

Lowering barriers for marginalized students through equitable multidisciplinary education in Science, Technology, Engineering and Mathematics

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Abstract

At Central Michigan University (CMU), the College of Science and Engineering (CSE) started in 2023 a new undergraduate program called InSciTE (Integration of Science, Technology and Engineering) to provide diverse students with an interdisciplinary, equitable space to explore Science, Technology, Engineering and Mathematics (STEM) challenges and solutions. Designed as a 15-credit certificate that complements existing STEM majors, InSciTE consists of five skill-based courses taken over a four-year period as a cohort. Each course is centered around transferable skills (including collaboration, communication, data and time management) with students driving the content of the course based on their interests. After two years of implementation, InSciTE students have produced research posters, presentations and review papers that exceeded the benchmarks the program established in their course deliverables. The majority of the students demonstrated good interpersonal skills in teamwork contexts and contributed effectively to teams. Moreover, designed upon inclusivity and accessibility, the InSciTE model has increased student motivation and persistence, broadened participation, and advanced equity in STEM. InSciTE cohort demographics showed more diversity than CSE's student body in all marginalized identities. All InSciTE students expressed a strong sense of belonging, and retention percentages in CMU and the program are higher than the institutional averages. Here, we share InSciTE's framework, methodologies, and outcomes aiming to inspire others to adopt similar models to further our disciplines.

Introduction

Complex challenges of the 21st-century increasingly demand multiscale and cross-disciplinary solutions [1], [2], [3]. To address these challenges, Science, Technology, Engineering and Mathematics (STEM)-focused industries and organizations are looking to hire diverse employees who are equipped with transferable skills [4], [5], [6], [7]. However, successful interdisciplinary work requires new approaches to STEM education that go beyond the typical university curriculum and focus on developing skills to effectively communicate across disciplinary boundaries and to integrate expertise [8], [9], [10]. Moreover, historical biases, both conscious and unconscious, have rendered the STEM community less diverse than the surrounding world, which, among other challenges, limits the potential for innovation.

Pedagogical approaches to teach transferable skills exhibit a high degree of variability that ranges from offering stand-alone courses that are discipline specific to internships and capstone projects [11]. Few institutions have embraced innovative methods to prepare students to construct their own knowledge, cross disciplinary boundaries and use their learning to make an impact in the world. Notable examples are the Olin College of Engineering, who emphasizes

multidisciplinary, experiential, project-based learning in their programs [12], and the University of Massachusetts Amherst, who pioneered a certificate that uses interdisciplinary team-based learning to address complex real-world problems [13].

At Central Michigan University (CMU), the College of Science and Engineering (CSE) has implemented a new model for undergraduate STEM education called InSciTE (Integration of Science, Technology and Engineering) to provide diverse students with an interdisciplinary, equitable space to explore STEM challenges and solutions. InSciTE adopts a less common strategy of a multi-year, multi-course approach to teach transferable skills in STEM while enabling intentional support of marginalized students, including non-white, LGBTQ, first generation, and/or low-income students. Designed as a 15-credit certificate to complement existing STEM majors, InSciTE consists of five skill-based courses taken over a four-year period as a cohort. Students from all STEM fields collaborate on research projects driven by students' interests in an active learning space. Successful implementation of InSciTE is leading to 75 new scientists and engineers per year whose education is encoded with a broader way of thinking. We present here a summary of the program creation and its strong multidisciplinary approaches while highlighting key equitable pedagogical practices at the core of the program. We share results from two years of implementation with more than 75 STEM students that highlight the success of this interdisciplinary equitable model to STEM education.

1. The InSciTE model

1A. The InSciTE mission, values and program objectives:

InSciTE was created in Spring 2022 from a coalition of 14 faculty from all 9 academic departments at CSE to form a truly multidisciplinary council. The council is formed by faculty with diverse ethnic and intersectional identities, a reflection of the authentic partnership and leadership of faculty impacted by enduring inequities in STEM and of the ethos of InSciTE. The council guided the creation of the program with all decisions reached through consensus building. The council defined the mission of the program as “to create an equitable student-driven environment for undergraduate students to develop skills on interdisciplinary communication, collaboration and real-world problem solving to become culturally competent and effective leaders”. To achieve the program mission, the council adhered to the core values of equity, collaboration, relevance to real-world problems, being learner-centered and supporting creative problem solving. Five assessable program objectives were developed, which are:

Collaborate successfully: Students develop professional relationships and work together in diverse teams to achieve a common goal.

Communicate effectively: Students express ideas effectively to both technical and general audiences through oral, written, and visual media; students listen actively to provide and receive constructive criticism.

Employ processes to achieve desired outcomes: Students decompose a problem to explore, design, and implement creative solutions, continuously evaluate progress, and navigate uncertainty.

Develop scientific habits of the mind: Students apply scientific content from diverse fields to appropriately design experiments, gather and manage data, analyze and draw conclusions.

Develop personal and professional identities: Students reflect upon their experiences to further their sense of self in order to become confident career-ready leaders.

1B. The InSciTE model

To accomplish the program objectives, InSciTE was designed as a stand-alone undergraduate certificate housed by CSE. This provides the independence and flexibility necessary to navigate the barriers that marginalized students face in academia and led to the successful implementation of a model that follows ‘radical pedagogy’ [14], [15]. InSciTE combines students’ technical excellence with skills that promote equitable practices and civic engagement, including conflict resolution, communication, collaboration, and scientific habits of the mind [16], [17], [18]. The certificate structure enables the program to be independent from majors or departments while being highly visible on a student diploma. Students take one course every spring as a cohort until their senior year, during which they complete an interdisciplinary, team-based research project (Figure 1). Each course is centered around students acquiring transferable skills, often referred to as the “21st-century skills” [19], [20], with students driving the course content based on their interests.

1C. Academic strengths of the InSciTE model

InSciTE is designed with strong pedagogical theory at its core, building on the Process Oriented Guided Inquiry Learning (POGIL), design thinking and Universal Design for Learning (UDL) pedagogies. POGIL has been established as an effective problem-solving pedagogy that relies on teamwork [21], [22]. Design thinking is a mechanism for problem solving that promotes inclusivity, incorporates empathy, and is holistic and content agnostic. Design thinking pedagogy involves students practicing transferable skills such as collaboration among multidisciplinary teams, strong communication skills, iteration through prototyping, and systems thinking [23], [24]. InSciTE expands on the POGIL and design thinking pedagogical models to foster a collaborative environment, where each voice brings a different perspective and is valued.

In each InSciTE course, groups of four to five students tackle authentic STEM challenges [25] following established norms [26], [27] and explicit structures in the groups [28]. Social and conflict resolution skills are introduced, reinforced, and practiced using active listening [29], [30], [31], accountability for addressing structural inequalities, and mindful consideration of viewpoints and effective communication [27]. Since the instruction is centered on skills, students drive the content of the instruction, leading to not only higher student engagement, but also opportunities to develop a stronger STEM identity [32] and a stronger sense of belonging [33], [34].

PROGRAM MISSION: To create an equitable student-driven environment for undergraduate students to develop skills on interdisciplinary communication, collaboration and real-world problem solving to become culturally competent and effective leaders.

INPUTS

FUNDING

- Applied to NSF-IUSE funding for assessment work and dissemination
- Sustained by tuition within 3 years
- Extensive external donor network

EXPERTISE

- Interdisciplinary faculty council as oversight and guidance
- Team instruction by faculty from multiple departments within STEM
- Faculty from multiple colleges within the university providing intervention and guidance

DIVERSE STUDENT BODY

- Recruitment of student identifying as first gen, financial risk, LGBTQA+, academic risk, historically marginalized, with disabilities

INSTITUTIONAL SUPPORT

- In-kind contributions from college, program director, and assessment coordinator
- Support from upper administration (Provost and University Board of Trustees)

EXTERNAL INVOLVEMENT

- Local industry partners offering people, problems, internships

PROGRAM VALUES:

EQUITY RELEVANCE TO REAL-WORLD PROBLEMS LEARNER-CENTERED
COLLABORATION CREATIVE PROBLEM SOLVING

PROCESS: 15-credit undergraduate certificate

InSciTE 1 1st year spring semester

- Introduce all skills, with a focus on collaboration and conflict resolution
- Student-driven case studies
- Team-based pedagogy

InSciTE 2 2nd year spring semester

- Skills focus on communication
- Reinforcement of collaboration and conflict resolution skills
- Student-driven case study design
- Team-based pedagogy

InSciTE 3 3rd year spring semester

- Skills focus on project management and data skills
- Student-driven affinity teams to solve current STEM problem

InSciTE 4+5 4th year fall & spring capstone experience

- Authentic research experience
- Affinity-based team
- Teams pitch project to faculty mentors that need to buy in (shark-tank model)
- Authentic deliverables

OUTPUTS

SUCCESSFUL STEM LEADERS: 50-75 students graduate each year that:

- Collaborate successfully
- Communicate effectively
- Employ processes to achieve desired outcomes
- Apply scientific habits of mind
- Develop personal and professional identities

KNOWLEDGE OUTCOMES:

- Dissemination in peer-reviewed journals and national conferences
- Identification of key pedagogical factors essential to a culture of belonging in STEM to allow skill building
- Replicable model for other institutions shared regionally

CULTURE SHIFT AT CMU:

- 20-30 within-college faculty involved in InSciTE yearly
- Faculty improve pedagogical skills in all courses
- Increased overall retention
- Leadership in DEI initiatives

BROADER IMPACTS

- Empowerment of STEM students
- Increase diversity in the work force
- More skilled workforce
- Improved student retention and job placement
- Change in culture within university

Figure 1. Logic model for the InSciTE program, highlighting inputs, processes and outputs.

Each InSciTE course introduces and puts into practice a specific set of transferable skills that are generalizable to all STEM fields. These skills progressively build on each other as students complete the certificate (Figure 2). In the first InSciTE course, students learn how to collaborate in diverse teams. This includes explicit teaching of conflict prevention and resolution, value work, and active listening. Students are also introduced to STEM research and complete their first research projects. In this process, students also gain skills in oral communication. In the second InSciTE course, students continue to build on their collaborative skills by working on a new project in a new team. This course emphasizes formal written communication and is a writing-intensive course. Students complete a full review paper on the interdisciplinary STEM challenge of their choice, addressed to a scientific audience. They then present the same topic in a 5-minute film that is showcased in a film festival at the end of the semester and is open to the public. With these two deliverables, students practice communication for different target audiences. In the third InSciTE course, students build on collaboration and communication skills and acquire quantitative skills of data analysis, data interpretation and presentation while working with yet a different team on a new project that involves databases related to the topic of their choice. This course also explicitly addresses project management skills. The certificate culminates with a 2-semester research capstone project, where students in teams complete a full STEM project of their choice, which includes a research proposal, a grant application, an oral presentation and a research paper. In this capstone project, students have the freedom to choose their team members. At this point, the cohort has spent 3 years building relationships and professional interests and skills. By choosing their teammates, the students have the opportunity to create a team with the students that will bring the necessary skills and leadership that their project requires.

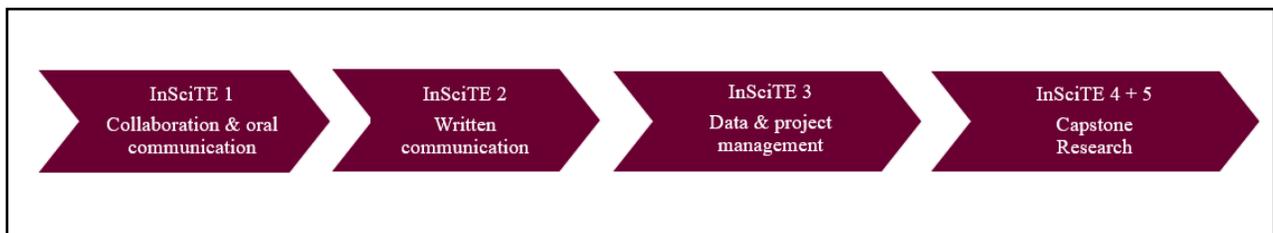


Figure 2. Course sequence in the InSciTE certificate. Each course in the sequence addresses a specific transferable skill set that builds as students progress through the model.

The deliverables in each InSciTE course are concrete, tangible projects that students can include in their professional portfolios and resumes, such as research posters, prototypes, research papers, and grant proposals, or professional development-oriented deliverables aimed to help the students achieve their professional goals, such as resumes, internship applications or graduate school applications (Table 1).

Table 1: Deliverables in each InSciTE course. The type of deliverable is either an individual professional development-oriented deliverable, a group deliverable, which is shared with the class, or a public group deliverable, which is public-facing and shared with the class and a larger community. Public-facing presentations often include prototypes created by the students.

InSciTE course	Deliverables completed during the course	Type of deliverable
InSciTE 1	Research presentation Research poster presented at a public session	Group deliverable Public group deliverable
InSciTE 2	Scientific review paper 5-min film sequence Resume	Group deliverable Public group deliverable Individual professional development
InSciTE 3	Data reports shared externally Data report presentations Capstone project pitch Summer internship application	Public group deliverable Group deliverable Group deliverable Individual professional development
InSciTE 4	Formal pitch at public session Research proposal Grant proposal Resume / Curriculum Vitae	Public group deliverable Group deliverable Public group deliverable Individual professional development
InSciTE 5	Research paper submitted to undergraduate journal Public presentation/poster at conference of choice	Public group deliverable Public group deliverable

2. The multidisciplinary nature of the InSciTE model

InSciTE is intentionally multidisciplinary, starting with its creation and through the projects completed by students, incorporating not only different STEM disciplines but also different perspectives. We describe below the aspects that make InSciTE truly multidisciplinary.

2A. The multidisciplinary nature of InSciTE students

Since students come from a variety of majors and take InSciTE courses together, the courses provide opportunities for students to tackle STEM problems in which they are invested in a truly multidisciplinary way. Students from the 2023 pioneer cohort came from 12 STEM majors, while students from the 2024 cohort came from 16 majors, all within the 9 departments in CSE. In each InSciTE course, students work in diverse teams across majors to complete deliverables (see Table 1).

2B. The multidisciplinary nature of InSciTE research projects

Because students are placed in truly multidisciplinary teams in InSciTE courses, the projects they choose are multidisciplinary in nature. InSciTE students have now produced and presented publicly 44 deliverables in InSciTE 1 and 2 courses. Projects cover a wide range of topics from Artificial Intelligence to water quality, wind farms, and artificial limbs (see Figure 3 for examples of 2024 projects). Because of the wide range of expertise required to advise students through their projects, students contact CMU and external experts. This has resulted in a highly diverse group of mentors advising InSciTE students, from faculty members not only across CSE, but across all colleges and offices in the university, to external organizations and companies. Notable examples are students working with the admissions office to increase the recruitment of transfer students, students traveling to Lake Superior to do geological research, and students working with local farmers to document the implementation of sustainable farming practices.

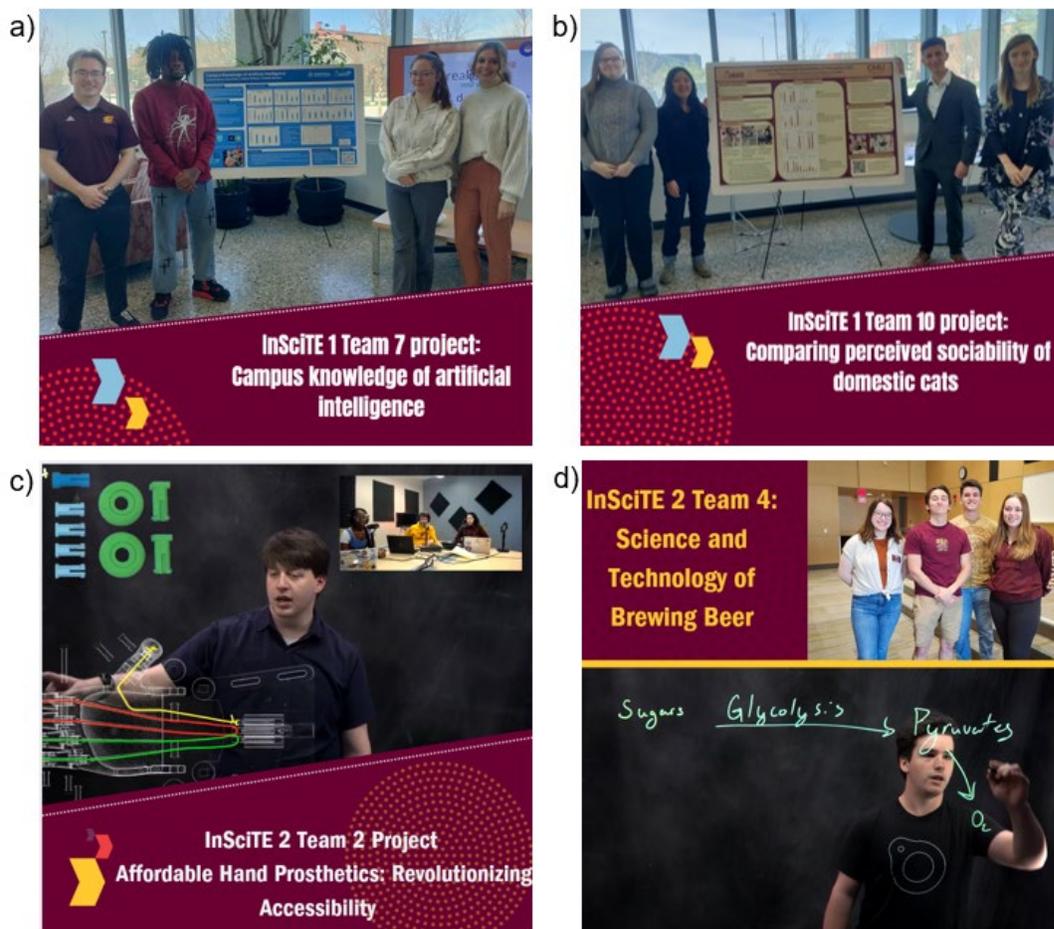


Figure 3. Examples of projects and deliverables created in InSciTE 1 (3a, 3b) and 2 (3c, 3d) courses in 2024.

2C. The multidisciplinary nature of InSciTE faculty

2Ci. The InSciTE Multidisciplinary Council

The InSciTE Multidisciplinary Council is the governance body of the InSciTE model. The council was first established in January 2022 to create the InSciTE program as a truly collaborative process and has since expanded. The council has members from all nine departments of the College of Science and Engineering, staying consistent with the multidisciplinary nature of the model. The council is charged with overseeing all the aspects of the InSciTE model. This includes serving as the main academic body of the program, assisting the InSciTE director in maintaining the vision and values of the program and providing input and advice regarding the evaluation of the program. The council achieves these tasks by reviewing student applications and assessment reports and providing feedback on the functioning of the model.

2Cii. InSciTE Teaching Fellows

InSciTE courses are taught by a multidisciplinary team of InSciTE Teaching Fellows. The current team is formed by 7 faculty members from 5 different departments within CSE. Each

InSciTE course is team-taught by 2 to 3 faculty from at least two different departments to model multidisciplinary professional collaboration [35]. CSE covers the replacement costs of the faculty to the faculty's home department to ensure high quality teaching (as opposed to "dividing" loads when team-teaching, a practice that does not support equity [36]). Faculty are selected via an application process consisting of short essays asking them to reflect on cross-departmental collaboration and expertise with student-driven instruction [37]. Regardless of experience, all InSciTE faculty receive extensive training before starting to teach in InSciTE to ensure that inclusive teaching practices are implemented. As course preparation, faculty teams work on conflict prevention and resolution, values, and active listening and create a Collaborative Teaching Agreement that ensures the continuity of the InSciTE model.

2Ciii. InSciTE partnerships

It is common practice in InSciTE to resort to experts outside faculty's disciplines and areas of expertise. As such, partners, guest lecturers, and invited speakers from a wide variety of fields are frequently involved with InSciTE and interact with students. These partnerships have been key in expanding the model to involve other colleges within CMU. For instance, InSciTE has a partnership with CMU's Institute for Transformative Dialogue which delivers a conflict resolution workshop in InSciTE 1. CMU's Center for Excellence in STEM Education provides the infrastructure for our students to practice design-thinking inspired challenges and a space to create, innovate and interact. The Educational Leadership program provides training to InSciTE faculty. Multiple invited speakers visit InSciTE courses, ranging from faculty to athletics administrators and university vice-presidents.

2D. The multidisciplinary nature of the InSciTE administration: leveraging distributed leadership

The daily operations of the InSciTE model are carried out by the InSciTE director (W. Pangle, a faculty in Biology) assisted by I. Marquez (an engineering faculty member) along with two undergraduate students (one majoring in computer science, the other in Biology and Business). Daily tasks range from analyzing assessment data to purchasing supplies for InSciTE's community building events. The InSciTE director also works closely with CSE's assessment director to manage the assessment plan of the model. Faculty in Educational Leadership advise on activities regarding the scholarship of teaching and learning and the intentional training of InSciTE Teaching Fellows. The InSciTE council provides accountability and oversight on the yearly assessment report. As InSciTE aligns closely with key priorities in CMU's and CSE's strategic plans, including expanding multidisciplinary opportunities to meet critical societal challenges and improve belonging culture [38], [39], InSciTE is strongly supported by CMU's administration. As such, the program director has frequent communications with CMU's Board of Trustees and the Provost. The program also has a close collaboration with several administrative offices across campus. For instance, the admissions office uses InSciTE as a recruitment tool and the program is represented in all recruitment activities. This coalition of partners and the leveraging of distributed leadership at all levels of the institution has led to a deep anchoring of InSciTE within the institution in just a few years [40].

3. Equity measures established in the InSciTE model

STEM fields have a long history of inequity ([41], [42], [43], [44]; reviewed in [45]) that is perpetuated in higher education [46], [43]. The InSciTE model is built on core values of equity and accessibility to explicitly address the discrimination historically inherent to STEM fields. We centered our focus of equity on three areas, recruitment, programming, and support, in which measures are taken to model what programs can achieve when built on anti-discrimination theory.

3A. Recruitment

Recruitment efforts target marginalized student populations with a focus on making personal connections with students. Both InSciTE faculty and current InSciTE students participate in recruitment activities to ensure that students' voices stay centered in the program. Assisting students with the application process avoids gatekeeping practices in the admission process that perpetuate homogeneity in the student body [47], [48]. For this, application workshops, led by current InSciTE students, are offered each fall ahead of the application deadlines. The application itself relies on non-discriminatory measures by being explicit in intent and prioritizing the potential for growth and accomplishments within our program rather than instituting GPA requirements or prior academic or extracurricular achievements [49], [50], [51]. The application is also designed to provide format flexibility, minimize stereotype threat, and encourage students with diverse backgrounds. Students are accepted into the program during the fall of their first year and complete it as a cohort. Cohort models create learning communities that increase student retention and sense of belonging, satisfaction, and engagement [52], [53], [54]. Transfer students can also join the program by taking two InSciTE courses simultaneously to complete the program in a shorter timeframe, which we have implemented successfully with two transfer students that will be graduating in Spring 2025.

3B. Programming

InSciTE follows evidence-based best practices for inclusive teaching [55], [56], [57] to foster a climate of belonging for all. Student learning objectives are centered on skills, rather than content, so that content can be student-driven via case-based learning [58]. Empowering students to drive the content of a course has been shown to ensure equitable opportunities [59], [60] and embed the curriculum with culturally relevant content. All courses follow the premise of UDL [61] to create an accessible learning environment that benefits all students. Emphasis is placed on equity in course development: each course has specific equity-driven assignments, built-in scaffolding for rubrics, and specific case studies that contain social justice components in STEM. Faculty and staff receive professional development workshops on inclusive teaching pedagogy and UDL in the classroom to support this culture [62], [63], [37], covering topics that include how to design truly accessible materials, avoid unconscious biases, and support all learners [64]. Before joining InSciTE, faculty reflect on their own biases and commitment to learning. Grading is based on student-written rubrics developed by consensus building [65] and adapted from the Association of American Colleges and Universities (AAC&U) VALUE Rubrics [66]. Grading takes the form of extensive feedback and is determined by effort and demonstration of growth.

All InSciTE courses share a common structure that maintains InSciTE's multidisciplinary, equitable, skill-based model without limiting academic freedom or imposing teaching styles. This common structure includes:

- Creating a social contract and outlining community rules that include students and instructors. This social contract is reviewed often during the semester and updated as necessary.
- Establishing diverse teams, maintained throughout the semester, that are formed by faculty following strategies for equitable group work [67], [68], [69]. Each team creates a group contract that is revised and updated as needed. Groups have multiple opportunities for feedback and reflection in project progress reports that are submitted weekly.
- Using deliverables as assessment tools for project-based learning. The expectations of these deliverables are explicit and tied to specific learning objectives. The learning objectives are continuously shared with students as well as their relation to each of the activities and deliverables in class.
- Grading is based on a non-punitive model without strict deadlines. Because the majority of assignments are submitted as a team and are related to progress in their project, students are aware that not completing assignments or missing class will affect the progress of their project. Students are always given the chance to submit later or do make-up work when a class is missed. Since students are invested in their project and have a social contract with their team, conflicts regarding late submissions or the share of work are not a common experience.
- Using a live student response system during class to allow multiple formats of participation and provide anonymity [70].

3C. Support

InSciTE is centered on multiple lines of marginalized student support that are implemented both in and outside the classroom environment [71].

3Ci. Mentoring is underacknowledged in its role to support and cultivate a sense of belonging and realize the potential of marginalized students [72], [71]. We developed a mentoring system where students in years 3 and 4 of the program mentor students in years 1 and 2, with formal training for mentors and support from faculty.

3Cii. Advising in InSciTE is individualized and student-need based, informed from applications, student surveys and assessment data. InSciTE faculty first build relationships, then dedicate significant time with the students to ensure that they are navigating their degree with all the support necessary [71]. Support includes helping declare a major, navigating general education requirements and competencies necessary for graduation, contacting potential research mentors to join research labs, reviewing applications for internships, sharing funding and job opportunities.

3Ciii. Professional development retreats are held every year for InSciTE students that have completed one course within the program. Students and all InSciTE teaching faculty spend three days at CMU's remote Biological Station on Beaver Island, MI, for community building and individualized student professional development. Faculty complete training, including on UDL, STEM equity and SafeZone while at the retreat. One of the cornerstones of the retreat is the marginalized student panel where students can share their stories and experiences with all participants.

3Civ- Scholarships for students to cover the cost of the 15-credit certificate are key for InSciTE equity measures. It is well documented that financial strain can deeply impact the persistence of marginalized students in higher education (e.g., [73]). As such, it is essential to make the InSciTE program as less financially burdensome for students as possible, which we approached from two sides. First, InSciTE was created to have all its courses ‘double count’ for specific general education requirements. Second, with donors and industry partners’ financial contributions, 20% of our InSciTE students have received scholarships so far – given solely based on financial needs - to cover the costs of InSciTE courses. We are continuing to build relationships with external partners to increase the percentage of students receiving scholarships for InSciTE.

3Cv- Shared space: InSciTE students have access to an InSciTE room at all times, which consists of a space where students can study, have project meetings or spend leisure time. The room has tables, desks and bookshelves with books and board games that students can borrow. There is also a microwave and a resource cabinet with new clothes, personal care products and non-perishable food. Students can freely take items from the resource cabinet and the cabinets are restocked as needed.

3Cvi- Community building activities are organized throughout the semester to provide opportunities for students to build and strengthen relationships. Some activities also include the faculty and the council. Many of these activities are proposed by the students, including trick or treating in InSciTE faculty offices during Halloween and game nights. At the end of the Fall semester there is also a welcome reception for the new cohort of students that includes all InSciTE students and faculty.

4. Assessment of the InSciTE model

We built a comprehensive assessment plan that would allow us to collect rigorous data, learn from the model and improve continuously. The information gathered for the assessment plan consists of a combination of quantitative data (from course assessments and program achievements) and qualitative data (from surveys and reflections), both direct (from courses) and indirect (from student achievements [74]). This mixed-method approach has been strongly recommended to avoid the misrepresentation from biased analyses of quantitative data common in STEM fields [74]. We present here the core of our assessment plan per course, followed but the longitudinal approach to assess the model and future directions.

4A. Assessment plan for each InSciTE course:

InSciTE courses follow a core assessment plan that consists of five elements, developed below.

4Ai: Deliverables: In collaborative teams, students complete deliverables such as data reports, presentations, podcasts, prototypes, infographics, posters, and pitches to communicate their ideas and findings (see Figure 3 for examples and Table 1 for the full list of deliverables). Expectations from each deliverable are clearly presented, with rubrics built with students and adapted from AAC&U VALUE rubrics [66].

4Aii: Progress reports: Each week, students complete team progress reports that communicate progress on projects, including challenges, successes, next steps, and reflection questions. This is the key assessment component of the InSciTE course model: students receive weekly feedback from course instructors, which provides progressive scaffolding to achieve the high standards of deliverables.

4Aiii: Reflections: Students reflect on their work, growth in the course, and contribution to a team both before, throughout and after each course. Students are presented with a framework for reflections to provide guidelines for meaningful reflections [75], [76].

4Aiv: Surveys: Students are surveyed before and after each InSciTE course. The surveys are adapted from validated survey instruments to evaluate changes in students' attitudes and self-assessments from program entry to program completion. Students' STEM identity and scientific habits of the mind are evaluated based on the STEM Professional Identity Overlap Measure [77] and the Project Ownership Survey [78] throughout the program. Surveys are spaced in time to minimize survey fatigue.

4Av: Comprehensive Assessment of Team Member Effectiveness (CATME) is a system developed by Purdue University to help manage and improve team-based learning and collaboration in educational settings [79]. It is widely used in academic institutions for assessing and supporting teamwork in classes, particularly in engineering and other collaborative disciplines [80]. CATME provides a structured approach for team members to evaluate each other's contributions to the group following five Teamwork Dimensions: contributing to the team's work, interacting with teammates, expecting quality, keeping the team on track, and having relevant knowledge, skills and abilities. The system is aligned with educational goals to prepare students for real-world team dynamics and improve their ability to work effectively in diverse groups. In InSciTE, students complete the CATME assessment mid-way and at the end of each course.

This level of assessment is intensive but realistic as each InSciTE course is team-taught by two or three instructors. In addition, due to the high hands-on content of the courses, InSciTE instructors are freed from typical lecture preparation and heavy grading; instead, faculty spend time providing in-depth feedback to each team of students.

4B. Longitudinal assessment across the program duration

With the InSciTE model following a cohort structure, we closely interact with InSciTE students through their university career. We have implemented a longitudinal data collection process that will allow the assessment of the program objectives and student achievements and success before and after the program. Because InSciTE is built on student voices, students determine what constitutes success for them [81]. Reflecting on the definition of success is critical to this work, with the literature dominated by implicitly discriminatory measures and a lack of student voices [81]. While we consider traditional measures of success like retention and placement rates, we also consider non-traditional measures of success such as the growth exhibited by students in the program, gaining leadership skills, building career networks, and desired job placement after graduation.

In addition to these measures, we examine the actual skills and growth obtained by students throughout the program. Assessment data collected from each course (as outlined in section 4A) is analyzed longitudinally to determine improvement in students' collaboration and project

management skills. Additionally, we assess students using adapted validated survey instruments to evaluate changes in students' attitudes and self-assessments from program entry to program completion. Finally, we examine scientific habits of the mind in short team-based challenges at CMU's Center for Excellence in STEM Education. This assessment consists of one-hour design-thinking challenges provided to randomized teams of InSciTE students at the beginning and end of the program. To make the assessment unobtrusive, we video-record the in-person sessions taking place at the Center and use the video-recordings and associated transcripts as the basis for the content analysis [82]. The content analysis assesses the ability of team members to ideate as a team (including working through the ambiguity of identifying a problem [83]) and the collaborative nature of the team (including recognizing team members' expertise) when designing a prototype. This provides a thorough evaluation of the skills gained in InSciTE by each student, which we can compare to control groups of CSE students that have not participated in the InSciTE model.

4C. Future directions

As our program continues to grow, and depending on funding, we are hoping to add two more elements to our assessment plan: an external evaluator and an external advisory board.

4Ci. External evaluator: An external consultant would fulfill two distinct purposes: (1) review key assessment reports generated by internal evaluators, and (2) conduct a fidelity evaluation of the InSciTE program. The external evaluator would help bolster the integrity of findings by visiting the program once a year to interview students and faculty, reviewing methods, findings, and interpretations of key assessments in the program [84], [85]. Additionally, a yearly fidelity evaluation would examine the adherence and integrity of implementing the overall stated goals in the InSciTE program. Given that the InSciTE team has a stated goal of replicability at other institutions, solid program fidelity is essential.

4Cii. External advisory board: To further our commitment to a relevant and current program, we would like to establish an external advisory board consisting of industry partners and experts in STEM interdisciplinary education. Several local industry leaders have reached out to InSciTE to inquire about becoming involved with the program. Maintaining this connection to employers is critical to the long-term success of the program: connecting InSciTE students with local industry partners opens real time opportunities for both to meaningfully work together, be it as internship opportunities for students or challenges from the industry brought into InSciTE classrooms. We anticipate growing relationships between InSciTE and local industry leaders as the program becomes established at CMU. The external board would meet once a year at CMU during the Spring semester to have opportunities to meet InSciTE students and faculty and view students' deliverables before submitting recommendations.

5. Results after 2 years of implementation

With its creation in 2022, InSciTE has now three cohorts of students, 28 of which have taken two InSciTE courses, 47 of which have taken one InSciTE course (we are currently finishing the recruitment of our third cohort). Our data indicate that InSciTE is making a large positive difference in the experience of our STEM students, and specifically our marginalized students. While we do not have results on job placement and pre/post program measures (as our pioneer cohort will not complete the full program until 2026), we present here the results on

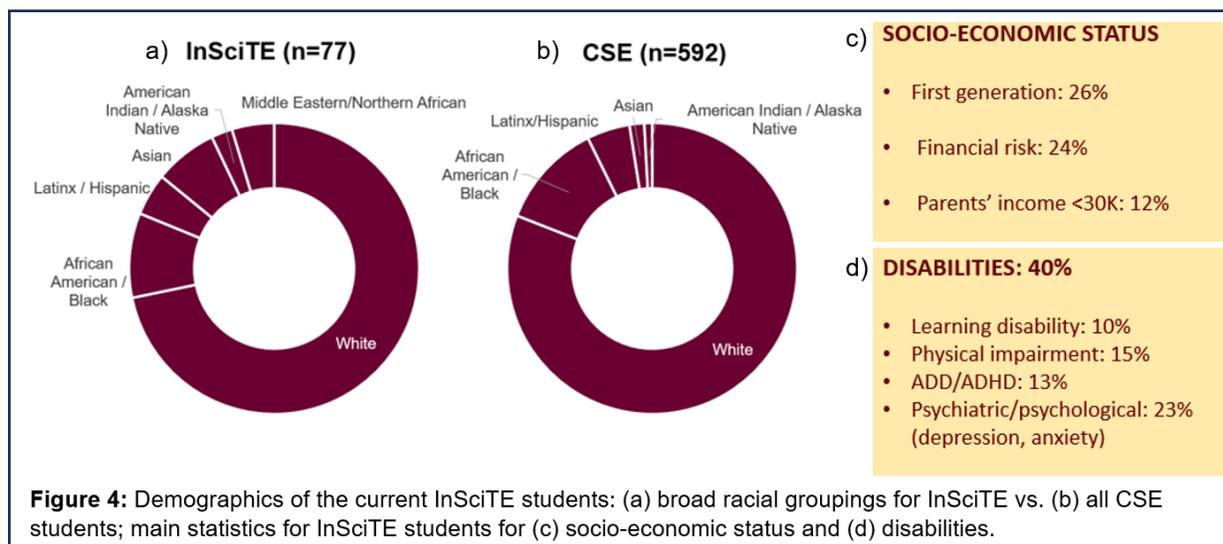
demographics, retention, satisfaction and sense of belonging in InSciTE, as well as STEM identity, skill development, and STEM co-curricular achievements.

5A. Demographics of the current InSciTE cohorts:

Our recruitment methods have been very successful at attracting students from diverse backgrounds (Figure 4). Currently, our first two cohorts of students are considerably more ethnically diverse than the rest of CSE for:

- **Broad racial group membership:** despite CMU being a predominantly white institution (PWI), InSciTE is attracting a higher number of underrepresented, racially minoritized (URM) students than expected if we had representational parity (Figures 4a and 4b). We expect this percentage (currently 28% URM students in InSciTE) to continue to increase as the program becomes established at CMU.
- **Belonging to marginalized populations:** 83% of students in InSciTE identify as belonging to one or several marginalized populations, which include: URM, first generation college student, low socio-economic status, belonging to the LGBTQ+ community, experiencing disabilities, and/or female in STEM disciplines (Figure 4b, 4c, 4d). In addition, InSciTE students had a larger number of marginalizing factors on average (2.1 ± 0.2) than non-InSciTE students (1.05 ± 0.2).

InSciTE students matched the rest of the CSE student body in terms of gender and sexuality, with 40% of all students (both InSciTE and non-InSciTE) identifying as sexual and gender minority students.



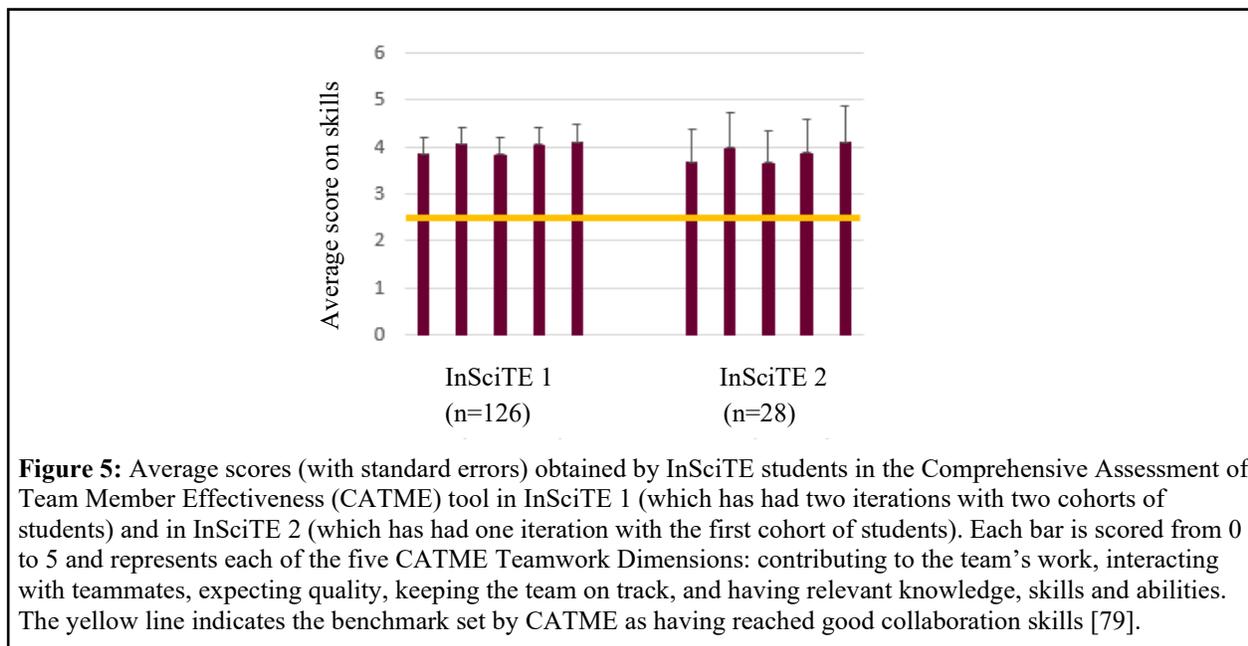
5B. Retention, satisfaction and sense of belonging in InSciTE:

- 98% of URM students that joined InSciTE are still a part of the certificate after two years of implementation of the program, as compared to CMU’s retention of 53% and CSE’s of 19.6%. Moreover, 92.6% of students that joined InSciTE are still a part of the certificate. Of the remaining 6 students, all but one (a student-athlete recruited by another university) are still currently at CMU. Two students switched to Art majors (applied arts and music), while 3 remain in STEM fields (all in Biomedical majors in a pre-medical school track).

- 100% of InSciTE students stated that the program was welcoming, very welcoming or extremely welcoming and felt a strong sense of belonging. 100% of InSciTE students are satisfied with the program. Our preliminary exploration of our qualitative data reveals themes of belonging, having found an academic home, and deep gratitude for all the support InSciTE provides.

5C. Skill-development and deliverable quality

The quality of the work produced by InSciTE students has far exceeded the benchmarks the program established as part of its program assessment. After two iterations of InSciTE 1, students in diverse teams produced 40 deliverables, 100% of which met expectations, 95% of which exceeded expectations, as defined by AAC&U Rubrics [66]. After one iteration of InSciTE 2, students produced 14 deliverables in teams, 100% of which exceeded expectations, as defined by AAC&U Rubrics [66]. Students were also assessed for their active participation in teams using CATME [79]: in both InSciTE 1 and 2 courses, >98% of students displayed good interpersonal skills in teamwork contexts and >94% contributed effectively to teams. When combining the scores on the five CATME Teamwork Dimensions (contributing to the team’s work, interacting with teammates, keeping the team on track, expecting quality, and having relevant knowledge, skill and abilities), students far exceeded the benchmark provided by CATME ([79]; Figure 5).

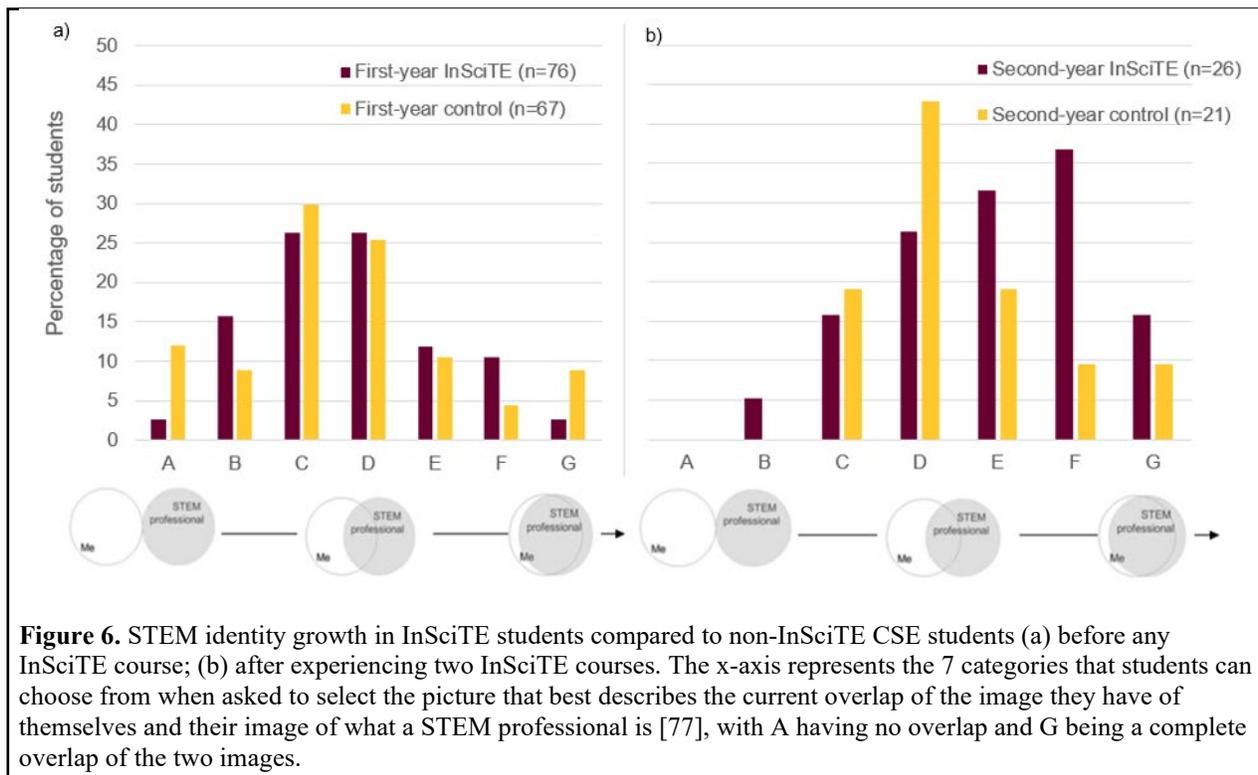


5D. STEM identity

InSciTE uses a validated one-step instrument from [77] to measure students’ growth in their STEM identity. After two years of surveying students, we found that InSciTE students start with similar STEM identity as their non-InSciTE counterparts (n=127) but show considerably larger growth in their STEM identity after two courses in InSciTE (Figure 6).

5E. STEM co-curricular achievements

InSciTE students are highly involved in co-curricular activities in CSE, CMU and beyond. As of July 2024, 62% of InSciTE students from the first cohort are involved in a STEM research lab (which is an unusually high rate for students at CSE within their first two years on campus). InSciTE students were also recruited in summer internships in 2024, including participating in national programs such as the National Science Foundation Research Experiences for Undergraduate students or the University Innovation Fellowship.



6. InSciTE’s impact beyond CSE

We are deeply aware of the size restrictions of the InSciTE model. Once InSciTE reaches its fourth year, we anticipate it will serve ~25% of students enrolled in CSE (300 students yearly with four cohorts of 75 students). While admitting more students in InSciTE would be ideal, we are also aware that maintaining the intentionality of the program requires small cohorts. However, we are creating an innovative academic model that is removing strongly established academic silos and has the potential to reach faculty and students beyond direct involvement with InSciTE [36]. We predict that once InSciTE reaches its full size, it will involve ~40 CSE faculty members (15 teaching faculty, 15 research mentors, and 15 involved in the InSciTE Council, with some faculty serving multiple roles), representing ~35% of faculty in CSE.

Moreover, we hope that sharing here specific details of the program will both inspire and help implement similar programs at other universities. We have found that key factors in our success, and potentially in replicability in other institutions, include having a core of faculty and their administrators deeply committed with the model, with one faculty “champion” dedicated to establishing the model. Administration support includes advocacy and promotion for the program while providing adequate funding, or support to obtain funding. Essential funding

elements we have identified include faculty time in the form of course releases, faculty replacement costs, facilities and supplies. Involvement of partners across campus, including higher administration, other colleges, and support offices like admissions and advancement are also key for successful implementation.

7. Conclusion

InSciTE is a new model for undergraduate STEM education that provides diverse students with an interdisciplinary, equitable space to explore STEM challenges and solutions and acquire transferable skills. The InSciTE model has shown to increase student motivation and persistence, broaden participation, and advance equity in STEM. Specifically, InSciTE cohort demographics showed more diversity than CSE's student body in most marginalized identities. All InSciTE students expressed a strong sense of belonging. Retention percentages in CMU and the program are higher than the institutional average. In addition, InSciTE students have exceeded the benchmarks the program established in their course deliverables and have demonstrated good interpersonal skills in teamwork contexts and contributed effectively to teams. They have also shown higher involvement in co-curricular activities than their non-InSciTE peers. As an equitable and highly innovative skill-based model with extensive pedagogical assessment, InSciTE is expected to not only positively impact the professional development and self-identification of its students, but also to contribute to a broader shift in STEM fields toward more inclusive, interdisciplinary and student-centered training. We hope that by sharing our model, processes, and results, we inspire others to implement similar models aimed at advancing our disciplines.

8. References

- [1] R. B. Mitchell and C. S. Weiler (2011). Developing next-generation climate change scholars: The DISCCRS experience. *Journal of Environmental Studies and Sciences*, 1(1), 54-62.
- [2] M. Mobjörk, C. Berglund, M. Granberg and M. Johansson (2020). Sustainable development and cross-disciplinary research education: Challenges and opportunities for learning. *Högre Utbildning*, 10(1), pp.76-89.
- [3] National Academy of Sciences (2005). Facilitating interdisciplinary research. *Washington, DC: The National Academies Press*.
- [4] D. McGunagle and L. Zizka (2020). Employability for 21st-century STEM students: The employers' perspective. *Higher Education, Skills and Work-Based Learning*, 10, 591-606.
- [5] National Academies of Sciences, Engineering, and Medicine (2016). Promising practices for strengthening the regional STEM workforce development ecosystem. *Washington, DC: The National Academies Press*.
- [6] President's Council of Advisors on Science and Technology (2020). *Recommendations for strengthening American leadership in industries of the future*. Washington, DC. Retrieved January 10, 2025 from https://science.osti.gov/-/media/ /pdf/about/pcast/202006/PCAST_June_2020_Report.pdf?la=en&hash=019A4F17C79FDEE5005C51D3D6CAC81FB31E3ABC

- [7] World Economic Forum (2020). *The Future of Jobs Report 2020*. Retrieved January 11, 2025 from: <https://www.weforum.org/reports/the-future-of-jobs-report-2020/>
- [8] O. E. LeDee, R. T. Barnes, R. Emanuel, P. B. Fisher, S. K. Henkel and J. R. Marlon (2011). Training a new scientist to meet the challenges of a changing environment. *Eos, Transactions American Geophysical Union*, 92(16), pp.135-136.
- [9] L. Potts and H. Jin (2022). *Cognitive strategies in STEM education: Supporting the development of engineers' multi- and cross-disciplinary competence*, Paper presented at 2022 Spring ASEE Middle Atlantic Section Conference, Newark, New Jersey. <https://peer.asee.org/40044>
- [10] G. Schmidt and E. Moyer (2008). A new kind of scientist. *Nature Climate Change*, 1(808), 102-103.
- [11] M. Caeiro-Rodríguez, M. Manso-Vázquez, F. A. Mikic-Fonte, M. Llamas-Nistal, M. J. Fernández-Iglesias, H. Tsalapatas, and L. T. Sørensen (2021). Teaching soft skills in engineering education: An European perspective. *IEEE Access*, 9, 29222-29242.
- [12] R. K. Miller (2019). Lessons from the Olin College Experiment. *Issues in Science and Technology*, 35(2), 73–75. <https://www.jstor.org/stable/26948996>
- [13] R. S. Wells, L. Chen, E. Kimball, B. Annan, S. M. Auerbach and J. T. Fermann (2024). Improving the perceived utility value of teamwork and collaboration among STEM undergraduates. *International Journal of Science and Mathematics Education*, 1-22.
- [14] D. Scobey (2023) The paradigm project: A call for radical renewal of higher education. *Change: The Magazine of Higher Learning*, 55:2, 14-19.
- [15] B. Barrett and G. McPhail (2023). Conceptualizing a radical visible pedagogy. *Journal of education*, 203(3), 726-735.
- [16] M. Çalik and R. K. Coll (2012). Investigating socioscientific issues via scientific habits of mind: Development and validation of the scientific habits of mind survey. *International Journal of Science Education*, 34(12), 1909-1930.
- [17] C. Gauld (1982). The scientific attitude and science education: A critical reappraisal. *Science Education*, 66(1), 109-121.
- [18] C. F. Gauld (2005). Habits of mind, scholarship and decision making in science and religion. *Science Education*, 14, 291–308.
- [19] B. Trilling and C. Fadel (2009). *21st century skills: Learning for life in our times*. John Wiley & Sons.
- [20] B. Thornhill-Miller, A. Camarda, M. Mercier, J. M. Burkhardt, T. Morisseau, S. Bourgeois-Bougrine and T. Lubart (2023). Creativity, critical thinking, communication, and collaboration: Assessment, certification, and promotion of 21st century skills for the future of work and education. *Journal of Intelligence*, 11(3), 54.

- [21] D. M. Hanson (2006). *Instructor's guide to process-oriented guided-inquiry learning*. Pacific Crest.
- [22] S. Purington and M. Nieswandt (2022). Integrated concentration in Science. *Journal of College Science Teaching*, 51(3).
- [23] I. Luka (2014). Design thinking in pedagogy. *Journal of Education Culture and Society*, 5(2), 63-74.
- [24] S. L. Rodriguez, E. E. Doran, R. E. Friedensen, E. Martinez-Podolsky and P. S. Hengesteg (2020). Inclusion & marginalization: How perceptions of design thinking pedagogy influence computer, electrical, and software engineering identity. *International Journal of Education in Mathematics, Science and Technology*, 8(4), 304-317.
- [25] H. Hamdy (2015). Problem-based learning, team-based learning, task-based learning, case-based learning and the blend. *Routledge International Handbook of Medical Education*, 128-132.
- [26] K. J. Chapman and S. Van Auken (2001). Creating positive group project experiences: An examination of the role of the instructor on students' perceptions of group projects. *Journal of Marketing Education*, 23(2), 117-127.
- [27] D. W. Johnson, R. T. Johnson and K. Smith (2007). The state of cooperative learning in postsecondary and professional settings. *Educational Psychology Review*, 19(1), 15-29.
- [28] R. M. Gillies (2013). Structuring cooperative group work in classrooms. *International Journal of Educational Research*, 39(1-2), 35-49.
- [29] D. Hicks (2021). *Dignity: Its essential role in resolving conflict*. Yale University Press.
- [30] D. R. Kaplowitz and S. S. S. R. Griffin (Eds.) (2019). *Race dialogues: A facilitator's guide to tackling the elephant in the classroom*. Teachers College Press.
- [31] B. Siegel and W. Gaudelli (2018). Listening and dialogue in educators' reflective practice. *Peacebuilding Through Dialogue: Education, Human Transformation, and Conflict Resolution*, 39-54.
- [32] A. Singer, G. Montgomery and S. Schmoll (2020). How to foster the formation of STEM identity: Studying diversity in an authentic learning environment. *International Journal of STEM Education*, 7(1), 1-12.
- [33] S. Chen, K. R. Binning, K. J. Manke, S. T. Brady, E. M. McGreevy, L. Betancur, L. B. Limeri and N. Kaufmann (2021). Am I a science person? A strong science identity bolsters minority students' sense of belonging and performance in college. *Personality and Social Psychology Bulletin*, 47(4), 593-606.
- [34] S. Zumbrunn, C. McKim, E. Buhs and L. R. Hawley (2014). Support, belonging, motivation, and engagement in the college classroom: A mixed method study. *Instructional Science*, 42(5), 661-684.

- [35] G. M. Bettencourt, R. S. Wells, S. M. Auerbach, J. T. Fermann and E. Kimball (2022). How STEM undergraduates choose, navigate, and integrate interdisciplinarity in college and beyond. *The Journal of Higher Education*, 1-26.
- [36] W. M. Pangle, J. Batzner, A. Dansen, K. Stenley-Bohn and H. Trommer-Beardslee (2022). *Removing the educational silos: Models of interdisciplinary and multidisciplinary education*. London: Intellect.
- [37] C. R. Rodgers and K. H. Scott (2008). The development of the personal self and professional identity in learning to teach. In *Handbook of Research on Teacher Education* (pp. 732-755). Routledge.
- [38] Central Michigan University (2023). *Five-year strategic plan (2023-2028)*. Retrieved January 10, 2025 from: <https://www.cmich.edu/about/university-mission-vision-values/cm-u-2023-2028-strategic-plan>
- [39] College of Science and Engineering, Central Michigan University (2024). *Five-year strategic plan (2024-2029)*. Retrieved on January 10, 2025 from: <https://www.cmich.edu/academics/colleges/college-science-engineering>.
- [40] S. P. Hundley (2022). Distributed leadership for assessment: considerations for individuals, institutions, and the profession. *Research & Practice in Assessment*, 17(2), 40-51.
- [41] R. E. Bernard and E. H. Cooperdock (2018). No progress on diversity in 40 years. *Nature Geoscience*, 11(5), 292.
- [42] E. A. Cech and T. J. Waidzunus (2021). Systemic inequalities for LGBTQ professionals in STEM. *Science Advances*, 7(3), 1-9.
- [43] K. Denaro, K. Dennin, M. Dennin and B. Sato (2022). Identifying systemic inequity in higher education and opportunities for improvement. *Plos one*, 17(4), e0264059.
- [44] J. L. Graves Jr (2001). *The emperor's new clothes: Biological theories of race at the millennium*. New Brunswick, NJ: Rutgers University Press.
- [45] Y. Xie, M. Fang and K. Shauman (2015). STEM education. *Annual Review of Sociology*, 41, 331.
- [46] C. S. Wilder. (2013). *Ebony and ivy: Race, slavery, and the troubled history of America's universities*. Bloomsbury Publishing USA.
- [47] S. Kriekle (2022). Gatekeeping admissions: Access to justice and inclusive admissions processes. *Dalhousie Journal of Legal Studies*, 31, 85.
- [48] D. Weston (2022). Gatekeeping EpiSTEMic territories: Disciplinary requirements in Engineering and Natural Sciences undergraduate admissions interviews at the University of Cambridge. *Linguistics and Education*, 69, 101017.
- [49] C. Rooney and B. Schaeffer (1998). Test scores do not equal merit: Enhancing equity & excellence in college admissions by deemphasizing SAT and ACT results. In *National Center for Fair & Open Testing (FairTest)*.

- [50] B. Shulruf, R. Turner and J. Hattie (2009). A dual admission model for equity in higher education: A multi-cohort longitudinal study. *Procedia-Social and Behavioral Sciences*, 1(1), 2416-2420.
- [51] G. Wang and B. Shulruf (2013). Admission model and equity in higher education. *The Asia-Pacific Education Researcher*, 22(1), 111-117.
- [52] M. R. Beachboard, J. C. Beachboard, W. Li and S. R. Adkison (2011). Cohorts and relatedness: Self-determination theory as an explanation of how learning communities affect educational outcomes. *Research in Higher Education*, 52(8), 853-874.
- [53] S. Lei, D. Gorelick, K. Short, L. Smallwood and K. Wright-Porter (2011). Academic cohorts: Benefits and drawbacks of being a member of a community of learners. *Education*, 131(3), 497-504.
- [54] K. Martin, M. Goldwasser and R. Galentino (2016). Impact of cohort bonds on student satisfaction and engagement. *Current Issues in Education*, 19(3), 1-14.
- [55] D. Elliott, M. Gamino and J. J. Jenkins (2016). Creating community in the college classroom: best practices for increased student success. *International Journal of Education and Social Science*, 3(6), 29-41.
- [56] T. M. Freeman, L. H. Anderman and J. M. Jensen (2007). Sense of belonging in college freshmen at the classroom and campus levels. *The Journal of Experimental Education*, 75(3), 203-220.
- [57] T. L. Strayhorn (2012). *College students' sense of belonging: A key to educational success for all students*. New York: Sage.
- [58] A. Rhodes, A. Wilson and T. Rozell (2020). Value of case-based learning within STEM courses: Is it the method or is it the student?. *CBE—Life Sciences Education*, 19(3), ar44.
- [59] N. A. Alias and J. E. Luaran (Eds.) (2016). *Student-driven learning strategies for the 21st century classroom*. IGI Global.
- [60] A. Hoare and P. Goad (2022). Culturally responsive postsecondary performance measurement: amplifying student perceptions of success. *Quality in Higher Education*, 1-17.
- [61] D. Gordon, A. Meyer and D. Rose (2016). *Universal design for learning*. Peabody: CAST professional Publishing.
- [62] L. A. Bell, S. Washington, G. Weinstein and B. Love (1997). Knowing ourselves as instructors. *Teaching for Diversity and Social Justice: A Sourcebook*, 299-310.
- [63] B. M. Dewsbury (2017). On faculty development of STEM inclusive teaching practices. *FEMS Microbiology Letters*, 364(18).
- [64] A. G. Greenwald and L. H. Krieger (2006). Implicit bias: Scientific foundations. *California Law Review*, 94(4), 945-967.
- [65] J. Feldman (2018). *Grading for equity: What it is, why it matters, and how it can transform schools and classrooms*. Corwin Press.

- [66] Association of American Colleges and Universities (2009). *Valid Assessment of Learning in Undergraduate Education (VALUE)*. Washington, DC: Association of American Colleges and Universities.
- [67] A. Apugliese and S. E. Lewis (2017). Impact of instructional decisions on the effectiveness of cooperative learning in chemistry through meta-analysis. *Chemistry Education Research and Practice*, 18(1), 271-278.
- [68] E. Treen, C. Atanasova, L. Pitt and M. Johnson (2016). Evidence from a large sample on the effects of group size and decision-making time on performance in a marketing simulation game. *Journal of Marketing Education*, 38(2), 130-137.
- [69] M. R. Stoeckel and K. O'Shea (2024). Strategies for supporting equitable group work. *The Physics Teacher*, 62(5), 326-329.
- [70] M. Mohin, L. Kunzwa and S. Patel (2022). Using mentimeter to enhance learning and teaching in a large class. *International Journal of Educational Policy Research and Review*, 9(2), 48.
- [71] E. O. McGee (2021). *Black, brown, bruised: How racialized STEM education stifles innovation*. Harvard Education Press.
- [72] D. D. Dickens, V. Ellis and N. M. Hall (2021). Changing the face of STEM: Review of literature on the role of mentors in the success of undergraduate black women in STEM education. *Journal of Research Initiatives*, 5(3), 14.
- [73] B. Eichelberger, H. Mattioli and R. Foxhoven (2017). Uncovering barriers to financial capability: Underrepresented students' access to financial resources. *Journal of Student Financial Aid*, 47(3), 5.
- [74] M. I. Pearson, S. D. Castle, R. L. Matz, B. P. Koester and W. C. Byrd (2022). Integrating critical approaches into quantitative STEM equity work. *CBE—Life Sciences Education*, 21(1), es1.
- [75] E. G. Allan and D. L. Driscoll (2014). The three-fold benefit of reflective writing: Improving program assessment, student learning, and faculty professional development. *Assessing Writing*, 21, 37-55.
- [76] T. Bourner (2003). Assessing reflective learning. *Education+ training*.
- [77] M. M. McDonald, V. Zeigler-Hill, J. K. Vrabel and M. Escobar (2019). A single-item measure for assessing STEM identity. In *Frontiers in Education* (p. 78). Frontiers.
- [78] D. I. Hanauer and E. L. Dolan (2014). The project ownership survey: measuring differences in scientific inquiry experiences. *CBE—Life Sciences Education*, 13(1), 149-158.
- [79] M. L. Loughry, M. W. Ohland and D. J. Woehr (2014). Assessing teamwork skills for assurance of learning using CATME team tools. *Journal of Marketing Education*, 36(1), 5-19.

- [80] A. C. Loignon, D. J. Woehr, J. S. Thomas, M. L. Loughry, M. W. Ohland and D. M. Ferguson (2017). Facilitating peer evaluation in team contexts: The impact of frame-of-reference rater training. *Academy of Management Learning & Education*, 16(4), 562-578.
- [81] M. Weatherton and E. E. Schussler (2021). Success for all? A call to re-examine how student success is defined in higher education. *CBE—Life Sciences Education*, 20(1), es3.
- [82] K. A. Neuendorf (2018). Content analysis and thematic analysis. In: *Advanced research methods for applied psychology* (pp. 211-223). Routledge.
- [83] J. M. B. J. L. Kingsley and A. Reeves (2022). WIP: A pedagogical intervention leveraging engineering design thinking to foster a tolerance for ambiguity. *American Society for Engineering Education*.
- [84] S. R. Jones, V. Torres and J. Arminio (2022). *Negotiating the complexities of qualitative research in higher education: Essential elements and issues* (3rd ed.). Routledge.
- [85] D. R. Krathwohl (2009). *Methods of educational and social science research: The logics of methods*. Waveland.