REVOLUTIONIZING MSI TO R1 GRADUATE PATHWAYS THROUGH DISTRIBUTED TEACHING

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Abstract

Morehouse College's Dual Degree Engineering (DDE) program has leveraged its relationship with Michigan Robotics to introduce its students to University of Michigan's undergraduate Robotics curriculum through the development of the Distributed Teaching Collaborative (DTC). The DTC connects students and faculty from Historically Black Colleges and Universities (HBCUs) and other minority serving institutions (MSIs) with doctoral universities that have very high research activities (R1 institutions) to deliver a unifying classroom experience, share distribution of resources, and prepare students for careers in AI. Since Fall of 2022, University of Michigan established a Robotics Department with an undergraduate program that emphasizes excellence in equity. A compelling feature of the department is its highly innovative approach to a robotics curriculum that allows for national scalability through collaborative distributed teaching. The curriculum, developed through active partnerships between Michigan Robotics and several MSIs, is adaptable to the teaching styles of MSI faculty, creating onramps to a robust robotics and artificial intelligence education that prepares students for R1 research experiences and graduate programs regardless of their background or where they are enrolled.
The aim of the DTC model is to build MSI-R1 pathways to graduate programs at R1 universities by establishing collaborative teaching courses that have at least a 90% completion rate due to their social- interactions through student-student, student-instructor, and instructor-instructor interactions. The success of this project will be viewed through the number of students that complete DTC courses, matriculate in graduate programs, and maintain successful careers in STEM longitudinally.

Keywords: *Innovation, collaboration, robotics, curriculum.*

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1. Introduction

Since 1969, Morehouse College has offered students the option of studying engineering through the DDE program, which allows them to receive a liberal arts degree from Morehouse and an engineering degree from several engineering institutions with whom Morehouse has a cooperative agreement, including the University of Michigan. Many students choose our DDE program because it allows them to embrace the culture of an HBCU as it instills value of self and confidence, and the opportunity to earn an engineering degree from an R1 institution. Although DDE has been the third largest major at the college for incoming freshmen for the last ten years, very little has been done to update its curriculum since the Cold War ended, which leaves little room to adequately prepare students for rapidly growing technological fields of study.

While our program does well in exposing students to mathematical concepts, principles that govern the universe, and programming languages, little is done to expose our students to the real-world applications of those theories. It has been reported that theory-based courses results in passivity in the classroom, and lack of motivation (Felder, 1993). DDE is the third largest major at the college and yet the retention rate for freshmen DDE students has ranged from 40% - 50% for the past three years. Studies show that poor performance in entry-level science, technology, engineering, and math (STEM) courses is directly proportional to retention in STEM (Dika, *et al*., 2016). With respect to DDE students, less than 40% of Morehouse freshmen are enrolled in Calculus I which ostensibly increases the number of courses they are required to take and therefore prolongs their transfer process. And the longer their process is prolonged, the less likely they are to remain in the program.

The DDE program's relationship with Michigan Robotics has introduced its students to an undergraduate Robotics curriculum through the development of the Distributed Teaching Collaborative (DTC). DTC, established by Michigan Robotics, connects MSI students and faculty with R1 institutions to deliver a unifying classroom experience, share distribution of resources, and prepare students for careers in AI. The curriculum, developed through active partnerships between Michigan Robotics and several MSIs,

is adaptable to the teaching styles of MSI faculty, creating onramps to a robust robotics and artificial intelligence education that prepares students for R1 research experiences and graduate programs regardless of their background or where they are enrolled. Currently, the DTC has three main objectives:

- Develop and offer Robotics courses at MSIs to serve as a pathway to careers in robotics and AI.
- Develop and promote Robotics Research Experiences for undergraduates (REUs) and offer immediate acceptance to MSI students who have excelled in DTC courses.
- Add more MSIs and R1 institution to the DTC.

2. Project goals & approach

The primary goal of the DTC model is not simply to introduce new courses to the DDE curriculum but to change the manner in which they are instructed. Our partnership with the DTC allows our DDE program to reimagine the way mathematics is introduced to engineering undergraduates by integrating various science-based disciplines, thus providing real-world engineering projects. This curricular innovation prepares students to experience computation, mathematics, and science as tools that have them constructing better, safer, more reliable machines while mitigating barriers they may face on the way to a degree.

Studies have identified factors associated with achievement gaps in academic coursework and research experiences supporting scholarly socialization (Posselt et al., 2021). As a result, a longstanding disparity exists in graduate applications and matriculations between undergraduates from MSIs in comparison to other colleges and universities. The introduction of these courses into the DDE curriculum along with the DTC shall address this disparity and produce a replicable model for realizing meaningful systemic change in the innovation ecosystem.

2.1. Distributed Teaching Collaborative

The DTC model promotes social interactions through new student-student connections, as well as student-instructor and instructor-instructor interactions. We wish to underline that courses in the DTC are completely different from massive open online courses. The first two offerings in DTC were ROB 101: *Computational Linear Algebra* in partnership with Morehouse College and U-M Robotics in fall 2020; and ROB 102: *AI and Programming* in partnership with Berea College and U-M Robotics in fall of 2021. Even during the heart of the pandemic, 10 of 10 Morehouse students and 34 of 36 Berea students completed these courses. Remaining at a 90 to 95% level of engagement to completion requires a focus on student well-being and success. There is direct communication with faculty across MSIs and partnering R1s to ensure that students have a connected and supportive experience. Financial and technical support is provided for teaching assistants at MSIs as well as providing access to Michigan teaching assistants throughout the day and late into the evening. Moreover, there is access to chat tools, such as Piazza, that encourage students to help one another.

We predict that we will see improved retention in our proposed robotics curriculum due to increased student self-efficacy about engineering tasks and a decision by students to choose an engineering path, as predicted by expectancy-value theory (Wigfield & Eccles, 2000). We are particularly interested in the concrete nature of our integrated robotics curriculum in attracting students from other majors, such as Computer Science, Math, and Physics.

2.2. Distributed collaborative courses

Table 1 consists of the proposed courses that will be added to revolutionize our DDE curriculum in the upcoming academic years along with its partnered R1 affiliate. Students who participate in integrated engineering curricula tend to have higher retention rates and report satisfaction (Olds & Miller, 2004). Notably, the effect can be measured explicitly for white women and racial minority students (Frair & Watson, 1997) (Quinn, 1995).

EGR 151 Progamming in Robotics: This course is designed to show how mathematics and computation are unified for analyzing data and making discoveries about the world. Linear algebra and programming are rapidly becoming the essential foundation for the modern engineer in a computational world. Our DTC aims to break the stranglehold that calculus has on the success rates of our students. As such, this first year course provides students with insights into the applications of linear algebra and its realization in practical computational tools. The mathematical content covered will be built around systems of linear equations, their representation as matrices, and numerical methods for their analyses. These methods will be given life through projects including building 3D maps for robot navigation from LiDAR data and controlling a planar model of a Segway using optimization, and other compelling applications of robotics. ‘

Table 1. Proposed DDE Courses.

Proposed Morehouse Course	Date of Implementation	Partnered R1 Course	Host R1 Institution/Department
• EGR 151: Programming in Robotics	• Spring 2024	• ROB 101: Computational Linear Algebra	• U-M/Robotics
• EGR 201: Autonomous Navigation	• Spring 2024	• ROB 102: Introduction to AI and Programming	• U-M/Robotics
• EGR 351: Applied Optimal Control	• Spring 2025	• EML 4316: Applied Optimal Control	• FAMU-FSU/Mechanical Engineering

EGR 201 Autonomous Navigation: Students acquire programming skills in the context of robot path planning and navigation which allows robots to observe their environment and then get from point A to point B. The course builds towards providing a broader conceptual foundation for modeling problems as graphs and inferring solutions through search. In artificial intelligence, search algorithms are just as important as data-driven machine learning solutions when it comes to reasoning with machines, and in many cases, a search-based solution is one's best bet. Students will learn about the foundations of modern intelligent systems through the lens of computational and programming tools.

EGR 351 Applied Optimal Control: This course serves as a portal to upper-level mechanical/computer engineering courses with a robotics concentration. It introduces students to numerical applications of optimal control techniques by applying multivariable calculus to a number of dynamical systems. Topics include trajectory/convex optimization, linear-quadratic methods, and model- predictive control with real-world engineering applications.

3. Conclusion

The success of our DTC initiative will be measured by:

- The number of Morehouse students that complete DTC courses.
- The diversity of their majors.
- The number of students that matriculate in graduate programs.
- The number of graduates that maintain successful careers in STEM longitudinally.

By completing one of our DTC courses students will be well-prepared for research experiences across robotics. Students completing multiple DTC courses will have exposure to robotics topics at the level of a common Engineering major – approximately constituting a Robotics minor. We will provide opportunities for Morehouse students who participate in DTC courses to connect with research experiences and maintain a sense of community. For interested DTC partners, we will work to establish best practices for implementing robotics curricula, certifications, and degree programs that leverage DTC courses. We envision that this effort will enable robotics degree pathways to be more widely available to more students at more schools within constraints for manageable teaching bandwidth.

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