

## **Merging STEM Education with Brain Science: Breaking the Silo Mentality**

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Conference Key Areas: Philosophy & Purpose of Engineering Education, Educational and Organizational Development

Keywords: Engineering Education Research Methods

### **INTRODUCTION**

Learning has been long studied through different disciplines, such as neuroscience, cognitive psychology, brain science, and education; all these fields, however, often operate in silos, using different research methods and following different professional practices. Therefore, learning is not frequently reviewed through a holistic lens, and findings can remain available within narrower academic communities instead of being shared broadly. Although the Engineering Education (ENE) field is cross disciplinary by nature, so far it appears that its scholars approach the learning aspect mainly by adopting the culture, practices and methods developed by the education community; however, ENE rarely appears to get informed by developments in other learning-related fields [1]. Many authors have argued that it is the

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“siloes nature of many engineering schools and universities that inhibits collaboration and cross-disciplinary learning” [2]. The pilot study discussed in this paper suggests new research approaches on learning, while at the same time bridging the gap between the disciplines of education, brain science, and beyond.

## 1 TRANSFORMING LEARNING THROUGH RESEARCH APPLIED PRACTICES

### 1.1 The Learning Across Scales Project

As technology and research regarding learning advance faster than ever, “there is a pressing need in higher education for deeper integration of research across the fields that impact learning” [3]. MIT has taken actions to address this need, including the founding of the MIT Integrated Learning Initiative (MITili) in 2016 [4] “through rigorous and interdisciplinary research on the fundamental mechanisms of learning and how we can improve it” [4]. A founding principle of MITili is that it, “draws from fields as wide ranging as cognitive psychology, neuroscience, economics, health, design, engineering, architecture and discipline-based education research (DBER)” [4].

The Learning Across Scales (LxS) Project was initiated in February 2016 to assess the level of integration across the silos of research. The goal was to:

- **Explore** the cross-disciplinary landscape of learning at different scales [Neuron, Brain, Classroom, MOOCs, Global Education].
- **Map** the existing learning related research approaches and identify unexplored areas that will allow for cross-disciplinary research opportunities.
- **Create** interdisciplinary pathways, such as a cross-disciplinary research repository, to inform new MIT educational & research initiatives.
- **Bridge** the gap between traditional education and the brain sciences.
- **Highlight** actionable implementations for the real world.

## 2 RESEARCH STUDY

In the summer of 2016, the first pilot study within the LxS project was designed and implemented. The scope of this pilot study was to provide an initial understanding of the most commonly researched topics within the communities of education and brain science, to explore potential common research ground, and to use both infographics and a website to communicate the results.

### 2.1 Data Collection

Data collection for this study involved recording and examining “call(s) for papers” of conferences and journals representing numerous subfields of education as well as brain science. A maximum of 5 conferences and/or 5 journals were first identified for each of the following subfields: mathematics education, physics education, engineering education, biology education, history education, music education, computer science education; 7 conferences and journals were identified which had the generic term of “education” in the title; 11 conferences and journals were identified under the field of “brain and cognition”; and 3 additional conferences and journals were identified and included under the term “neuroscience.” A different data set was collected for the fields of e-learning and MOOCs due to the very special nature of the latter, that calls for a distinct pedagogical approach. The conferences and journals were identified through a Google search via relevant terms such as

[subject name] education conference call for papers, or [subject area] education journal call for papers. Experts in every field were also contacted within MIT in order to contribute towards identifying the most appropriate conferences and journals. To further establish validity, in this first pilot study, only conferences organized by universities or entities formally related to education were included. For every conference or journal included in the data set, the research topics identified under the “call for papers” section were further catalogued.

## 2.2 Data Analysis

Mixed methods were used during data analysis. As a first step, the data was split into 2 groups, namely data from the fields of education and data from brain science. Due to the particular nature of the subfield, a separate group emerged out of the *education* data that included data related to e-learning with MOOCs. A general inductive open coding qualitative method [5] was used to identify thematic research categories. *Table 1* presents a sample of 3 conferences on engineering education and includes identified research topics along with highlighting the color-coding scheme that was first applied.

Table 1. Color-coded data sample representing research topics identified by 3 conferences in the field of engineering education

Conferences	SEFI	ASEE	IEDEC
Research Topics	Engineering Education Research	College Industry Partnerships	Student Projects and Internships
	Entrepreneurship in Engineering Education	Design in Engineering Education	Learning Environments, Technology and eLearning/e-Assessment
	Gender in Engineering Education	Engineering and Public Policy	Distance Learning and Distance Teaching
	Curriculum Development	Educational Research and Methods	Innovation and Creativity in Engineering Design
	The Importance of Internships	Engineering Ethics	Women in Engineering
	Ethics in Engineering Education	Continuing Professional Development	Social Media in Engineering Education

The two researchers then met with an expert who had separately analyzed a sample of the data. The thematic categories were further discussed and redefined until the whole group came to a consensus with regards to the definitions. At the end, as presented in *Table 2*, 16 thematic categories were defined, and the whole data set was again analyzed according to the new definitions. Research topics that did not fit in any of the thematic categories were not included in this pilot study but will be incorporated at a future point.

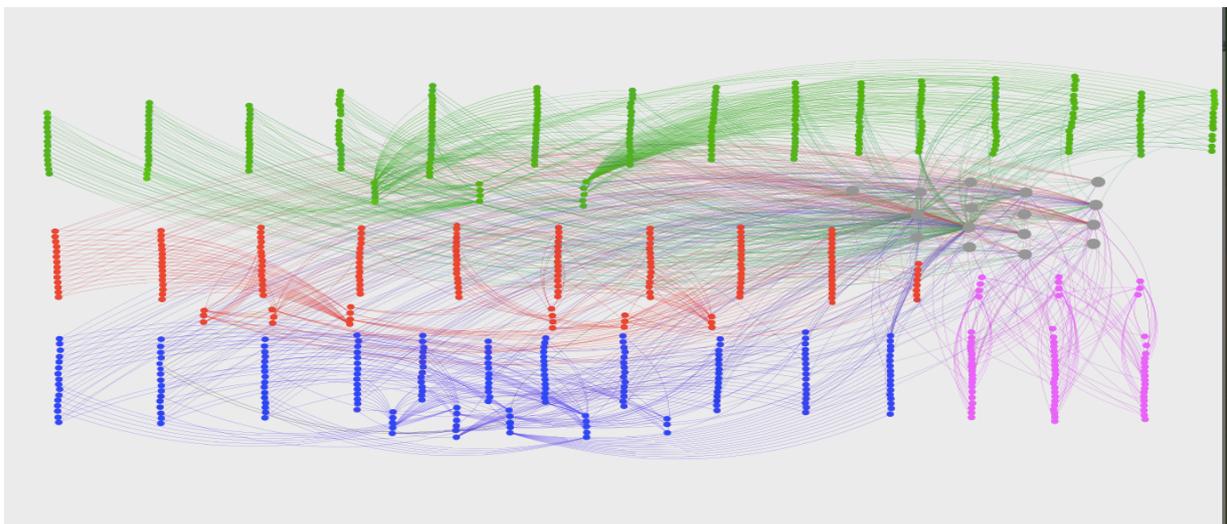
Table 2. The 16 thematic categories that emerged from the data analysis

<b>Research Thematic Category</b>	<b>Definition Used</b>
Technology	Research regarding how technology can be used to enhance the learning experience.
Sociocultural Issues	Research regarding sociocultural issues (of, or relating to, to a combination of social cultural elements such as socioeconomic status, race, religion, age, etc.).
Gender	Research regarding how gender affects education.
Innovations	Research regarding innovations that develop within/for the delivery or creation of content and curriculum in the classroom.
Ethics	Research regarding ethical considerations in education (both regarding the practice and the content to be taught).
Student Psychology	Research regarding student psychology factors, such as motivation, that influence students while they are learning and ultimately affect retention and understanding.
Assessment of Learning	Research regarding how teachers or a MOOCs platform test whether someone has learned their material.
Assessment of Teaching	Research regarding how a teacher can be assessed for the way he/she maintains a classroom and teaches.
Assessment & Accreditation of Programs	Research regarding program assessment or accreditation.
Teacher Development	Research topics related to how teachers get further educated with regards to development of new content, or new delivery and assessment methods.
Collaborative Learning	Research regarding collaborative learning.
Curriculum Design	Research regarding curriculum design.
Business Opportunities	Research topics related to business models, partnerships, and opportunities for funding that emerge within education, especially through e-learning.
Connections with Industry/Job Market	Research regarding how education connects to the real world, and how education translates to the job market or further employment.
Policy	Research regarding principles and government policy-making in the educational sphere, as well as the collection of laws and rules that govern the operation of education systems.
How Learning Works	Research regarding how the brain processes the information received to form learning.

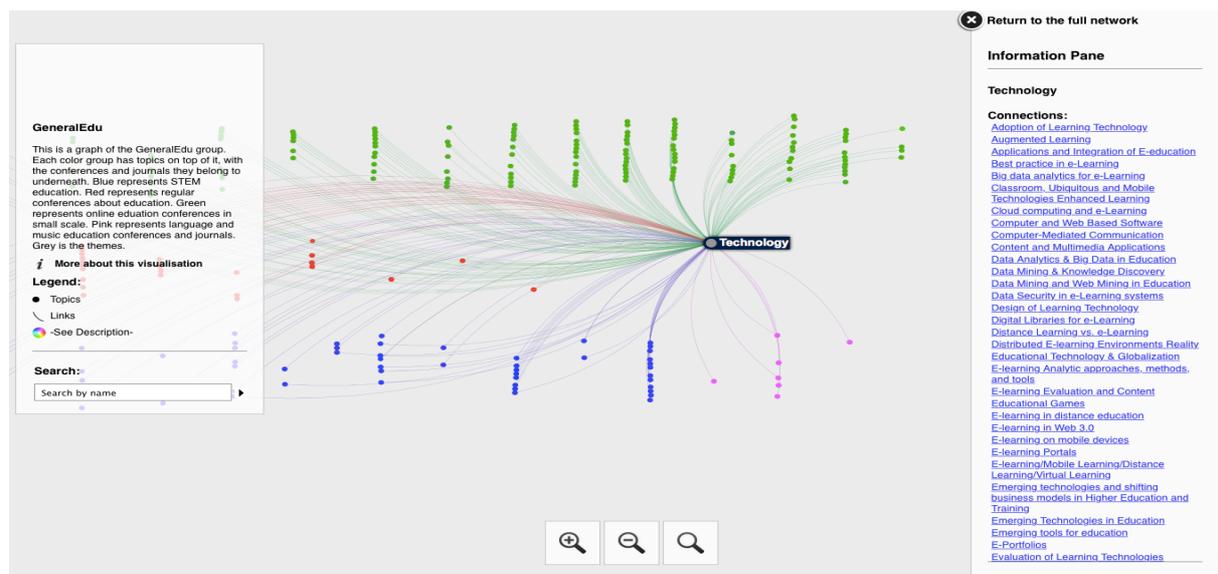
### 3 FINDINGS AND INTERPRETATIONS

#### 3.1 Interactive Maps

As the point of this pilot study was to identify potential research ground of common interest between different fields studying learning, an info-graphic was selected as a medium to communicate the results. The first set of maps independently present the research in the field of brain science, education, and MOOCs in relation to the 16 thematic categories. The second set presents comparative interactive maps across the Learning fields. As a sample of our findings, *Fig 1* and *Fig 2* illustrate the interactive graphs created for the field of education. In these Figures, blue represents conferences and journals on STEM education, pink represents Music and Language education, green represents Online Education in class, while red represents all remaining conferences and journals. The 16 gray circles represent the 16 research thematic categories identified.

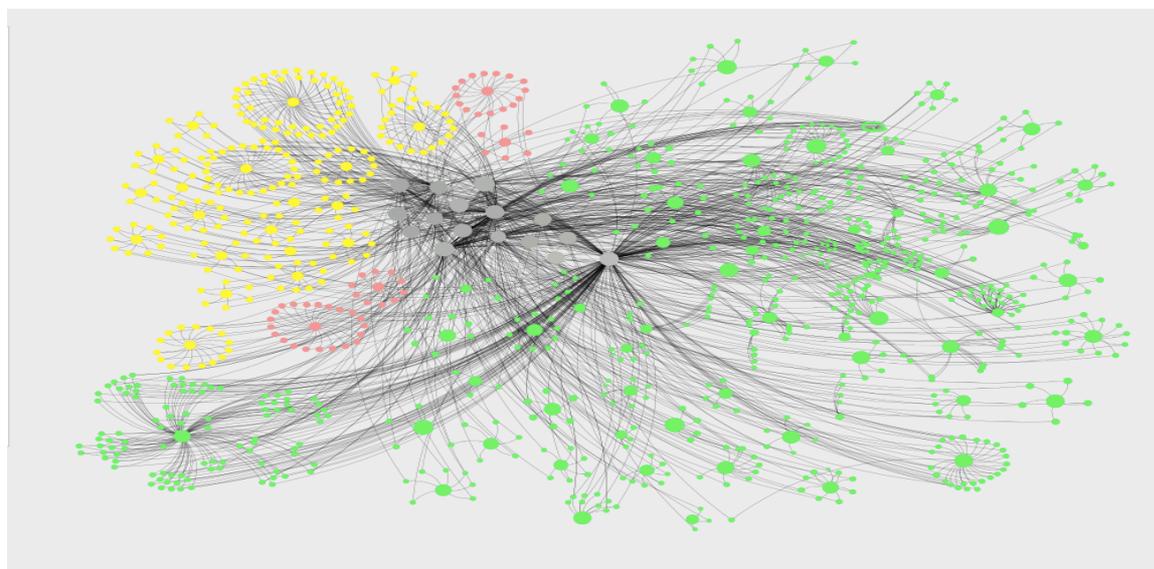


*Fig 1.* Interactive map presenting all data gathered for the field of education.

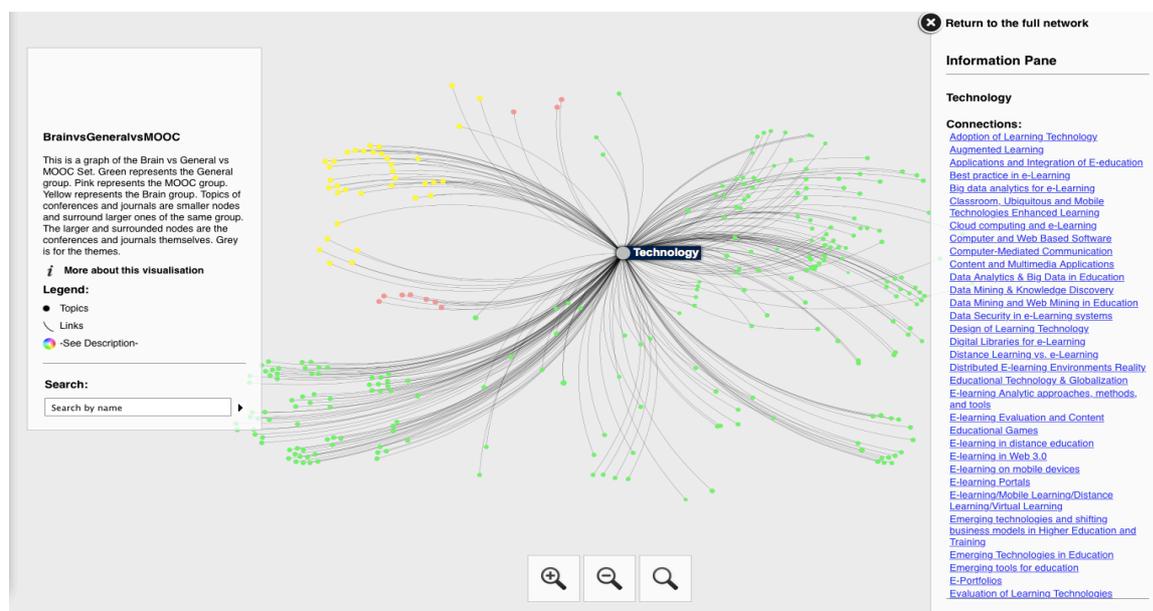


*Fig 2.* Interactive graph highlighting conferences and journals that include the research theme of technology

When examining the common ground among fields, *Fig 3* and *Fig 4* present the comparative interactive graphs between the fields of brain science, education, and MOOCs. In the following figures, yellow represents conferences and journals from the field of brain science, green represents conferences and journals from the field of education, and orange represents conferences and journals on MOOCs. The 16 gray circles represent the 16 research thematic categories identified.



*Fig 3.* Comparative interactive map representing all conferences and journals gathered for the fields of brain science, education, and MOOCs



*Fig 4.* Interactive comparative graph highlighting all conferences and journals within the 3 fields that include the research theme of technology

### 3.2 The Common Ground

In this first pilot study a total of 217 different research topics were identified in the field of brain science, a total of 652 topics were identified in the field of education, and 53 were specifically identified as research topics in MOOCs.

Examining research that appears to be more prominent within the STEM education community, as shown in Fig 5., *Technology*, and *Teacher Training* appear to be the most popular themes followed by *Curriculum* and *Assessment of Learning*.

However, while taking a more holistic comparative view across the Brain Science, Education and MOOCs fields, as shown in Fig 6., research themes of common interest appear to be slightly different. Considering that the scope of this project is to identify and highlight possible research themes that can serve as a starting ground for collaboration across the different fields that study learning, the topics of *Technology*, *Assessment of Learning*, *Policy*, *Sociocultural Issues*, *Student Psychology*, *Teacher Training* and *Collaborative Learning* appear to be of interest to all fields. Taking a closer look at the overlap, *Technology*, *Teacher Training* and *Assessment of Learning* appears to be the common ground between the Brain Science, the STEM Education and the MOOCs communities.

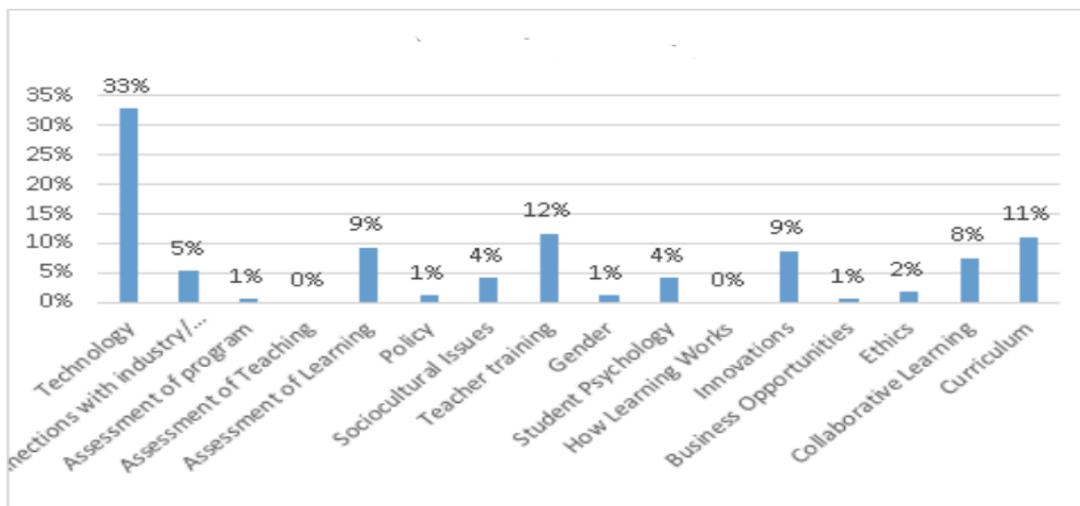


Fig 5. Popular research themes within the STEM Education Community.

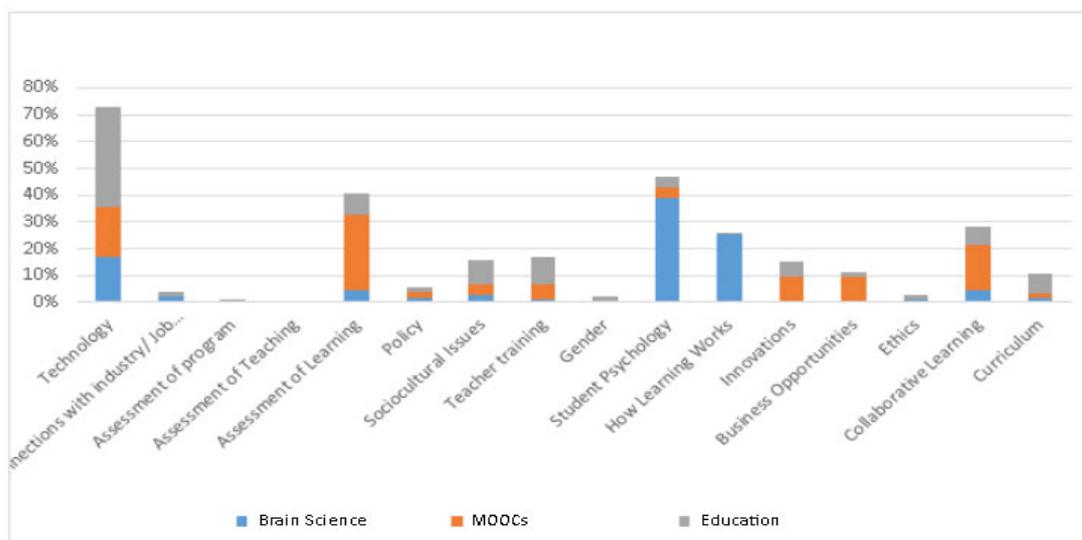


Fig 6. Research themes of common interest across the brain science, education, and MOOCs fields.

## 4 FUTURE WORK

As this is a pilot study with a limited set of data collected for each field, a study including a more comprehensive data collection is required. Furthermore future work of the research group includes development a digital platform that will automatize the process of data collection and analysis, as well as provide a richer set of visuals.

## 5 SUMMARY AND ACKNOWLEDGMENTS

The research team would like to thank A.J. Chabowski, J. Moksh, and S. Sahu for assisting this project, as well as the MIT Office of Open Learning for funding the LxS Project.

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