Education Innovation Grants Impact Report

Academic Year 2023-2024

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About Education Innovation Grants

The MIT Jameel World Education Lab (J-WEL) awards annual Education Innovation Grants that power MIT research in interdisciplinary subjects addressing barriers to education. Since 2017, these grants have enabled MIT educators and researchers to develop novel teaching methods, pioneer new tools for learning, and connect evidence and ideas to address barriers to education.

14	**11**	**$6m**
projects awarded in 2023	MIT DLCIs represented	in grant funding awarded since 2017

Stats for AY2023-2024

In the 2023-2024 academic year grant cycle, J-WEL awarded grants to 14 research projects exploring a range of topics including electrical engineering, extended reality, physical movement, and ecological sustainability. The grants supported researchers from 11 departments, labs, and centers across MIT.

J-WEL is excited to share the reports from our grantees that highlight project goals, outcomes, outputs, and key lessons learned.

A note from Anjali Sastry, J-WEL faculty director

“To advance higher education everywhere, the MIT Jameel World Education Lab seeds global dialogues and collaborations that surface core challenges, explore practical approaches, and examine the potential of educational innovations.

Our Education Innovation Grants support MIT faculty and researchers in developing new ideas that could advance learning and student experiences. Every year, we select projects born of MIT’s experience that offer the potential to advance higher education on campus and across settings. Projects link the curriculum to real-world needs, prototype new ways to embed evidence-based insights into teaching, and develop novel approaches for bringing educational opportunities to underserved transitional learners.

Thanks to the reach of our global community and MIT colleagues' investment in dissemination, educators in dozens of countries can learn from the efforts that we support on campus to tackle challenges and opportunities in higher education. The projects completed in 2024 explore new ways to connect important topics, address gaps in educational approaches and subjects, and tap into creativity and invention to enable learning goals. Read on to learn more about MIT innovators who are leading the way."

About the MIT Jameel World Education Lab

The MIT Jameel World Education Lab is the world's portal to MIT's expertise in research, teaching, experimentation, and a laboratory for educational innovation. We collaborate with ambitious and committed institutions around the world to bring our shared vision to life: education designed for everyone to thrive. Our three pillars of focus – Pathways for Talent, Architecting Learning, and Campus as Catalyst – shape who we serve with our work, how we equip and empower educational institutions to make change, and how we reimagine the use of the institution's capabilities, physical, and virtual campuses. Together with our members, we apply MIT know-how to the questions, challenges, and opportunities educational institutions are facing today to positively impact learners, educators, and society.

Project Summaries and Deliverables

Minor Notes: Teaching the Archival Arts

Joshua Bennett, Distinguished Chair of the Humanities and professor in MIT Literature
See full project report

Minor Notes is an initiative aimed at engaging high school students in archival research and artmaking to foster a sense of literary culture and community. The project involved bi-weekly sessions with high school students and faculty advisors, exploring community archives in Boston and Cambridge. The students produced original artworks inspired by their archival studies, demonstrating the integration of historical research with arts education. The program exceeded its goals, expanding statewide with support from the Radcliffe Emerging Leaders Program.

Deliverables:

- Original artworks by students
- A forthcoming second volume of the *Minor Notes* Penguin Classics anthology series dedicated entirely to “Young People’s Poetry”

Studying Educators’ Practices in Makerspaces to Build a Curriculum for Maker Skill Learning

Stefanie Mueller, the TIBCO Career Development Associate Professor in the Department of Electrical Engineering and Computer Science and head of the Human-Computer Engineering Group at the Computer Science and Artificial Intelligence Laboratory
See full project report

This project team investigated educators' experiences in teaching maker skills across various makerspaces. Through interviews with educators from diverse makerspaces, the study identified key competencies, strategies, and challenges in makerspace education. The findings were published in a journal article, providing a framework for further research on educational technologies and practices in makerspaces.

Outcomes/Deliverables:

- *Educational Technology Research and Development* article: "Understanding the educators’ practices in makerspaces for the design of education tools"

Promoting Creative Learning through Festivals of Invention and Creativity: Building on a Successful Model from Brazil

Ann Berger Valente, educational research manager at the MIT Media Lab; and
Leo Burd, director of the Lemann Creative Learning Program at the Media Lab
See full project report

Since 2018, Festivals of Invention and Creativity (FICs) have supported and inspired K-12 educators in Brazil to integrate creative learning ideas into their classrooms. To broaden the reach of these experiences, and empower educators to host their own FICs, the project team set out to develop a "FIC Toolkit." With input from educators in Brazil and other countries, and through filming and observing the 27 FICs that took plan throughout 2023, the team identified the toolkit content. The materials include a set of guides, inspirational videos, support materials, and example activities.

Outcomes/Deliverables:

- The FIC toolkit website, which includes:
- Come Discover the FICs - a comprehensive description of the essential components
- Three FIC Scenarios exemplifying FICs in different settings
- Quick Guide - a reference guide that lays out 9 steps to organize a FIC
- A shared Google Drive with editable graphic communication materials including flyers, backdrops, and social media inserts
- A set of editable supporting documents including sample activity selection forms, an example fundraising presentation, letters of invitation, etc.

Climate and Environmental Justice (CEJ) Inclusion: Exploring CEJ Teaching Practices across Departments, Labs, or Centers at MIT

Christopher Rabe, education program director at the MIT Environmental Solutions Initiative; and

John Fernández, director of the MIT Environmental Solutions Initiative and professor of building technology in the Department of Architecture

See full project report

This project explored the inclusion of climate and environmental justice (CEJ) content in courses across MIT. The study involved observations, interviews, and surveys to understand instructional practices and student experiences. The findings will be published in two academic papers, focusing on CEJ inclusion and student learning experiences.

Outcomes/Deliverables:

- Two forthcoming academic papers
- Slide deck summarizing findings

An Online Platform for Explaining, Promoting, and Facilitating Embodied Education at MIT and Beyond

Jennifer Light, the Bern Dibner Professor of the History of Science and Technology and professor in the Department of Urban Studies and Planning

See full project report

Light's work on embodied education aims to close the gap between the growing body of research on movement, the learning process, and the pedagogical strategies that educators use. She developed a website to promote embodied education, integrating movement and learning. The site provides resources, lesson plans, and videos to support educators in incorporating embodied pedagogies. The platform has been well-received and is being used by students and educators to enhance their teaching and learning practices.

Outcomes/Deliverables:

- Embodied Education website with resources and lesson plans
- Example videos of physics through partner acrobatics and judo

MICRO 2.0: Cultivating Students' STEM Identities through a Blended Learning Research and Education program

Jessica G. Sandland, principal lecturer in the Department of Materials Science and Engineering and digital learning scientist in MIT Open Learning

See full project report

MICRO 2.0 is a blended learning program aimed at providing research opportunities to undergraduate students from underserved backgrounds. Building on the success of Materials Initiative for Comprehensive Research Opportunity (MICRO), the program included online research projects, lectures, mentoring, and an on-campus summit at MIT. The project successfully enhanced students' STEM identities and provided valuable research experiences.

Outcomes/Deliverables:

- On-campus MICRO Summit held in January 2024
- Related research to be published in the '24 IEEE Frontiers in education Conference Proceedings: S. France Tribe, J.G. Sandland, C. Chazot, "Broadening Participation in Online Research and Learning in Materials Science and Engineering: The Impact of Recruitment Strategies"
- Program website: https://www.mse-micro.net/

Light Up Kicks: Engaging Youth in Shoe Design Using Culturally Sustainable Pedagogy

Liza Goldstein, invention education pathway administrator at Lemelson-MIT;

Cristina Sáenz, invention education manager at Lemelson-MIT; and

Michael Cima, the David H. Koch (1962) Professor of Engineering in the Department of Materials Science and Engineering and faculty director of Lemelson-MIT

See full project report

The "Light Up Kicks" (LUK) project introduced upper elementary students to invention education and electronic circuits through creating a light-up shoe prototype. The curriculum, designed for 4th and 5th graders, included 16 sessions over eight weeks and integrated culturally sustaining pedagogy. It was linked to NGSS Science and Engineering standards, Common Core ELA, math, social studies, and National Core Arts Standards. The curriculum was piloted informally in two California classrooms and formally at Modesto Christian School. The program successfully increased students' interest in STEM, taught new hands-on skills, and enhanced cultural awareness.

Outcomes/Deliverables:

- Light Up Kicks curriculum for educators
- Light Up Kicks student slides

Making Implicit Knowledge Explicit: Tacit Knowledge Transfer from Expert Glassblowing Instructors to Less Experienced Students at MIT's Glass Lab

Andrés Salazar Gómez, research scientist at MIT Open Learning;

Alexandre Armengol Urpi, postdoctoral researcher, Department of Mechanical Engineering; and

Sanjay Sarma, the Fred Fort Flowers and Daniel Fort Flowers Professor of Mechanical Engineering

See full project report

This project aimed to capture and convey the tacit knowledge of expert glassblowing instructors at MIT's Glass Lab to less experienced students. The project involved instrumenting the Glass Lab with non-invasive sensors to quantify expertise and capture unspoken nuances. The data collected was used to create instructional videos with intuitive visuals to complement traditional teaching methods. Despite challenges such as the harsh environment and difficulties in coordinating with instructors, the project successfully developed instructional materials and gathered valuable insights into the differences between expert and intermediate glassblowers.

Outcomes/Deliverables:

- Instructional video
- Poster for SMART workshop
- FIE 2024 paper

Full Grant Reports

Minor Notes: Teaching the Archival Arts

***Joshua Bennett**, Distinguished Chair of the Humanities and professor in MIT Literature*

Restatement of Project Goals

As a scholar of African American literature and cultural history, I often find myself struck by the number of exciting writers I come across in long-out-of-print collections and forgotten journals, whose work has been neglected and, in some cases, entirely ignored, even by those academic circles devoted to its study. Minor Notes is an excavation initiative that addresses this issue by fostering a sense of literary culture and community among high school students, and by engaging them through the joy of archival discovery. It is also a public humanities project that addresses current gaps in K-12 arts education through a novel approach that combines archival research with collaborative artmaking.

Prof. Joshua Bennett speaks at the students' final exhibition.

For our pilot program in Massachusetts, we met bi-weekly with a cohort of high school students, as well as their faculty advisors, to explore several community archives in Boston and Cambridge: The Schlesinger Library at Harvard's Radcliffe Institute, MIT Distinctive Collections, and the Boston Athenaeum. By the close of the spring semester, the students produced a suite of original artworks inspired by this archival study undertaken over the course of the academic year. These deliverables served as material examples of our overarching claim: that there are dynamic, practicable ways to combine historical research with arts education as a means of preparing young people for college-level work in the humanities and beyond.

It bears mentioning here that this program was inspired in no small part by my time as a scholar-in-residence at several high schools over the past three years: the Roxbury Latin School in Boston, Friends Seminary in New York City, and, most recently, Thayer Academy in Braintree, Massachusetts, where I also served as the commencement speaker. Although I have worked as an arts educator for 15 years now, it was these most recent experiences that clarified for me the timeliness, and potential power, of a pedagogical program that combined the transcendent beauty of the arts with a deeper knowledge of one's place in both local and global history. Minor Notes emerged, then, as a response to a larger question not only about the future roles of the arts and humanities, but about certain kinds of civic education, in the lives of our young people.

Put another way, our aim was to create a working, portable model that combines arts education, and civic education, with archival methods. All in order to equip the next generation not only with the skills needed to engage in college-level research in the arts and humanities, but also a sense of communal belonging. We achieved that goal, and in doing so laid the groundwork for a much larger set of initiatives.

Final Outcomes and Outputs

We not only met our project goals but exceeded them. In addition to producing an ensemble of original adaptations with our initial cohort of eleven students, we are now in the process of expanding our program throughout the state of Massachusetts with the support of the Radcliffe Emerging Leaders Program. As presently imagined, Emerging Leaders would create a summer cohort composed of students from Cambridge Rindge and Latin School, Somerville High School, and Watertown High School. This cohort would represent an "Archival Studies" wing of their already existing programming.

We measured impact towards stated goals through attendance at our bi-weekly studio sessions and various trips to archives, as well as the progress on individual projects from start to finish. Since the closing of the J-WEL grant, we have been able to continue fundraising and gained interest from another of different parties in terms of building out Minor Notes pedagogy elsewhere.

Lessons Learned: Milestones, Accomplishments, and Challenges

The greatest initial challenge we faced had to do with sticking to our core ethos. We had a range of expertise in our cohort: people who were practicing painters and filmmakers, and others who had never created a work of art before, thinking that this might be an interesting way to explore another part of their imaginations. This challenge, in a way, transformed into one of the most significant accomplishments of our time together, which was that our entire cohort made it to every trip, and everyone had work on display at our gallery opening. To achieve this heading into the final weeks of the school year, and the final weeks of high school as such for several of our Minor Notes Fellows, was no small triumph.

Gallery of student projects.

Every single student produced a working adaptation and written explanation of their process. This first year of the program also helped contribute to my thinking about a second volume of the *Minor Notes* Penguin Classics anthology series: one that is dedicated entirely to "Young People's Poetry." It is forthcoming in 2025.

Contributors

Kim Gilmore, Allyn Lodge, Kate Hayman, Kiley Gilbert, Tess Harper, Peter Chen, Matt Sullivan, Abigail Devine, Teri Homicile, Merritt Grillo, Kenzie Murphy, Emily Guilfoyle, Meg Corry, and Renee Martel.

Related Media

Following this link, you can see footage of our final event, as well as a number of the individual works of art crafted by our students.

Studying Educators' Practices in Makerspaces to Build a Curriculum for Maker Skill Learning

***Stefanie Mueller**, the TIBCO Career Development Associate Professor in the Department of Electrical Engineering and Computer Science and head of the Human-Computer Engineering Group at the Computer Science and Artificial Intelligence Laboratory*

Restatement of Project Goals

Current research examining learning in makerspaces is primarily centered around the learners' experiences and not the educators, thus presenting a gap not only in our understanding of educators' perspectives but also in how we design educational technologies and curriculums for learning in makerspaces. Furthermore, there is little focus on studying practices across geographically and culturally diverse makerspaces to identify the similarities and differences between them. With the funding from this proposal, we will address this gap through an interview study investigating educators' experiences of teaching maker skills across various makerspaces, including local ones in the Boston Area, as well as makerspaces across the US and internationally. For this, we are leveraging our existing contacts, including our on-going collaboration with NuVu Innovation School (which has a presence in the US, UK, and India) and the Fab Foundation (which has a global presence with over 1,750 fablabs worldwide).

Final Outcomes

We published a 30-page journal article titled 'Understanding the educators' practices in makerspaces for the design of education tools' in the journal of 'Educational Technology Research and Development' (2024) 72:329–35. The journal paper includes figures and overview charts of the main insights for easy access by readers.

For the journal paper, we interviewed seven educators across five makerspaces. We utilized a purposeful sampling approach (Emmel, 2013) to select interviewees, targeting makerspaces with diverse organizational formats. This ranged from part-time after school temporary makerspaces in libraries serving schools facing systemic inequities, to full-time semester-long permanent maker-schools catering to private school students in our metropolitan area.

We examined our interview data through a thematic analysis with six rounds of coding focused on the following three research questions:

1. What types of knowledge, skills, and attributes do educators prioritize in their practices within makerspaces, and why?
2. What strategies do educators employ to facilitate their students' learning and competency-building?
3. What challenges do educators face in their pedagogical practices within makerspaces?

Our thematic analysis resulted in a codebook consisting of six sets of competencies that educators valued most, five sets of strategies they deployed, and three sets of challenges that educators encountered in their practices in makerspaces. This codebook presents a comprehensive snapshot of educator practices in makerspaces and contributes to the existing literature as a potential framework for further studying makerspace learning.

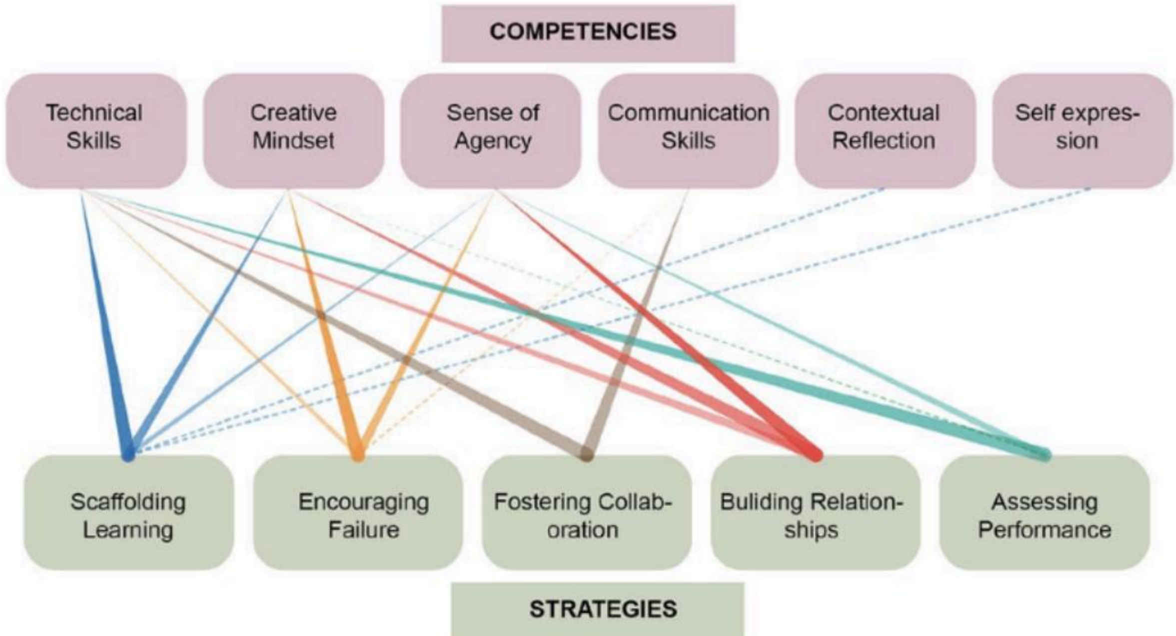
Our analysis further revealed that educators prioritize diverse knowledge, skills, and attributes in their practices within makerspaces that go beyond mastering technical skills. These include skills such as communication, creative problem-solving abilities, and interpersonal skills like collaboration. Educators emphasized the importance of fostering a creative mindset and self-driven curiosity in learners, while also providing support and scaffolding to help learners persist through challenges. Educators employ various strategies to facilitate their students' learning and competency-building, such as promoting collaboration, guiding learners while also fostering resilience towards failure, and providing opportunities for learners to teach and critique one another. Our analysis revealed interconnected themes between strategies and competencies pointing to ways in which educators deploy strategies to build the competencies.

Finally, we articulate the discussion of our findings by identifying opportunities for further research on technologies for scaffolding problem-based and project-based learning, collaborative work, supporting communication within makerspaces, and building trust and care within makerspaces. Through this discussion, we lay the groundwork for incorporating the findings on educators' perspectives, practices, and needs within the design of the technologies for makerspaces.

Competencies

Strategies	Technical Skills	Creative Mindset	Sense of Agency	Communication Skills	Contextual Reflection	Self-Expression
Scaffolded Learning	58.10%	41.89%	32.43%	2.70%	0.27%	21.62%
Encouraging Failure	27.77%	55.55%	38.88%	22.22%	0.00%	5.55%
Fostering Collaboration	51.85%	37.03%	29.62%	55.56%	3.70%	3.70%
Building Relationships	40.90%	54.54%	59.09%	18.18%	9.09%	18.18%
Assessing Performance	76.19%	28.57%	38.09%	38.09%	4.76%	4.76%

Percentile by Row: 1% – 99%



<u>Lessons Learned</u>
We acknowledge that our study has several limitations and hence the findings of this work need to be tested further through more studies.

Small sample size & possible selection bias: The limited sample size of participants may not capture the full diversity of educators in makerspaces, including variations in experience, background, and teaching approaches. Furthermore, even though we followed purposeful sampling for selecting our interviewees, the participants were selected based on our networks, which could lead to a non-representative sample. We acknowledge these limitations and their impact on the ability to draw broader conclusions or make generalizations about educators' practices in makerspaces.

Subjectivity in the analysis & possible bias in coding: The subjectivity of interpreting data and identifying themes during the thematic analysis process can introduce biases into the coding. Different researchers may interpret the data differently, potentially leading to discrepancies in identifying and defining themes. Despite efforts to ensure interrater reliability agreement of 80% in each round, biases may still be present in the coding and analysis process.

Limited scope and context: Our study specifically focused on the pedagogical practices, and not on other important factors such as organizational structure, resource allocation, or community engagement. This limits our insights and a holistic understanding of the complexities involved in educators' practices in makerspaces. Finally, even though we diversified the types of makerspaces, the locations of our makerspaces primarily include the geographic region of the North American continent, which may limit our insights. Educational contexts vary across different locations, and the practices and challenges faced by educators in one setting may not necessarily apply to others. This study is in no way exhaustive of the competencies, strategies, or challenges that maker educators might communicate. We aimed to provide an analysis of these educators' perspectives in order to shed light on the various avenues for design that are being left out. As a community, we must continue this investigation and iteration of educational maker technologies that integrate the perspectives, knowledge, and practices of all stakeholders, including educators. For future work, we plan to dive deeper into educators' strategies and challenges within diverse formats and contexts of makerspaces and how it impacts the learner's experiences.

Final Outputs/Deliverables

The main output from our project is a 30-page journal paper that described the thematic analysis of the interview data and details the insights gained from it.

Dishita Turakhia, David Ludgin, Stefanie Mueller, Kayla Desportes. "Understanding the educators' practices in makerspaces for the design of education tools"
Journal of 'Educational Technology Research and Development' (2024) 72:329–35.

The journal paper includes figures and overview charts of the main insights for easy access by readers.

Contributors

Dishita Turakhia (PhD student, graduated, now faculty at NYU)
David Ludgin (IDM Master student, graduated)
Stefanie Mueller (Associate Professor MIT EECS/MechE)
Kayla DesPortes (Assistant Professor NYU)

Promoting Creative Learning through Festivals of Invention and Creativity: Building on a Successful Model from Brazil

***Ann Berger Valente**, educational research manager at the MIT Media Lab; and*

***Leo Burd**, director of the Lemann Creative Learning Program at the MIT Media Lab*

Restatement of Project Goals

Over the past six years, Festivals of Invention and Creativity (FICs) have supported and inspired K-12 educators in Brazil to integrate creative learning ideas into their classroom practice. FIC events take on many different formats depending on the local context, with the signature element being the interactive demo sessions highlighting examples of hands-on, project-based, collaborative activities to support creative learning.

FICs bring together teachers, school leaders, students, and families to foster supportive communities within the school ecosystem. In this project, the Lifelong Kindergarten group – as part of its Brazilian Creative Learning Network initiative – aimed to develop a "FIC Toolkit" containing a robust set of guides, inspirational videos, support materials and example activities for teachers as well as for Secretaries of Education, universities, and organizations to help them plan and execute their own FICs. In order to broaden the reach of creative learning experiences through FICs in countries around the world we aimed to gather input during the development process from educators in Brazil, Chile, Mexico, South Africa, and other countries to iteratively refine the resources.

The ultimate goal of this initiative is to enable the grounded development of a novel learning experience that will generate new learning opportunities for MIT and other international educators.

Final Outcomes

Quantitative data was collected on the FICs that took place in 2023. A total of 27 FICs were organized throughout Brazil, reaching approximately 33,000 participants. Initial dissemination to other countries included two FICs in Colombia, two in Mexico, one in South Africa and one in the US, reaching an estimated total number of nearly 3000 participants.

In-depth interviews were conducted with six of the organizing committees. These interviews provided detailed feedback on the existing support materials and the kinds of information and resources that were either missing or hard to find. The interviews also revealed that it was common practice for organizers from the BCLN network across the country to share best practices. Most importantly, we learned how the FICs played into their broader objectives of teacher professional development and community mobilization.

The film crew was sent out to five FICs in different parts of the country. The video and photographic documentation captured the events from start to finish. Interviews were captured with organizers, teachers, and the general public. These filming sessions provided ample material to edit the videos and to illustrate the print materials for the new Toolkit. Interviews were conducted with LLK educational partners in Chile, South Africa, Thailand and India in order to explore ways in which FICs could be meaningful in their countries, and to learn what support materials would be needed to make the model accessible. Partners showed interest in the model but had many questions. The process of trying to explain the festivals to an audience that had never experienced a FIC helped to clarify its key components which we, as designers of the model, had previously taken for granted.

Through this investigation we were able to identify the content that needed to be documented and shared in the Toolkit. These needs included: guides for both new and veteran organizers; illustrations of different scenarios in which a FIC could take place; descriptions of the types of organizations involved; diverse examples of the kinds of hands-on activities offered; direct access to key support materials for organizers; and extensive visuals with descriptions to illustrate the experience of organizing and participating in FICs.

<u>Lessons Learned</u>

The in-depth interviews and the video documentation accompanied by BCLN staff members gave us an up-close snapshot of the dissemination of FICs in Brazil. The video editing allowed for a fine-grained analysis of what was actually happening on the ground, the types of projects, and the ways in which teachers, youth, families and other visitors engaged with the activities. The documentation revealed innovative uses of high- and low-tech materials, fantastic examples of communities of practice and peer learning, expert mediation in interactive activity stations, as well as delightful instances of family engagement. However, we also observed cases where there was a certain dilution of some of the core components of the original FIC design. The engaging "hard fun" that we would anticipate in the interactive stations was replaced by passive experiences of watching demonstrations of completed projects (similar to the format of most science fairs). In some FICs, the celebratory aspect of the Festival predominated over the opportunities for exploration and learning. These issues in the activity curation process were evidenced by teams that were organizing a FIC for the first time as well as veteran organizers with several FICs under their belts.

These findings lead us to realize that each of the guides needed to be aimed at both audiences – those new to FICs as well as previous organizers. We celebrate the growing autonomy of members of the BCLN community as FICs spread across the country, but in order to bring out the potential for supporting more creative learning opportunities, there is a need to continuously revisit some of the more nuanced ideas.

<u>Final Outputs</u>

Another lesson learned was related to FIC uptake by the international community. BCLN is unique in that FIC organizers are usually connected to universities, departments of education, independent organizations or maker spaces. They represent communities larger than a particular school. Consequently, mobilization for the FIC naturally brings together people from diverse backgrounds and settings. When we talked with some of our international partners, they were coming to the conversation thinking about organizing a FIC in their individual school or even a single classroom. Not being part of a broader community, there was somewhat of a disconnect between our examples and their contexts. As we explore the FIC model across an international audience, we recognize the need to adapt to differing realities, including smaller scale FICs with a more homogeneous audience, and incorporate these examples into the Toolkit.

This is the landing page for the FIC Toolkit. All the materials are available in English, Portuguese and Spanish languages.

The Toolkit contains the following guides and print materials:

1. Come Discover the FICs - a comprehensive description of the essential components.
2. Three FIC Scenarios exemplifying FICs in different settings.
3. Quick Guide - a reference guide that lays out 9 steps to organize a FIC.
4. A shared Google Drive with editable graphic communication materials including flyers, backdrops, and social media inserts.
4. A set of editable supporting documents including sample activity selection forms, an example fundraising presentation, letters of invitation, etc.

The video materials include:

1. A three-minute introductory video;
2. An eight-minute video illustrating in greater detail how to organize a FIC;
3. 3. Eight short 1-minute clips exemplifying various activities for the interactive stations.

Related Media:
The following are posts since the launch of the FIC Toolkit:
Prêmio Brasil Criativo - World Creativity Organization (WCO) - September 12, 2024 BCLN receives an award of creative economy, with support from the Ministry of Culture, for the FIC initiative in the category of Accessible Technologies
https://www.instagram.com/reel/DAIz2V4RyoV/?igsh=czNqbWtjdXJqYXA1

Webinar Release of the FIC - Toolkit
BCLN presents the Toolkit and discusses the FIC experiences with community organizers in Vinhedo, SP and Salvador, BA
https://www.youtube.com/watch?v=zDPOqrXSPR8

FIC Brasilia, DF - August 16, 2024

- Instagram account dedicated to the event https://www.instagram.com/ficbrasilia/
- FIC Brasília is featured on a major TV network https://g1.globo.com/df/distrito-federal/df1/video/sesi-lab-tem-festival-de-invencao-e-criat ividade-com-oficinas-de-graca-12829376.ghtml
- FIC Brasília is featured in local newspapers https://noticias.r7.com/brasilia/sesi-lab-recebe-festival-gratuito-sobre-aprendizagem-criat iva-nesta-sexta-feira-15082024/ https://www.agenciabrasilia.df.gov.br/2024/08/16/estudantes-participam-de-festival-de-in ovacao-e-criatividade-no-sesi-lab/
- FIC Brasília is posted on the BCLN FIC Portal https://fic.aprendizagemcriativa.org/fic-brasilia-1-edicao

FIC Jaguariúna, SP - August 24, 2024

- Organizers posted this reel showing their preparations and the new FIC Toolkit communications materials https://www.instagram.com/reel/C_GhW4LOMKw/?igsh=ODQzZmY2a2xobzk0
- Organizers posted a few pictures from the 76 activities that were designed by teachers and pedagogic coordinators throughout the school system https://www.instagram.com/p/C_Gq6Cty8tF/?img_index=1
- FIC Jaguariúna is posted on the BCLN FIC Portal https://fic.aprendizagemcriativa.org/fic-jaguariuna-3-edicao

Contributors

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Exploring Climate & Environmental Justice (CEJ) Teaching Practices and Learning Experiences at MIT

***Christopher Rabe**, education program director with the MIT Environmental Solutions Initiative; and*

***John Fernández**, director of the MIT Environmental Solutions Initiative and professor of building technology in the Department of Architecture*

<u>Restatement of Project Goals</u>

The primary goal of this project was to better understand how climate and environmental justice (CEJ) content knowledge and instructional practices were included across courses within different Departments, Labs, and Centers (DLCs) at MIT. In addition, as the project evolved, we sought to learn more than we had initially intended about the learning experiences and sentiments of belonging and inclusion among students in these classes.

In addition, the original goal was to study courses that had clear focuses on environmental or climate justice. However, as the participant sampling and recruitment process progressed, it was clear that based on course titles, descriptions, conversations with faculty members and initial surveys of syllabi, the range of climate and environmental justice inclusion was much larger and more varied than anticipated. The participants/courses sampled allowed for the study to have a broader collection of courses and a discussion that also focused on innovative climate education that focuses on community engaged and experiential instructional methodologies.

Our main objective for a final deliverable for this project was at least one academic article for publication. We are currently in the drafting process of ***two*** academic papers to be submitted before the end of the 2024 calendar year. One of these papers will focus on the instructional aspects of CEJ at MIT (CEJ inclusion, faculty perspectives and pedagogical methodologies), and the other paper is focused on student learning experiences and sentiments of belonging and inclusion.

<u>Final Outcomes</u>

Data Collection took place during the academic year 2024-2025. During this time, we studied 11 different courses across at least 6 DLCs at MIT. Our data collection within these courses included 2-3 observations of each course, collection of all course syllabi, interviews with 9/10 faculty members participating, and 43 survey responses from students across 9/11 courses.

Data was analyzed over the summer of 2024 with the help of two UROPS from MIT, one student intern from UMass Boston, and another Northeastern co-op student intern. The goal was to have a diverse group of students working on this study that sought to better understand how students can experience CEJ education. The data analysis process was finalized in late August/early September.

Currently, we are in the process of drafting two academic papers that will summarize our research methodology, key findings and implications and take-aways for environmental and sustainability faculty, administrators, and relevant higher education leaders.

- One of these papers is more focused on the way CEJ content and pedagogical practices are included across the courses and uses a "Spectrum of CEJ Inclusion" to illustrate this.
- A second paper focuses primarily on student learning experiences and sentiments of belonging and inclusion. We decided that findings from the survey we distributed to students (n:43, with 63 total quotes) and student comments and questions from observation notes (n:159) warranted a completely separate paper.

Lessons Learned

Significant Milestones

As described above, significant milestones included the creation of participant criteria and sampling procedures, outreach to faculty members and instructors, finalizing a list of official participants, data collection (including observations of 11 courses [2-3 times each], 9 interviews, and survey outreach to students), and data analysis.

One notable aspect of data analysis was that with the collaboration of four student interns, we were able to produce a workable draft of the methodology, findings, and discussion of two papers during the summer from June-September, 2024. We are currently finalizing the introductions, implications and conclusions of both manuscripts.

Two forthcoming milestones will occur in late fall when we submit both of these manuscripts to different journals focused on environmental education.

Greatest Challenges:

Locating CEJ courses: due to a lack of CEJ course content in higher education and at MIT, few courses across all disciplines contain significant focuses on CEJ issues. In some cases, course descriptions describe course content and activities with the use of general terms, and for these two reasons it was challenging to find CEJ related courses. Some courses were found at the last minute due to word of mouth and during unrelated interactions and meetings. Other courses were not being offered during our window of data collection due to sabbatical or other circumstances. However, working through this challenge was rewarding, and as described earlier, created a richer and more nuanced study because the courses contained a greater variety and focus on CEJ content. This generated a more interesting discussion of how and why these courses included CEJ, to what extent, and its impact on students.

Communicating with faculty members/instructors and scheduling classroom observations: MIT faculty members and instructors are extremely busy, so communicating with them was challenging, and often required persistence. For this reason, we have been unable to track down one faculty member for their interview. In addition, scheduling the classroom observations was extremely challenging, especially during the 2024 spring semester where we observed 9 different courses at least 2-3 times each. However, being able to attend so many different courses at MIT related to CEJ issues was very interesting, and provided a case study and snapshot into student experiences within these courses and disciplines.

Final Outputs

- Please see a presentation slide deck that provides more specific details of the overall project and the findings and implications of both papers.

Contributors

Chris Rabe, Education Program Director, Environmental Solutions Initiative, MIT
Madeline Schegel, Northeastern Co-op
Olivia Girard, MIT UROP
Julia Reich, Wellesley UROP
Ashanti Mclain, Student Intern, UMass Boston
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An Online Platform for Explaining, Promoting, and Facilitating Embodied Education at MIT and Beyond

***Jennifer Light**, the Bern Dibner Professor of the History of Science and Technology and professor in the Department of Urban Studies and Planning*

Restatement of Project Goals

As I wrote in the initial proposal, I've been working on a multipronged effort to close the gap between the growing of body of research on movement and the learning process and the pedagogical strategies that educators use. The deliverable for this J-WEL sponsored project was to be a website, an open access resource to make as much information as possible freely available beyond MIT. The site's overarching goal as proposed was to explain what Embodied Education is, provide some examples, and make it as easy as possible for interested parties to introduce it into their educational programs, with a centerpiece of the content being text-, slide-, and video-based lesson plans and ideas – from me, from my students, and from colleagues around the world. These curricular resources were to be searchable by grade level, academic subject, and movement tradition.

I additionally imagined the site would have three main audiences:

1. For MIT students in the classes I offer using embodied pedagogy, it would support their project-based work by (a) offering easy access to relevant multidisciplinary research and (b) providing a platform to make their work publicly available (not required, but encouraged, based on the exceptional quality of student-produced lesson plans in my Fall 2022 course).
2. For scattered colleagues around the world who have been exploring the theory and practice of movement and learning in sub-disciplinary silos, the site would seek to build community through awareness and appreciation of one another's contributions – and expand audiences for the work they've already done by showcasing how it's part of a much larger conversation about the future of education.
3. For academic subject teachers, coaches, movement arts instructors, and school administrators, the project would provide an introduction to "the why" and "the how" of Embodied Education – talking points for including such activities in the academic curriculum as well as detailed lessons plans to facilitate their dissemination for various subjects and grade levels.

Final Outcomes/Lessons Learned

I was able to complete a functional website, with links to a database of resources comprised of research articles and lesson plans/ideas in text, slide and video form. These include many MIT student projects as well as the work of others outside MIT who are part of this emerging field. I also created a few lesson plans/ideas of my own--some text-based and others on video. The latter, two "how-two" videos, were produced in collaboration with Thierry Lincou (MIT Judo instructor), Joel Herzfeld (acrobat), Dr. Benita Comeau (MIT Department of Mechanical Engineering) and MIT Video Production.

While it has only been live for a few months, the site is functioning well. It has already been incredibly useful as a resource for students in my fall 2024 course on dance as a learning science (STS.024J/CMS.524J Thinking on Your Feet), initially for orienting students to this emerging interdisciplinary area and subsequently motivating their imaginations as they consider midterm and final projects. (Their projects will enhance the site with additional lesson plans on video and text.) The site has served as a reference point for two HASTS PhD students in the TLL Teaching Development Fellows Network to imagine a workshop for MIT TAs on "Why and How to get Students Out of their Seats" (for spring 2025). And colleagues working in this area who I didn't previously know have contacted me through the website interface (embodiededucation@mit.edu) and sent additional materials that I will review and potentially upload; this has sparked some conversations about the possibility of an online or in-person gathering.

In the coming months I'll be adding to the site while also seeking additional ways to generate traffic, particularly among interested teachers/coaches. My own research and teaching aims to do some of this; for example, I am presenting with MIT Director of Physical Education and Wellness Carrie Sampson Moore at a professional conference of physical education directors and designing a new service-learning course with assistance from Rohan Kundargi in the MIT Office of Government and Community Relations that I hope will connect with local educators. And Professor Tammy Dudman at Mass College of Art (Chair of Film/Video) is making a short video about my work with Community Jameel funding that I hope will direct audiences there as well.

The greatest challenges during the project period were technical/labor related with the result that I took on greater responsibility for the technical work than anticipated. I'd originally planned to work with UROP students to build the website itself but my summer experience with a UROP made clear the mismatch between students' desire for a high-tech web development experience and my need for a simple interface. The students I interviewed from both MIT and Wellesley were largely seeking a technical experience; although I hired the student who seemed most interested in the educational side and delegated the technical work to her while I figured out the text, images, and page organization, even she had visions of a project to showcase her technical abilities. So at the end of the summer when her term was over I ended up scrapping our first draft of the website (on Bluehost), and started again with Google Sites. Although time consuming to build it entirely myself the final product has the simplicity I was looking for, particularly when it comes to expansion/maintenance after the closeout of this grant. I hope the Google platform will offer longevity since I anticipate uploading additional student projects this academic year and in the future as well.

The video portion of the project was also more labor-intensive (and costly) than anticipated. I recruited Dr. Benita Comeau from the MIT Department of Mechanical Engineering to help with some of the technical content. With neither of us ever having made anything of this variety, many iterations were required. Due to time and funding constraints we completed two rather than three videos, although film for a third lab taught by MIT Music and Theater Arts Lecturer McKersin Previlus was captured and edited but not completed.

Final Outputs/Project References
I wrote in the project proposal that success for this effort and the related projects described in the answer to “How will your findings reach these users?” would ultimately be apparent in the sense of community among the theorists and practitioners working in this emerging field and the growing use of embodied pedagogies in schools. These are long-term ambitions that will extend past the life of this grant. In the short term, success was to include a functional website that is used and added to by MIT students and non-MIT users alike – which we have definitely achieved!

In the coming months I will be tracking how the site is being used, and by whom, which will help guide further site development as well as outreach associated with my related projects. I am also working with Raechel Soicher at TLL to design an evaluation study of my own embodied instruction at MIT in Spring 2025 that could potentially be shared here as well.

Find the MIT Project on Embodied Education website here. An example of a student-produced lesson plan (“A Game of Antibody Tag”) is here. The videos on physics through partner acrobatics and physics through judo can be viewed here and here.

Contributors
Benita Comeau, MIT Judo instructor
Thierry Lincou, Boston-area acrobat
Joel Herzfeld, MIT Video Production
Diya Khanna, MIT UROP
All the students in STS.014 Embodied Education: Past, Present, Future and STS.041 Exercise is Medicine: From Ancient Civilizations to Modern Healthcare Systems

MICRO 2.0: Cultivating Students' STEM Identities through a Blended Learning Research and Education Program

***Jessica G. Sandland**, principal lecturer in the Department of Materials Science and Engineering and digital learning scientist in MIT Open Learning*

In 2021, the Department of Materials Science and Engineering began a fully online research and education program known as MICRO – the Materials Initiative for Comprehensive Research Opportunity – to provide meaningful research opportunities to undergraduate students from outside of MIT who come from traditionally underserved backgrounds. This pilot program, which received its initial seed funding through a J-WEL grant, has grown into two-university collaboration between the Materials Science and Engineering (MS&E) departments at MIT and Northwestern University. Across the two universities, 18 students have completed the program and another 12 are currently participating. Program alums are currently pursuing graduate studies at MIT, Northwestern, Caltech, UCLA, the University of Chicago, ETH Zurich, and Iowa State University.

MICRO is a mentoring-intensive program that aims to provide valuable research and education experience through (1) a fully online research project, (2) introductory MS&E lectures, (3) interaction with both research and professional mentors, and (4) professional skill-building workshops and activities. Thanks to a follow-on J-WEL grant, we were able to add a fifth component, an on-campus visit, in 2024.

The Inaugural MICRO Summit

In January '24, MICRO program participants at both Northwestern University and MIT travelled from across the country to MIT for a three day in-person event that we called the MICRO Summit. Participants conducting research at MIT were also invited to extend their trip for up to a week to allow them to work in-person with their lab groups. The Summit consisted of a variety of activities, including the following:

Campus Tours: Students toured MIT, seeing campus highlights such as the Great Dome and the Banana Lounge. We also toured the MIT.nano facility, exploring the One.MIT exhibit and the microscopy facility.

Presentations: Each MICRO student had the opportunity to present their work to their peers and program mentors. Presentations included *Machine Learning Prediction of the Al-Ce-Ni-Mg System Mechanical Properties* (Pablo Luna Falcon) and *Development of Automated Active Learning Loop for the Prediction of Zeolite-OSDA Binding Energies* (Nga Vu).

Workshops: During their visit, the MICRO students attended two panel discussions. In the first, graduate students from MIT's Materials Science and Mechanical Engineering departments shared their experiences in graduate school and answered questions from the MICRO students.

In the second, graduates from the Materials Science doctoral programs at Northwestern University and MIT discussed professional opportunities in the field. Professionals from industry, academia, and government were represented on the panel.

Social activities: The summit included ample time for social activities like dinners at local restaurants to give the students an opportunity to get to know one another and form a strong community bond. These activities also gave the students and mentors a chance to get to know one another better and interact in a more informal environment.

Identity Development through the MICRO Program

One goal of the MICRO 2.0 program is to investigate the development of participants' identities as materials scientists and as members of the broader scientific community. We use the work of Carlone and Johnson to guide our work[1]. In their paper "Understanding the science experiences of successful women of color: Science identity as an analytic lens", the authors identify three essential dimensions of STEM identity: competence, performance, and recognition. They define competence as the knowledge and understanding of relevant scientific content, performance as the social performance of relevant scientific practices and recognition as being recognized as a scientist both by oneself and one's peers.

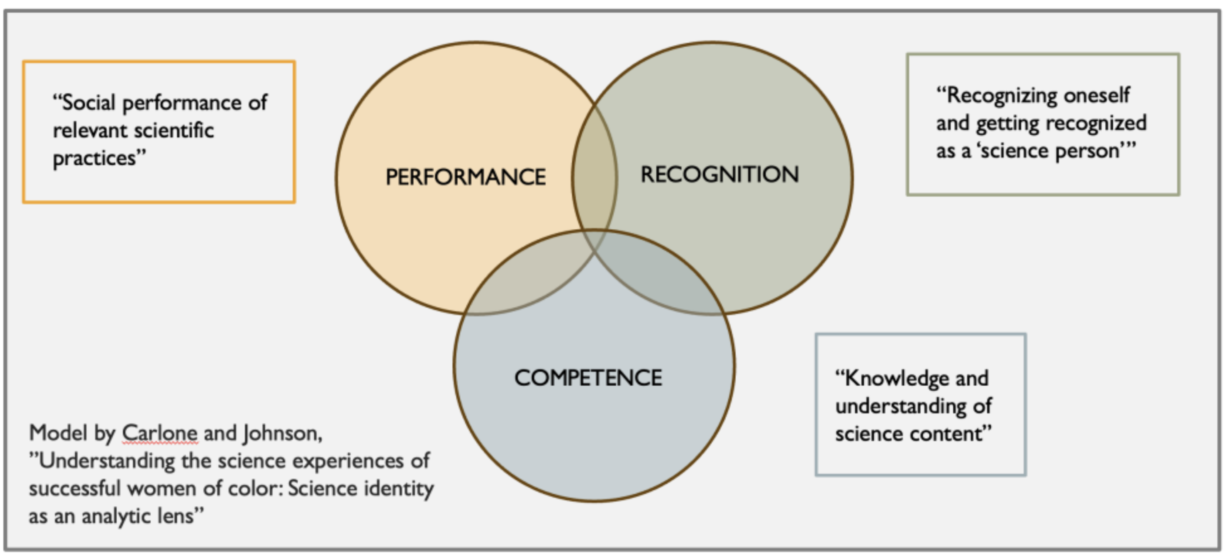

Figure 1: Carlone and Johnson's STEM identity model

To better understand how MICRO participation influences STEM identity development, we developed a survey that interrogates students' perceptions of how the MICRO program contributed to their identity development. Activities were categorized as relating to one of the three dimensions of the Carlone and Johnson identity model, and participants were asked to indicate using a 5-point Likert scale (ranging from strongly disagree to strongly agree) whether or not the MICRO program improved their ability in that area.

[1] Carlone, H. B. & Johnson, A. Understanding the science experiences of successful women of color: Science identity as an analytic lens. *J Res Sci Teach* **44**, 1187–1218 (2007).

Performance:
- Participate in a lab group meeting
- Have conversations with other materials scientists
- Give a scientific presentation
- Have a conversation with fellow scientists

Competence:
- Understand the field of materials science and engineering
- Contribute to a scientific research project
- Discuss your work from the perspective of a materials scientist
- Develop your technical abilities (e.g. learning a new programming language or lab skill)

Recognition:
- Contribute to an academic paper
- Prepare a successful fellowship application
- Successfully apply to graduate school
- Feel more confident as a scientist or engineer
- Feel part of the materials science community
- Feel part of the scientific community

The survey was sent to all current and former members of the MICRO program and was completed by six program alumni and four current participants. Recruitment of participants to complete the survey was the largest challenge faced in our research, which was additionally complicated by the fact that a relatively small number of students have participated in the program. Ultimately 10 out of the 22 participants and alums (45%) participated. All data were collected anonymously. Across all dimensions of STEM identity, participants indicate that the program improved their abilities and feelings of confidence and belonging. The results are shown in Figure 2.

	Mean Score
Have conversations with other materials scientists	4.7
Give a scientific presentation	4.3
Have a conversation with fellow scientists	4.6
Participate in a lab group meeting	3.8
Understand the field of materials science and engineering	4.7
Contribute to a scientific research project	4.8
Discuss your work from the perspective of a materials scientist	4.5
Develop your technical abilities	4.8
Contribute to an academic paper	3.8
Prepare a successful fellowship application	3.8
Successfully apply to graduate school	4.1
Feel more confident as a scientist or engineer	4.7
Feel part of the materials science community	4.4
Feel part of the scientific community	4.8

Figure 1 Survey results. Participants were asked to rank how much they agreed or disagreed with the following

Beyond understanding whether MICRO increases participants' perceived performance, competence, and recognition, we would also like to understand which components of the MICRO program are most important to this goal. Specifically, this question is interesting to us because MICRO is currently a very high-touch program, with significant resources, especially mentoring resources, invested in each participant. As we consider the potential for program expansion, it is important to understand which of these program components are particularly important to the students' development.

The second half of the survey asked participants to indicate which program components contributed to each area of identity development. The program components they could choose from included the following:

- *Research mentor*: The mentor, typically a graduate student or post-doc, who worked directly with the student on their research project
- *MICRO staff*: The mentors, including faculty, graduate students, and instructional staff, who support professional development, fellowship applications, and the graduate school admissions process
- *Research project*: The student's remote research project
- *Online MSE lectures*: A series of videos selected from MIT OpenCourseWare and MIT's Department of Materials Science YouTube channel designed to provide a short overview of the field of MS&E

• *MICRO Summit*: Only participants who were part of the program the year the MICRO summit occurred were asked to rate its importance. Four students responded.

Figure 3 shows the relative importance of the various program components for each aspect of identity development as indicated by the responders.

	Research Mentor	MICRO Staff	Research Project	Online MSE Lectures	MICRO Summit
Have conversations with other materials scientists	89%	89%	33%	33%	100%
Give a scientific presentation	56%	67%	67%	0%	67%
Have a conversation with fellow scientists	89%	67%	44%	22%	100%
Participate in a lab group meeting	56%	22%	33%	11%	0%
Understand the field of materials science and engineering	67%	56%	67%	89%	67%
Contribute to a scientific research project	67%	44%	67%	0%	33%
Discuss your work from the perspective of a materials scientist	78%	44%	44%	56%	100%
Develop your technical abilities	78%	44%	89%	33%	33%
Contribute to an academic paper	44%	33%	44%	0%	0%
Prepare a successful fellowship application	22%	78%	11%	0%	33%
Successfully apply to graduate school	33%	78%	11%	11%	67%
Feel more confident as a scientist or engineer	67%	78%	33%	33%	67%
Feel part of the materials science community	44%	78%	22%	11%	100%
Feel part of the scientific community	67%	78%	33%	22%	100%

Figure 2: Participant rating of relative importance of various program components

Critically, the mentorship aspect of the program proved particularly important to the various aspects of identity development that the survey inquired about. The in-person component of the programming also proved particularly important, even though it only lasted a few days. Again, note that the sample size for the question regarding the in-person programming was small; only four responded to this question.) participants indicated that the research program played an important role in some areas, especially those relating to performance and competence, and the online lectures helped with factors relating specifically to the field of Materials Science and Engineering. As we move forward with program development and expansion, it is going to be important for us to balance the desire to serve a greater number of students with the knowledge that individualized mentoring and, perhaps, in-person programming are identified as the most important components of the MICRO program.

<u>Contributors</u>

This project was led by Jessica Sandland (Principal Lecturer, MIT Department of Materials Science and Engineering) working in conjunction with Cécile Chazot (Julia Weertman Professor in Materials Science and Engineering, Northwestern University). Serafina France Tribe (student, Northwestern University) contributed to the research. Sam Figueroa (graduate student, MIT Department of Mechanical Engineering) and John Harrold (Instructor, MIT Department of Materials Science and Engineering) contributed to the success of the MICRO Summit. Sam Figueroa (graduate student, MIT Department of

Mechanical Engineering) and Mrigi Munjal (graduate student, MIT Department of Materials Science and Engineering) served as program mentors.

Related Media:

The program was featured in the MIT Press: "Fostering research, careers, and community in materials science", https://dmse.mit.edu/news/fostering-research-careers-and-community-in-materials-science/

The program also featured in an Open Learning blog post: "Increasing access to materials science and STEM education via unique research experiences", https://medium.com/open-learning/increasing-access-to-materials-science-and-stem-education-via-unique-research-experiences-f66868719174

Related research to be published in the '24 IEEE Frontiers in education Conference Proceedings: S. France Tribe, J.G. Sandland, C. Chazot, "Broadening Participation in Online Research and Learning in Materials Science and Engineering: The Impact of Recruitment Strategies"

An article relating to the first iteration of this program was published in Maber: C. A. C. Chazot, M. L'Etoile, J.G. Sandland, "MICRO: An online undergraduate program to promote equitable access to research and education in materials science and engineering" https://doi.org/10.1016/j.matt.2023.03.003

Our program website is: https://www.mse-micro.net/

Our OCW page can be found at: https://ocw.mit.edu/courses/res-3-006-micro-mentoring-resources-and-materials-science-curriculum-spring-2021/

Light Up Kicks: Engaging Youth in Shoe Design Using Culturally Sustainable Pedagogy

***Liza Goldstein**, invention education pathway administrator at Lemelson-MIT;*

***Cristina Sáenz**, invention education manager at Lemelson-MIT; and*

***Michael Cima**, the David H. Koch (1962) Professor of Engineering in the Department of Materials Science and Engineering and faculty director of Lemelson-MIT*

<u>Restatement of Project Goals</u>

Lemelson-MIT (LMIT) received a 2023-2024 J-WEL Innovation Grant to develop *Light Up Kicks* (LUK), a curriculum that introduces upper elementary students (ages 9 -11) to invention education and electronic circuits through their building of a prototype shoe that lights-up. Many young people at this stage of development begin to lose interest in STEM. We set out to maintain and enhance interest among students from diverse backgrounds by reinforcing the value of multilingualism and multiculturalism (i.e., culturally sustaining pedagogy) and by celebrating the knowledge and assets diverse students bring to invention.

The hands-on invention curriculum was intended for 4th and 5th grade teachers to use as their science curricula for eight weeks. There would be two meetings (approximately 45 minutes in duration) written for each week, hence 16 meetings total. The curriculum would take students through the invention process with a culminating project of building a light-up, wearable shoe prototype. The curricula will be linked to the 4th grade NGSS Science and Engineering standards. As the students would conceptualize and build their inventions, they'd draw from culturally relevant examples in nature such as animal hooves/paws in designing their shoe soles and indigenous or culture-specific textile designs for the shoe fabric. We would include the local community in the development of the curricula by having a teacher pilot the program with their class and would use contractors from various ethnic/cultural backgrounds to provide case studies for the guide.

Our intention was to train the teacher in the fall of 2023 and have their class pilot the program in the spring of 2024. Qualitative findings would be available to share by June of 2024. The curriculum would be adaptable and respond to the needs of the international audiences that participate. Examples of how students build their shoe prototypes using the unique cultural wealth in their localities would be added back to the curriculum to enhance its ability to make a global impact.

<u>Modifications to Initial Proposal</u>

Lemelson-MIT successfully developed LUK (as described above) in the 2023-2024 school year. We designed both an educator version and student slides to accompany the educator version. Five case studies, using research and lived experiences from individuals from around the world (Brazil, Uganda, Tunisia, Taiwan, and Serbia) were incorporated in the curriculum. In addition to linking the curriculum to NGSS Science and Engineering standards, we tied the content to Common Core ELA, math, and social studies standards and National Core Arts Standards (visual arts).

In the spring of 2024 LUK was informally piloted in two 4th grade classrooms: one in Modesto, CA and the other in Pajaro, CA. Write-ups from the informal pilot teachers provided us with excellent initial feedback and some photos to include in the guide. However, our formal pilot school, Codman Academy Charter Public School in Dorchester, MA fell through due to staff turnover at the school and lack of communication with LMIT staff. With permission from the J-WEL administrator, we formally piloted LUK in the late fall of 2024 with a 4th grade class at Modesto Christian School in Modesto, CA. Our researcher compiled and analyzed the qualitative findings after the completion of the pilot in December 2024.

Final Outcomes

Pre/Post Student Survey Descriptions:

Fourth grade students at our official pilot school, Modesto Christian, were invited to complete a pre- and post-program survey designed by the researchers of this study and administered electronically via the Qualtrics tool between October and December 2024. The pre-survey was administered by the teacher before the start of the program. The survey consisted of 16 items focusing on students' demographic and academic background, their previous experiences with invention, using makerspaces, using various technological tools and equipment, their self-perceptions as inventors, interest in STEM areas, among others. In addition to these items, the post-survey also contained questions about students' experiences with the LUK program, including the new knowledge and skills learned during the program and their experiences learning about different cultures.

Summary of Pre/Post Student Results:

Overall, there were 17 students who completed the pre-survey. Eleven participants identified as male, and four participants identified as female. With regards to ethnicity, there was a multiple-response item providing students with an opportunity to select more than one answer. Five students identified as Hispanic or Latino/Latina, seven students identified as White-Caucasian, two students identified as Asian, and one student identified as African American or Black. There were several students who chose to self-describe their ethnicity, some of which included American and Mexican, American, Filipino, Scottish, and Portuguese American.

In response to the statement of "*As of today, I believe I am an inventor",* 72.2% of the students responded *Yes*, while 5.6% responded *No* and 5.6% responded *Not Sure*. The majority of the students (77.8%) indicated that, as of today, they believed they could solve problems. When asked *"How interested are you in science, technology, engineering, and math (STEM) subjects?*", most students responded that they were either extremely interested (60%) or very (20%) interested. Similarly, when asked "*how confident do you feel in your ability to come up with creative ideas or inventions?",* most of them responded that they were either extremely confident (57.1%) or very confident (21.4%).

The survey also asked the students about the importance of learning about different cultures and traditions at school. Results showed that 44.4% of the students found it extremely important, 27.8% found it very important, and 11.1% found it moderately important.

Lastly, example responses to the open-ended question of "*What do you hope to learn from the Light Up Kicks project?"* include, "I hope to learn how to make a shoe," "I hope to learn more about science," and "Have fun!"

The post-survey was administered on the last day of class in December 2024. There were 16 students who completed the post-survey. We found that 80% of the students attended all LUK lessons, while 33.3% missed only 1 lesson, and 6.7% missed 4 or more lessons. In response to the statement of "*As of today, I believe I am an inventor",* 86.7% of the students responded *Yes*, while 6.7% responded *No,* and 6.7% responded *Not Sure*.
When asked *"How has your interest in science, technology, engineering, and math (STEM) subjects changed since participating in the Light Up Kicks project",* 40% of the students responded that they were *a lot more interested* (60%) or a little more interested (20%), while 13.3% indicated that their interest *stayed the same*. Similarly, when asked *"How has your confidence in your ability to come up with creative ideas or inventions changed since participating in the Light Up Kicks project",* 53.3% responded that they felt *a lot more confident*, 40% felt *a little more confident*, and 6.7% indicated that it *stayed the same*.

The students also asked about the new skills or knowledge that they learned after doing the *Light Up Kicks* project. Example quotes include, "I think my skills are a lot better and when I do any other project, I will know more than I did," and "I have learned how to use a hot glue gun and wire cutters." The students were also asked if they felt more motivated to continue learning and exploring STEM topics because of their participating in the LUK project. The majority (86.7%) confirmed that they felt more motivated.

The students also shared that they learned various things about different cultures and traditions by participating in the program. Example quotes are "I learned a ton more about Africa (country I chose)," "I have learned that all shoes are different," and "I have learned about Australia and their traditions and the kind of shoes they have."

Teacher Post Interview Summary:

Upon the completion of the LUK program, we conducted a one-hour semi-structured interview with the teacher via Zoom. The goal of the interview was to explore the teacher's experiences and perceptions related to the LUK curriculum implementation, its impact on students, and challenges. The interview protocol consisted of 17 broad questions and related prompts. The semi-structured nature of the protocol allowed the interviewer to ask additional follow-up questions depending on the participant's responses.

Overall, the experience made the teacher feel empowered and grateful, and, as a teacher, she felt she could make an important difference in students' life. According to her the LUK curriculum was "an eye-opening experience" and provided an opportunity to grow as a professional. She said, "...knowing that I can make a difference, no matter what grade level I have adapted to over the years. I just truly feel I can't say enough great things about Lemelson-MIT. I'm so grateful for this opportunity."

There were a number of LUK curricular features that the teacher considered impactful in terms of making both the teacher and students' experiences fun and engaging. One of the most prominent features about the LUK curriculum was that it incorporated diverse perspectives and cultural elements. Another unique feature about the curriculum is its transdisciplinary nature and its applicability to different disciplinary areas. She also indicated that she was able to reinforce STEM concepts through the LUK curriculum. Here are some examples of things she told us:

"...they don't have shoes in this country or in this part of the world. And now they're opening a door to where now there's curiosity. Now I feel like I can grow, not even just with shoes, but maybe certain clothing, or you know whether it's style or just the notion of it. It needs to be something to where it should be a necessity versus it, you know, being something that we just have, and we're fortunate to have, you know. So, I think that opens the door for new perspective, especially at such an early age."

"...the science, the art, the social studies, the ELA that all of that component, all of those are, I guess, all that criteria it made it so much easier to teach, because all of that was cross curriculum..."

When asked about the challenges experienced during the LUK curriculum implementation, the teacher shared that the research component of the curriculum presented one of the biggest challenges considering the young age of the learners. She shared that many students could hardly type and had difficulties using their computers for research purposes. Another challenge was that the students were new to science. She shared that the students, especially Special Education students, needed a lot of scaffolding form the teacher to accomplish research-related tasks and learn science concepts.

Multiple times during the interview, the teacher mentioned how grateful she felt for all the support and training she received from the LMIT staff. She was especially thankful for the curricular resources and the constant guidance she received during the curriculum implementation. The teacher indicated that, overall, the LUK curriculum was very effective and there weren't many changes she would suggest. She provided several recommendations such as increasing the PD duration for future LUK teachers, providing extra support through Google classrooms, and including a graphic organizer.

<u>Lessons Learned</u>

The development of the LUK guide with eight weeks of activities (16 meetings) was a huge accomplishment that included testing activities, writing them up, rounds of editing, graphic design, implementation, testing, and assessment. The post survey results, and teacher interview indicate that the program increased students' interest in pursuing future STEM activities, taught them new hands-on skills, and increased their awareness and knowledge of different cultures and traditions. The teacher praised the transdisciplinary nature of the guide and how she could touch on different subject areas/concepts with the program. We will integrate her feedback on including more instruction for educators on how students can conduct research, and scaffolding suggestions for learners at different levels.

The greatest challenge/roadblock in the process was having to pivot when our original formal pilot site did not materialize as expected in the spring of 2024. Furthermore, working with an outside design company to design the guide proved challenging at times. We are very pleased with the final products, thrilled that our Partners in Invention Education (PiE) members are starting to use it, and hope the program is integrated into elementary classrooms around the globe.

Final Outputs/Deliverables

LMIT successfully developed and designed the *Light Up Kicks* curriculum that was outlined in the proposal. We created both an educator version (in PDF) and student slides (in PowerPoint). Please see the following google drive link which includes: https://drive.google.com/drive/folders/1VlFDfquxy-hrB1C09rM-qwVYEfqE1jbS?usp=sharing

- Educator version
- Student slides
- Photos from pilot testing at Modesto Christian School

Contributors

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Making Implicit Knowledge Explicit: Tacit Knowledge Transfer from Expert Glassblowing Instructors to Less Experienced Students at MIT's Glass Lab

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Restatement of Project Goals

1) Instrument the MIT Glass Lab and glass blowers with non-invasive sensors to quantify expertise and capture unspoken nuances that only expert instructors focus on, and that are not commonly verbalized to the students.
2) Create instructional videos with intuitive visuals that represent the information captured with sensors to convey expert knowledge in a more explicit manner. These videos seek to complement the traditional method of teaching glass-blowing skills.
3) Compare the learning rate and glass-blowing performance between students who have access to the complementary instructional videos and students who do not.
4) Explore quantifiable differences in the sensed data between experts and beginners.

Final Outcomes

1) This goal was completed successfully. Some unexpected hurdles were encountered when we had to deal with the harsh environment of a glassblowing shop with flaming hot furnaces and tools. For example, some of the cameras that were used to record the glassblowers would heat up and stop recording due to the proximity to the furnace. In this case, we solved it by installing a shield with reflective coating between the camera and the heat source.

   The Glass Lab was instrumented as follows: We collected video of glassblowers performing a cup and jar task, from the front and side, while working in a workbench. We tracked their attention and their field of vision using an eye tracker, collected data of the air pumped into the glass using a sensor at the air pedal and the rotation of the glass pipe via an accelerometer installed on the glass pipe.

2) This goal was successfully completed. The major challenge was to synchronize all the visual guides coming from different sensor streams with their own timestamps. This was solved by using a single timestamp (Unix time) obtained from the internet via a WIFI enabled microcontroller. Please see a sample of the instructional video showing a glassblower instructor creating a cup

3) This goal was only partially fulfilled. The reasons were twofold: 3.1) access to the glassblowing students (naive learners), and 3.2) coordinating recording sessions with the Glass Lab instructors. 3.3) To solve the absence of novice data, we collected some from intermediate glassblowers.

3.1) The MIT Glass Lab instructors were not comfortable with naive learners carrying the sensors in their bodies (i.e. eye-tracking glasses and muscle activity arm band). They claimed that learners already had enough challenges and cognitive load during the class, and that adding another burden (even if minimal) could jeopardize their learning and safety. Moreover, given the short time to access the Glass Lab, instructors preferred for learners to focus on the lab's activities rather than participating in research (even if the disturbance of the instruments for data collection was minimal).

3.2) Coordinating time for recording data from Glass Lab instructors became challenging given that outside the training sessions, the experts used the Glass Lab time for their own personal projects. We found it very hard to collect data during the personal project's time given instructors preferred to focus on their activities.

3.3) We collected data from intermediate glassblowers during their personal project's time, and were able to extract preliminary results that suggest nuances on how the expert glassblowers perform their craft.

4) The absence of data from novices, did not allow for comparison between them and experts. Nevertheless, we captured some data from intermediate glassblowers that led to some insights regarding the craft. These differences include: experts show more constant velocity while rotating the pipe (acceleration closer to zero) and smoother transition of the pipe rotation when changing direction. Moreover, experts pay attention not to the area where the tools are but mostly at the tip of the glass (which allows better alignment of the glass and better shape). Experts take less time to complete each stage of the glassblowing tasks, hence conserving heat in the piece and requiring fewer reheating cycles.

<u>Lessons Learned</u>

Instrumenting the MIT Glass Lab for the first time was a significant accomplishment for us. We were able to collect data from very diverse sensor categories simultaneously. We tried to be as minimally invasive as possible so as not to affect the usual workflow of the glassblowers, and we believe we succeeded on that. Instructors that accepted to participate in the recordings acknowledge that the sensors did not disturb their craft. A delay obtaining the equipment (eye tracking system) led to starting only to test the data collection pipeline in November 2023, rather than in August 2023, which decreased our timeline for accessing the experts and novice learners.

The largest impact of our study so far has been the publication of a paper at the FIE 2024 (IEEE Frontiers in Education Conference), which was received very enthusiastically by the audience at the conference. We got very positive feedback from the attendees, which were mostly coming from the education field. We were interested in discovering their opinions from the education point of view.

We also presented this project in a workshop at SMART (the Singapore-MIT Alliance for Research and Technology) in Singapore, which sparked interactions with local industry partners such as Toyota and has led to exploring collaborations with robotics labs in the city/country that might lead to a project exploring extracting implicit learning from table tennis experts.

Moreover, this approach has opened other research avenues to explore the extraction of expertise from other activities that require a less controlled environment, hence facilitating the data collection and participation from research subjects. We are exploring instrumenting expert table tennis players, who already have expressed interest in the study, have offered their time to being recorded, and are enthusiastic to get this data to train robot or other equipment to replicate the expertise extracted or to provide direct feedback to them so they can improve their game. We have also received interest from other MIT labs, which want to team up to connect our research with robotics (teach robots to become coaches by replicating the expert's behaviors using our collected data, i.e. a table tennis coaching how to hit the ball).

This project involves interacting and cooperating with glassblowing experts and artists who have very tight schedules and a focus on their craft, so the greatest challenge was to be able to discuss with them the project, plan the best approach for data collection, sensor placement, and coordinate with them the time to perform the data collection experiments. Moreover, given the Glass Lab is a small place that only houses up to 4 teams working in their glassblowing activities, access to the space was also very controlled due to the space constraints that increase risk when interacting with hot-melted glass. As mentioned above, another big challenge that we were not able to solve was the instructors' reticence to involve students in the experiments, though initially they were open to the idea. This was an important obstacle for this project because a large part of it was to capture data from novices to compare it with the experts' data.

Final Outputs/Deliverables

We include a publication in an international IEEE engineering education venue, a poster presented in Singapore at a SMART workshop on education, and a sample of an instructional video combining the different data sources.

1) Instructional video:
https://www.youtube.com/watch?v=oN_Lo5Ja3y8&ab_channel=AlexArmengol
2) Poster for SMART workshop:
https://drive.google.com/file/d/1fZ22caYlHwXSnFF26d9XYBJFke1BfUJJ/view?usp=drive_link
3) FIE 2024 paper:
https://drive.google.com/file/d/1Un6LYly9uFRnMwsi2Hdn4lZnKTqsK35g/view?usp=sharing

Project References/Resources

Please find photos of expert and intermediate glassblowers performing a cup or jar task:
https://drive.google.com/drive/folders/11n4eHGkekWYsQ3ruJNg7eY31iaP_oqcp

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