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BOARD # 388: Learning Through Making Instrument (LMI) project: Current status and future directions [NSF RFE program]

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Learning Through Making Instrument (LMI) project: Current status and future directions [NSF RFE program]

While makerspaces have significantly grown in popularity over the last decades, it is still difficult to understand the impact of using these spaces on students' learning, especially within higher education. Makerspaces have originated outside of formal education as places where users have the freedom to use equipment and materials in order to explore their creativity while making something tangible [1]. These spaces have been introduced in Higher Education Institutions (HEIs) due to their ties with engineering activities, their potential for facilitating prototyping, and the development of technical and non-technical skills experienced by users of these spaces [1], [2], [3]. It is estimated that there are currently over 1000 active makerspaces worldwide [4], with over 41% of state colleges and universities in the US having or being interested in having a makerspace [5]. Many researchers have already investigated the impacts of making in student learning, finding links to disciplinary knowledge and professional skills [6]. However, the existing literature on the impacts of making at a larger scale is scarce, which is partly due to a lack of an appropriate instrument to measure this at a large scale.

It is in this context that the LMI project is situated, being funded through the NSF's Research in the Formation of Engineers (RFE) program. Our main goal is to develop a quantitative instrument that can measure many aspects related to learning in makerspaces. The development of such an instrument will not only enable large scale studies of makerspaces, but also allow individual spaces to better understand how they are currently impacting their students and how they can better support their users. For this poster presentation, our focus is on providing a general overview of the project, as well as a status update on our progress as we near the end of the second year of the project. We also encourage those interested in our instrument to reach out to us and connect to help us pilot the survey across the nation in the near future.

General overview of the project

The goal of the LMI project is to develop and generate validity, fairness, and reliability evidence for an instrument that will measure learning in makerspaces. To accomplish this, the project is divided into five distinct phases, which are explained in Table 1. These phases cover the instrument development process from its theoretical background all the way to its statistical validation process [7], which will be further detailed below.

In our first phase, titled "Construct theory and definition", our focus was on establishing a solid theoretical base upon which the LMI instrument would be built on. We started with the Learning Typology for makerspaces [8], which describes students' experiences with learning in makerspaces through categories that broadly describe how (Mode of Learning) and what (Product of Learning) students learn. The categories in the typology formed our starting point for defining the constructs of the LMI. Our team, which consisted of experts in the typology and in instrument development, engaged in a process of reflexivity, discussion, and review of additional literature to further develop the meaning of our constructs [9]. Our final construct definitions were also reviewed by more than 20 experts in makerspaces and in instrument development. We believe our final constructs provide an accurate representation of the original typology while also expanding on those definitions through the use of concepts explored in the literature about makerspaces, such as bricolage, activity theory, and tinkering [10], [11], [12], [13].

Table 1

Status of study phases and main outputs.

Phase	Goal	Status	Outputs
I: Construct theory and definition	Define constructs to be measured with the instrument	Complete	Constructs, process documented in [9].
II: Item generation and judgment	Create and refine items to be used in the instrument	Complete	Final list of items. Further investigations with think-aloud interview data.
III: Validation study #1	Identifying the factor structure of the instrument	Ongoing	Tentative factor structure for the instrument and potential removal of items.
IV: Validation study #2	Confirming the factor structure for the instrument	Not started	Final factor structure for instrument.
V: Validation of instrument scores for fairness	Establishing guidelines for instrument scoring and group comparisons	Not started	Instrument scoring guide.

Following from our definition of constructs, we proceeded into the second phase, “Item generation and judgment”. The focus of this phase was on creating a set of items theoretically aligned with the constructs, and on gathering evidences of content validity to refine the writing of the items. We initially wrote the items as a team and reviewed them for consistency, writing, and content. Next, we shared the items with the experts detailed in Phase I for additional feedback. We then iterated on our items once more, and subsequently used the first version of our instrument to conduct cognitive interviews with students who use makerspaces. The interviews consisted of having participants read the questions in the instrument aloud while also talking through their interpretation and thought process when selecting a response. Our goal was to assess how students were interpreting the questions in our instrument and make changes where appropriate to ensure that the items are measuring what we wanted them to measure.

With these refinements made to the instrument, we moved on to Phase III. The goal of this phase is to deploy our instrument's preliminary version to students who use makerspaces so we can analyze the factor structure. Through an Exploratory Factor Analysis (EFA), we will be able to determine how the items align statistically and make informed judgments based on our theoretical definitions. In other words, we will verify how each item is able to measure the constructs we initially outlined. We expect this phase to be finished by the end of spring 2025.

Phases IV and V will require collecting more responses from the refined instrument, which will happen in at least 6 institutions across the US. For Phase IV, we will perform a Confirmatory Factor Analysis (CFA) with our nationwide data to further validate the factor structure verified in Phase III. With the factor structure finalized, we move on to the final phase (V), in which we will prepare a guide for interpreting scores in our instrument and evaluate the fairness of those scores through measurement invariance and group comparison analyses.

Progress made in the last year

As previously described, in Phase II we conducted cognitive interviews with students who represent the population of our intended respondents. Through these interviews, we evaluated their understanding of the items in our survey to ensure appropriate interpretations. We conducted a total of 25 cognitive interviews with students from a variety of demographics at three different institutions in the US. We recruited students from a variety of backgrounds (i.e., major, ethnicity, gender, and others) to investigate any early signs of cultural bias in our items.

Through the interviews, we detected some problems with our initial survey design, including the rating scale and the writing in some of the items. For the scale being used, we initially presented all our items with the following prompt: "To what extent do you agree with the following statements about your makerspace experience?" Each item was then rated on a scale that ranged from 1 (strongly disagree) to 7 (strongly agree). After our first few interviews, however, we noticed that students were not exploring the full range of the scale and would very infrequently choose options lower than 4. After some discussions and investigations of the literature, we decided to change our scale to a self-description one, as our statements are positive and not socially desirable [14]. Our new prompt thus changed to "How well do the following statements describe your makerspace experience?" and the responses ranged from 1 (not at all) to 5 (completely). With this change, students more frequently explored the full range of the scale in their responses. For the writing of our items, we made tweaks to convey meanings more explicitly and to simplify concepts as appropriate, which we will detail in a future publication.

At the time of writing this paper, we are piloting the current version of our survey instrument with students. To do that, we transferred our refined instrument into a digital survey that we could easily disseminate to our target population. After creating the digital version of our survey, we created our initial recruitment strategy and filed an IRB protocol with our institutions to ensure compliance with ethical practices. For our recruitment, we wanted to ensure that our respondents would have at least some experience with makerspaces, thus we recruited from classes that include a makerspace component. We recruited students in the Fall semester of 2024 and are preparing for a second round of data collection in the Spring semester of 2025. Given the length and complexity of our instrument, we are looking for at least 200 good-quality responses from students in order to perform the EFA proposed for this phase.

Conclusions

We want to acknowledge the progress we made in the almost two years of the project as we look into the future and anticipate the impacts of our research. First, we successfully delineated and defined the constructs we want to measure with our instrument. Second, in conducting the cognitive interviews for Phase II of the study, we were able to refine our instrument to ensure its suitability for our population of interest. We also realized that these interviews would allow us to answer more questions than originally anticipated due to the richness of the data. Third, we have started the data collection for Phase III, but we will have to engage with additional data collection to get enough data for our EFA study. Fourth and finally, as we get ready to start with data collection for Phases IV and V, we invite those from interested institutions to reach out to us so they can be included in our nationwide pilot of the survey. This outreach will ensure greater representation of the higher education landscape in the country.

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