (HBCU) and 1.5/5.0 (non-HBCU). Conversely, when asked if their GA duties boosted their confidence, the average rating was 4.0/5.0 (HBCU) and 3.5/5.0 (non-HBCU). Moreover, when asked about the appropriateness of their GA duties relative to their knowledge and background, the average rating was 3.4/5.0 (HBCU) and 4.5/5.0 (non-HBCU). Thus, it appears that the GA responsibilities not only financially supported the students but also utilized their existing knowledge and background to positively impact their confidence. The full table of numerical ratings for both groups of students is given below in Table 4.

Moreover, the students were also asked to identify reasons for their challenges at GVSU. Options included: *No appropriate academic background*; *Pace*; *No peer study group*; *Academic workload*; *Other* (with space to provide details); and *Not applicable*. They were encouraged to select all applicable options. Of the five HBCU respondents, four cited lack of an appropriate academic background as a struggle, and four mentioned pace as a challenge. Three respondents noted the academic workload, while two identified the absence of a peer study group.

Additionally, one student mentioned a lack of time to dedicate to courses as a challenge. The lack of appropriate academic background was the most prevalent challenge for HBCU students. The struggles were most common in their foundational classes, which requires a sound knowledge in math and physics. The solution to this issue requires a joint effort between GVSU and its partner institutes; therefore, a team of faculty members from both sides are in talks to develop a better plan moving forward. For the non-HBCU students, the major common concern was the academic workload and not the academic background. The academic workload is the common concern for both groups, and this is expected given the crunched timeline. In the future, it is recommended that the Graduate Program Director discusses with each onboarded student their academic workload and strategically reduce the credits per semester so as to reduce the academic workload early on in their graduate journey. This may delay graduation by a semester but does avoid academic burnout.

Table 4: Survey results for students pursuing their MSE through the HBCU Consortium

HBCU Consortium Students		Non-HBCU Students	
Questions on Likert Scale (1=low ; 5= very high)	Average Score	Questions on Likert Scale (1=low ; 5= very high)	Average Score
What was your level of interest in your current major before joining GVSU?	4.0	What was your level of interest in your current major before starting the Master of Science in Engineering (MSE) program?	4.3
How much did you know about a typical curriculum for your current major before joining GVSU?	3.0	How much did you know about a typical curriculum for your current major before starting the MSE program?	3.0
How much do you know about the profession in your current major?	3.6	How much do you know about the profession in your current major?	4.5
How academically prepared were you to assume graduate assistant (GA) duties in your first semester at GVSU?	4.4	How academically prepared were you to assume graduate assistant (GA) duties in the first semester that you received GA duties in the MSE program?	3.5
Did the first semester GA duty negatively impact your confidence?	1.8	In the first semester that you received GA duty, did the GA duty negatively impact your confidence?	1.5
Did you feel emotionally supported during the first semester at GVSU?	2.6	Did you feel emotionally supported during the first semester in the MSE program?	4.0
Did you feel financially supported in the first semester at GVSU?	4.6	Did you feel financially supported in the first semester in the MSE program?	3.8
Did you feel academically supported in the first semester at GVSU?	2.4	Did you feel academically supported in the first semester in the MSE program?	4.3
Did the first semester GA duty boost your confidence?	4.0	In the first semester that you received GA duty, did the GA duty boost your confidence?	3.5
How worried are you about your financial situation for the upcoming semester(s)?	2.4	How worried are you about your financial situation for the upcoming semester(s)?	2.0
Do you feel GVSU has adequate infrastructure to support minority students?	2.2	Do you feel GVSU has adequate infrastructure to support you as a student?	4.0
Did you get sufficient personal guidance/counseling in socially adjusting to GVSU?	2.0	Did you get sufficient personal guidance/counseling in socially adjusting to graduate school?	3.5
Do you feel like people at GVSU treated you fairly irrespective of academic performance?	3.4	Do you feel like people at GVSU treated you fairly irrespective of academic performance?	4.3
At this point, do you feel like coming to GVSU was a life changing positive experience irrespective of your academic performance?	3.8	At this point, do you feel like enrolling in the MSE program was a life changing positive experience irrespective of your academic performance?	4.0
Did you feel like the first semester GA duty was appropriate to your knowledge and background?	3.4	Did you feel like the first semester GA duty was appropriate to your knowledge and background?	4.5

Students were also encouraged to provide comments for improvements based on their experiences to date. Portions of the individual student responses are given here.

HBCU consortium students:

“Underprepared for GA work due to environment. More transparency into undergraduate courses. Struggle with speaking to classmates since they have already taken classes together.”

“More inviting study spaces. Unable to develop student groups. Fellow HBCU peers only had 1 class together. Assign faculty mentor in that discipline (same as student’s).”

“Workload is mentally draining. Not many supports for minority students. Summer program was good.”

“Summer program was a good decision. During recruitment have student panel consisting of HBCU students and others in addition to faculty mentors. Communication between department staff and consortium must be clear and more frequent.”

“Although I was aware of the cultural climate, it was still challenging when getting there. Be more detailed and transparent about GA contracts. Do not have a central advisor and connect us better with resources.”

Non-HBCU students:

“I think if I had been informed that this kind of time commitment would be necessary to succeed, I would have been a little bit more prepared for it. In situations where students are uncertain about their career goals, encouraging them to promptly define their aspirations—while offering guidance on specific course paths aligned with various career options—could greatly aid their decision-making process. And to choose their classes correctly, they should be informed about all the options and classes available to them. Overall, my experience at GVSU has been great.”

“My only two issues were not having a wide variety of courses offered every semester and limited classes offered in the summer semester.”

“Getting my combined degree program worked out and accepted was a big chore. While I knew that I created my own and thus was the first for many exceptions, it would be great if the process could be made easier for future students.”

“My only real complaint with the MSE program is that I wish the 500 level courses cross listed with the senior level 400 courses had offered more of a challenge and had greater variation from the undergraduate content.”

Career Prospects

Graduate exit surveys from the last 5-6 years have consistently shown that a majority of our MSE students (70%) secured employment in the engineering field immediately after graduation. The remaining students are typically part-time continuing to work at the companies they started at or were hired at companies they did internships with during their undergraduate tenure. A smaller subset of our students (37%) has also reported being offered career advancement opportunities as a result of getting a graduate degree. Most graduates from our program find employment in their respective industries locally, although there are a handful who choose to

pursue PhDs. Notable success stories include a student who co-founded and now serves as CTO for a cutting-edge radiopharmacy and molecular diagnostics and therapy center near GVSU. This student has hired six of our graduates and intends to further leverage our program to foster new industry growth locally. Other alumni are employed across various sectors, including major medical device, furniture, manufacturing, automation, and automotive industries.

Conclusions

GVSU has experienced an increase in interest from students with non-engineering undergraduate backgrounds to pursue a master's in engineering. The Graduate Committee has developed a general plan to onboard students from a variety of non-engineering undergraduate backgrounds. This has allowed GVSU to partner with Historically Black Colleges/Universities (HBCUs) that do not have engineering degrees to provide pathways for graduates from those institutions to pursue a graduate degree in engineering. The onboarding process for the students has been discussed, and students from both within and outside of the HBCU consortium were surveyed to gain insights from their experience transitioning to GVSU. Both groups of students expressed that they were financially very well supported and that attending the graduate program at GVSU was a positive experience irrespective of their academic performance. However, survey results clearly indicated that the HBCU students felt (i) that they were not emotionally and academically supported; (ii) that GVSU does not have adequate infrastructure to support minority students; and (iii) that they did not receive sufficient personal guidance/counselling in socially adjusting to GVSU. These results were in direct contrast to those students who were not part of the HBCU pipeline. While the summer orientation program was praised, this was only a quick fix to a much larger problem that the authors are currently investigating. The students from the HBCU consortium cited lack of appropriate academic background and academic workload as the major concerns, and a team of faculty members from both sides are in talks to develop a better plan moving forward. The non-HBCU students cited academic workload as the major concern. Recommendations to address some identified issues have been included in this paper.

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