Self-Organized Maker Education: Action Research at A Cross-Disciplinary University

Qingqing Xing, Yihan Cai, Nan Zhu, Jing Yu, and Yingbo Liu*

***Abstract*—Fostering soft skills in students has long been the subject of intense research in the wake of the digital revolution. Various research efforts, such as Students as Partners, have also explored the possibilities of involving students as stakeholders in the co-construction of learning environments. Makerspace suitable for individual or group learning enables students to develop their knowledge, skills, and identities as designers, researchers, and/or engineers. However, little self-organized academic makerspace learning takes place at the university level in China, and few attempts have been made to conduct action research on soft skill acquisition based on maker education. This paper reports how a Chinese cross-disciplinary university cultivates the soft skills of graduate students through a series of teaching and learning activities extended from the academic makerspace. The administrative and instructional design of the master's program is analyzed at the macro (university), meso (program), and micro (curriculum) levels. The results from observation and in-depth interviews show that a "Self-organized Maker Education" culture is being built at this cross-disciplinary university, leading to resilience in academic identity formation in the learning process.**

***Index Terms*—Self-organized maker education, cross-disciplinary, soft skills, academic makerspace**

I. Introduction

One of the least investigated areas in China's higher education literature relates to the lack of soft or transferable skills, which are essential in today's labor market to both enterprises and individuals. Soft skills such as life skills, social skills, interpersonal skills, leadership skills, transversal competences, social competences, and meta-competences are widely used as the "emotional side" of human beings [1], and the rapidly evolving work contexts calls for future-capable graduates that can demonstrate enterprise capabilities such as critical thinking, problem-solving, collaboration, and value creation [2]. However, although the demand on soft skills is growing fast, this is not always reflected in either administrative or curricula design at the Chinese universities. It has long been criticized that Chinese primary and secondary education focuses on test preparation, leaving little time or space for fostering analytical and creative skills in tertiary education.

The adaptation to new teaching models and learning methods, reflected in the transformation of traditional classroom architecture and redesign, is a clear sign of China's efforts to reform education. Echoing the national call for "mass innovation and entrepreneurship," a great number of Chinese universities offer programs and activities to help students develop their soft skills, such as workshops, seminars, and mentoring programs. Some studies have been implemented on formal soft skills education curricula in Chinese universities [3], but there is still little research on designing learning environments that enable students to cultivate soft skills in a student-centered learning culture to facilitate individualized learning.

Academic makerspaces are designed to foster collaboration and innovation among students, faculty, and staff and have established themselves as a robust means of supporting learning and research. Academic makerspaces that sprang up on university campuses around the world two decades ago, such as at Georgia Institute of Technology, Massachusetts Institute of Technology, Northwestern University, Stanford University, and Yale University, are an important signal for the promotion of STEM learning. There are also successful academic makerspace examples at Chinese universities, such as Fablab O Shanghai, which was established by the College of Design and Innovation at Tongji University in 2012.

Few in-depth studies have been completed in China on the educational philosophy, implementation, and student perception of academic makerspaces, and their direct impact on cultivating soft skills in students is still unclear.

Bottleneck questions remain unanswered such as the cost at the university end on effort, management and assessment needed to teach soft skills, how students with liberal arts backgrounds benefit from this exclusively high-tech learning resource is also another challenge.

To address these issues, we initiate action research among faculty members, administrators, and students at a new cross-disciplinary research-oriented university in China to answer the following questions:

- How did this Self-Organized Maker Education (SOME) come about at the university?
- How have students obtained and shared learning resources through the use of the academic makerspace?
- How did students' perceptions of acquiring soft skills change during the 6-month learning period?

The innovation for our action research is the design, implementation, and reflection of our Self-organized Maker Education (SOME) model to support student soft skills learning. This research aims to transform student-centered teaching into a community-based unit while responding to rapid technological developments, such as generative AI communication tools. Qualitative data were collected through ethnographic observations, semi-structured focus

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interviews, and participant artifacts. We also sought to create a coherent narrative of the 6-month academic socialization process for first-semester master's students at a newly established cross-disciplinary university in China. The research intends to expand the present study of Student as Partners (SAP) [4] in co-construction of learning environment.

II. Background

A. Research Context

The establishment of a completely new cross-disciplinary university (hereafter referred to as “the University”) is an ambitious attempt to initiate higher educational paradigm shift in China. Exploring new university models in the societal transformations has been in the central agenda of higher education research for years [5]. Regardless of the tremendous efforts and various experiments, many of which have been top-down, how to reconcile Chinese and Western elements in Chinese higher education has remained an unsolved puzzle. The most profound initiative to reform China's research universities is the recent policy call to build neo-type research universities, officially launched with the "Draft 14th Five-Year Plan (2021-2025) for National Economic and Social Development and Vision 2035 of the People’s Republic of China released in March 2021.

This action research is taking place at one of the "neo-type research universities" in China. Located in the third largest city in China in the Greater Bay Area, the university is officially established in 2022 and has 569 students at its first enrollment. The majority of the ethnic make-up for the university was from Chinese mainland (96.1%); Hong Kong/Macao Special Administrative Region of China (1.2%); other countries (2.7%). English is the medium of instruction.

Fig. 1. The “Hub” Structure on Campus.

New concepts of learning permeate the physical space and facilities of this newly founded university. The networked structure of the buildings and the smart classrooms and makerspaces suggest an open and dynamic culture, symbolized by the two metaphors. Instead of "departments" and “schools”, “academic units are organized around the most pressing scientific problems in 15 "thrust areas” and grouped into 4 “hubs”. “Hubs + Thrusts” is an entirely new way of organizing higher education institutions that lowers the cost of interdisciplinary collaboration and creates a supportive environment for student-centered research.

B. The Student Cohort and the Course Involved

The first cohort of 266 MPhil students is our research target group. Since the university intends to help students build a student-centered learning environment, our action research first involves faculty members and administrative staff and then students after they are physically onboard. The reason for the selection of the student cohort is due to the different learning paths of the students. Among the first cohort of 569 graduate students officially admitted, each of the 303 PhD student is directly supervised by two faculty members from different thrusts, who are named separately as “primary supervisor” and “co-supervisor”. The primary supervisor provides pastoral support as well as project management resources, while students also receive direct academic supervision from the co-supervisor. This arrangement confirms that the intertwining between the student and two supervisors effectively complements the social and academic adjustments shortly after the student begins his or her studies. This practice of dual supervision is also found at other universities and is considered effective in promoting project-based learning. However, the 266 MPhil students take a different learning path: their learning begins with a 6-month “gap” we call Self-Organized Maker Education to complete common core curricula requirements and a two-month Challenge Project. With centralized academic and logistical management, these students are considered an integrated learning community. After the end of the first semester, they either propose their own research proposals and ask faculty members to assist them as (co-)supervisors, or they join project teams assembled by faculty members to complete their work over the next 18 months.

C. Researcher Subjectivities & Positionality

This ongoing action research involves a group of individuals who play a critical role in implementing the “inquiry-based, interdisciplinary active learning model”: a teacher researcher, a senior administrator responsible for teaching assessment, and 3 master’s students who represent 15% of the students with liberal arts backgrounds. We are particularly interested in this group of students because they are more likely to explore how soft skills development can help them overcome the “underrepresented identity” at a science-technical, research-oriented university.

As a course instructor for Cross-disciplinary Design Thinking, the teacher researcher's primary role is to help students integrate communication skills into their academic socialization process. This teacher researcher co-teaches, models, and plans for the improvement of instructional practices based on intensive interactions with other faculty members, quality control administrators, and students. This process gives her the opportunity to conduct research as an insider collaborating with other insiders [6].

As another insider, the quality control administrator, who is actively involved in the development of the makerspace intervention from its conception, ensures that all outcomes, both positive and negative, are reported and that all data analysis receives additional review from higher levels of the university.

The two researchers are “founding members” of the university who participated in and witnessed the implementation of the university's cross-disciplinary pedagogy. Their experiences, observations, and discussions with other professionals indicate that there is a great concern for teaching soft skills to students through the development of the hardware and software provided by the University.

The 3 students are not only actively involved in the teaching and learning process but are “Students as Partners" in this research. They function as critical researchers in this project: they managed both oral interviews and ethnographic observations too among their peers. All of them participated in grounded theory research, a process in which we intentionally moved back and forth between phases of data collection and analysis. We believe that their participation in this action research strengthens the quality and significance of the data collected. By including their learning experiences, we are able to create a more inviting and exciting learning environment for our future undergraduate students who have never ventured into maker projects, such as most Chinese high school graduates.

D. Pedagogy Implemented

A Maker approach to education builds on constructivist social learning theory, which develops the idea that knowledge is built through experience. We develop it further into a Self-organized Maker Education model that is illuminated by the student-centered teaching philosophy rooted in the university.

At the university level, this brand-new university has a goal of “cultivating future leaders”. Leadership, communicative skills, and JIT (Just in Time) learning abilities are exercised in Project-based learning. Students are expected to establish a common vision and to empower each other with their own expertise. With the goal of cultivating future leaders, impact-driven leadership development initiatives are developed to foster students’ ability in empowering each other in the same project team.

New learning experiences need to be implemented to offer students experiences firstly with communicative competency in soft skills. The teacher researcher thus proposes “interactive sprints” to replace the traditional language classes. Through the 5-15 minutes reiteration of academic ideas through formal presentation every week, students practice their communicative abilities. These “interactive sprints” closely connect with and serve the Challenge Project initiative, which requires students to go through the whole process of Design Thinking in 2 months: they are supposed to work in teams to empathize, propose, rethink, and prototype a research project. This exploratory phase, later described by students as “self-directed, self-disciplined, self-monitoring, and self-correcting,” is featured by students advocating, recruiting team members, and managing the project progress. Students must learn and cooperate with each other, seek out resources, and ask for help when needed.

This self-exploratory period of 2 months enables students to co-design and implement a customized, inclusive, boundaryless social and academic space to maximize the allocation of resources based on their own goals. These makers emerge in unpredictable ways and cannot be predetermined.

E. Definition of Terms

The working definition of “soft skills” of this research is cited from the University’s website: "To deal with the escalating challenges on all fronts--economic, social, technological and environmental, it is important to prepare our graduates to be citizens of the knowledge society who possess the competencies of Critical Thinking, Creativity, Communication and Collaboration.”

Self-Organized Maker Education is the counterpart of any educational practice that follows a standardized operational procedure. The Self-organized Maker Education model represents a customized, inclusive, boundless form of pedagogy and soft skill development in the context of science, technology, engineering, and mathematics. It is embodied by an interactive design and implementation of the student-centered, active learning model through Challenge Projects.

Makerspaces are collaborative, community spaces that extend normally inaccessible resources to a larger population. The Makerspace in this research is the signature area of Self-Organized Maker Education at the University. With a total area of more than 9700m^2, it offers space for 450 students. The Maker Space enables student-centered teamwork by breaking down physical and disciplinary boundaries between students. With a target audience of more than 260 master's students from diverse academic backgrounds, a project-based learning (PBL) approach is designed to encourage students to explore real-world problems together.

Fig. 2. The “Makerspace”.

III. RESEARCH DESIGN

The nature of the research questions decides that a qualitative research method is needed to analyze the graduate student learning experience. We collected more than 170 hours of observations and field interviews over the 6 months of the learning activities happening in and outside the Makerspace. As a geographically limited case study, it collects narrative data as the main source through semi-structured interview questions. In-depth individual interviews were performed, particularly with 3 group leaders of the 2-month Challenge Projects. Other qualitative data collected and analyzed include program descriptions, syllabi, lesson plans, and instructional materials. Additional observational and interview data were collected from university administrators and course instructors, which supplemented key interview data. Makerspace survey data provided summary information about the physical space of student academic socialization to form the community of practice. These triangulated data sources provide a comprehensive description of students’ learning experience.

This qualitative action research aims to deepen practitioners' understanding of the populations they work with at a deeper level with three phases. The first phase is planning, in which the teaching philosophy of the academic makerspace is discussed among the teacher researcher and the quality assurance administrator; in the action phase, students are asked to use various physical spaces and communication channels to promote soft skill development; in the reflection phase, students write learning logs and conduct in-depth interviews/discussions with teachers. Modified action steps are implemented with this cycle to explore potential problems, considerations, and improvements. Case studies are also explored.

Ethnographic observations and semi-structured interviews were carried out by the 3 students to gather general information about the distribution of university resources, such as physical space and academic resources, from the entire student cohort. Their individual learning paths during the 2-month challenge project were recorded, and discussions were held with the instructional researcher. In-depth interviews were directed on three topics: previous experience as an initiator of the project (background in soft skills), reflection on acquiring soft skills through the Challenge Project, and future plans. The first theme was addressed in an interview that sought to understand perceptions about soft skills that were not necessarily research oriented. Regarding soft skills acquisition, participants were asked to compare themselves to peers they had recruited as team members in terms of time management, project management, and the need for additional academic training. Questions about future plans focused on how this Challenge Project experience influences their choice of master's thesis project. Although there was a list of questions, not every interview was identical and the lines of communication with different interviewees varied. Appropriate modifications were made for each case.

Three MPhil students are invited to participate in the discussion of “Self-Organized Maker Education” concept initiated by the quality assurance administrator. All three agreed to participate. All students were actively involved within their learning community, and they identify themselves as being interested in “doing things to make changes happen”. Another important reason for them to be invited is because they are from the “underrepresented group” of students with liberal arts background. Of the 266 master's students, 40 have a liberal arts background, representing 15% of the total number of students. During the orientation, some of the students expressed anxiety of future development due to the lack of “hard skills”. To better examine the student population, we conducted a survey among 135 students about their undergraduate majors. We used the U.S. Department of Homeland Security (DHS) STEM Designated Degree Program List [7] as a reference. New and interdisciplinary degree programs were also classified as STEM if the student's self-report included math/computer science/engineering-related content. For example, Smart Campus and Blockchain are classified as STEM. The results turned out that 94 out of 135 students are from STEM majors. After discussion and reflection, we decided to observe more closely on the students with liberal arts background. We choose the 3 students to conduct close observation and invite them to contribute ideas to teaching and learning process.

TABLE I: THE 3 STUDENTS FOR CASE STUDIES

Name	Bio	Previous major
Julia	Challenge Project leader who investigates the distribution of learning resources.	Undergraduate major - Economics Minor - Art
Reagan	Challenge Project leader who develops an oyster raising program with commercialized potentials.	Undergraduate and 1st master’s Major: Applied Linguistics
Core	Key Opinion Leader who initiates a university wide discussion on ChatGPT.	Undergraduate major: Finance

IV. RESEARCH FINDINGS

A. Use of Physical Makerspace

An important component of the Self-Organized Maker Education is the enhanced participation of the physical Makerspace. By participating in a community of practice, makerspaces support the development of self-efficacy, motivation, and interest, which grounds the idea of knowledge through action [8].

Fig. 3. Team area arrangement at the makerspace.

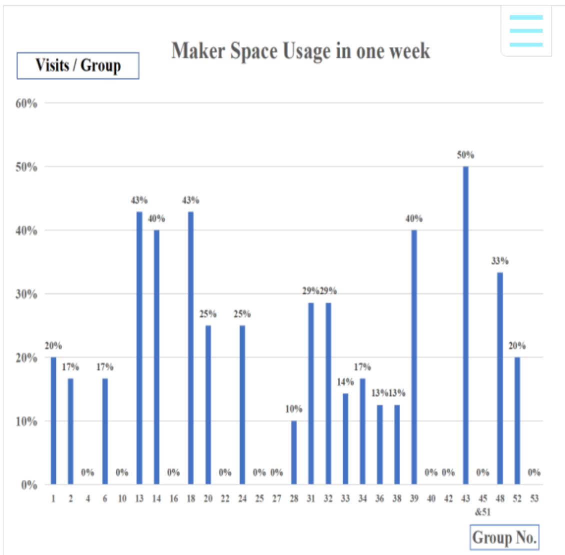

Fig. 4. Team Makerspace Attendance Rate.

B. Reflection on Design Thinking Ability

Students showed increased attention to defining the problem over the study of design thinking. Our observations show that students spent little time considering the design aspects of the Challenge Project during the first week. This changed over the course of the study. For example, Reagan spoke about this:

“Taking Oysteria (oyster + hysteria) as an example, we are made up of 6 members from 6 different disciplines (project management, oceanography, economics, social

science, robotics, and material science). At first, we came together because we were passionate about oyster farming, and it happened that we came across the fact that a piece of technology could shorten the growing cycle of oysters so that they could reach market size more quickly. With this assumption, we promptly set the goal for our project to be the creation of a marine ranch that would utilize this piece of technology to farm oysters and make use of the oysters' shells to produce more products. After that, we soon realized the project goal was too vague that it seemed like several independent projects "sewed" into one piece. We then started to perform the empathy process that lasted for two months. We did a tremendous amount of research online and investigated numerous factories and aquaculture sites."

C. Creativity

The interview data collected show that students increasingly identify creativity as an important part of problem solving. The empathy phase, finding possibilities and iterating ideas in the design thinking course, and the Challenge Project roadshows encouraged them to develop a clear purpose as they tried to figure out what a real project is. For example, Reagan reflected on how important he thought it was to define a true research question. When talking about creating a metaverse community to build a beach cleaning robot, he said:

"…At first, everything seemed to be new and exciting: like-minded people formed Challenge Project groups, ideas kept jumping out, and countless real-world problems were raised to be solved. However, most of these ideas would be eliminated once all members join to perform the empathy process. A crucial point I learned is that students tend to be biased with the information from their discipline when they generate an idea to solve a problem, or even how they would define a problem or what they would consider as a problem."

D. Self-perception of Soft Skills Development

Qualitative data collected during this study showed that students developed their own contexts and structures towards soft skills development. Here we are taking one of the earliest recruited students as the "top 50", Core, with his growth path, to represent how the liberal arts background students benefit from the Self-Organized Maker Education.

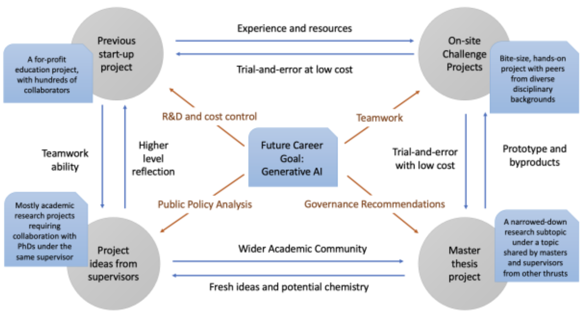

Fig. 5. Core: The collaborator empowered by a self-organized network.

Fig. 5 shows how Core, a student with a liberal arts background, managed to build the intersection of his four project types and find his long-term career goal through a self-organized network. This student has worked with hundreds of stakeholders and actively participated in the Challenge project prior to enrolling at the University. His original experience and skills gained in starting a business made it easier for him to collaborate with his group mates so that he could contribute his ideas and efforts to the overall Challenge Project, which per se functioned as a trial and error to test new ideas that he could not venture before. The on-site Challenge Project also served as trial and error for his master's thesis project and helped him better understand and narrow down his master's thesis project. It is important to emphasize that at the college, master's thesis projects are coordinated by a practice mentor rather than an academic supervisor, and students are also encouraged to play an active role in other research projects proposed by their academic supervisor. These two types of projects, one coordinated by a mentor, and one coordinated by a supervisor, can be mutually reinforcing and provide students with a broader academic community that helps them better navigate the academic world. It should also be noted that this student has surrounded his four types of networks with one center: generative AI, which is related to most, if not all, of his projects and future career.

"My master thesis is about disruptive technology like generative AI…However, my Challenge Project was about Micro-Bubble technology and its application in oyster breeding process. They are apparently, irrelevant. It may sound weird if this happens in most of the traditional universities in China Mainland, for no one wants to 'waste' three months in doing something way apart from his or her own background and facing the risk of generating almost nothing academic in this period of time. However, I think this Challenge Project matters a lot to me. It is a shift of my mindset. Only when you feel safe doing something interesting but full of uncertainty can you boost your creativity. Only when you embrace disciplines that you are not familiar with and embrace risks can you gradually get to know what you really want to research and pursue."

The use of hands-on activities, like university experiences as a whole, has been shown to increase student engagement. Our research has shown that student performance can be significantly improved through increased engagement. Despite regular failures and mistakes, students in this study reported feeling more engaged and motivated to learn in various aspects of university life than a new academic practitioner. Take Reagan, for example, whose motivation goes beyond scholastic goals, but who actively works for the common good. It has also been noted that his community service activities also foster perseverance and passion in leading a project.

A second characteristic that has helped students develop greater stamina is, in Reagan's case (Jing Yu), the chronic development of soft skills in a variety of settings and communities: within the university, in personal extracurricular activities, and in service learning in communities. As an active organizer of music groups and sports activities, and as the founder of an environmental protection NGO, he acts as a "facilitator" between different fields. This mobility sparks our further interest in the impact that self-organized maker education has on learner identity.

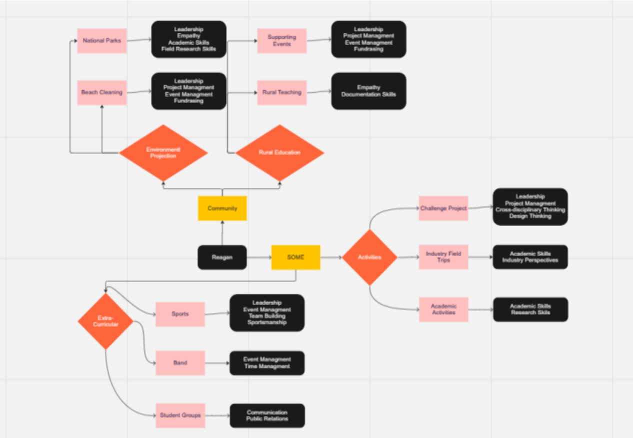

Fig. 6. Reagan: The communicator with extended social spaces.

E. *Dealing with Frustration*

Failure is perceived as inherent in the creative process of making and learning, and as such, it is celebrated, contrasting with traditional education [9]. Students addressed dealing with frustration as an important feature in overcoming soft skill problems. Among 366 students, there were over 50 challenge projects in the beginning. Towards the end, only about 20 students presented in the final online roadshow to recruit for their project teams. Interviews and observations during the first and second round of roadshow of the study indicate that dealing with frustration was an important aspect of developing soft skills. As one of the team leaders who had to give up her own project, reflecting on the most difficult part of the challenge, Julia related:

"My strategy was to convince a CMA professor to be my project mentor, recruit team members to the best of my ability and join a friendly Professor project at the last minute if I could not form a team. I pasted our poster next to the Makerspace gate, had an online roadshow, marketed my idea in front of the canteen door until the last minute of team formation period to recruit. Simultaneously, I listened to professor projects and found out one that is about data visualization and serious game on biology and environmental data, which overlaps with my own project interest."

V. Conclusions

This action research examines the administrative and instructional design of the master's degree programme patterned after "Self-Organised Maker Education" based on observation, in-depth interviews, and quantitative data analysis during a six-month semester at a newly established interdisciplinary university. It provides insights into how soft skills can be developed in a makerspace learning environment. The paper also provides implications for other universities looking to foster soft skills in their students.

A key theme of our findings is that in Self-Organized Maker Education, makers go beyond the physical resources and create their own social or academic networks, communities of practice, and their own learning and development paths. The shared understanding among research members of the educational philosophy of the university allows for the integration of academic and sociocultural issues, with the Makerspace serving as an extended physical environment for the creation of entrepreneurship and academic socialization.

Soft skills serve as tools to create new things and new identities, rather than being affiliated as part of the STEM skills and prototyping in this maker education pattern. The development and implementation of a self-organized Maker Education learning environment has changed the way we think about teaching and learning soft skills. Students have learned to plan and design their own innovation based on critical analysis. Despite frustration, the freedom to initiate the project themselves encourages them to handle pressure and motivate themselves. Through this process, we have developed a better sense of how to design learning experiences that are responsive to students' backgrounds and needs. We plan to continue to incorporate these learning experiences and instructional designs into our research in the future.

Another important theme is the effort to get teachers to embrace self-organized Maker education among a wide range of faculty members, especially adjunct faculty. The teacher researcher has encountered resistance from language teachers who are unwilling to change the traditional "teacher-centered way" and the pressure to provide immediate feedback on student academic presentations during interactive sprints is "daunting" This requires tremendous preparation to foster a self-organized Maker mentality for students to collaborate, create, design, and explore, and therefore relies on training in facilitation techniques for instructors.

Limitations of this study included the participant population, access to panoramic information, and the potential bias of the teacher researcher as a participant observer. As a veteran of 20 years of teaching at a traditional Chinese research university and, as a 46-year-old woman from mainland China with a PhD background in higher education, I acknowledge that there are certain biases that might enter into the research, such as considering the needs of students as a priority, and the belief in developing meaning from direct experiences.

In our practice of Self-organized Maker education, the full role of hubs and thrusts are yet to come into play. The "hubs" serve as centers for interdisciplinary activity, bringing together researchers from different disciplines to work on common problems. "Thrusts" are more specialized research areas that provide a deeper understanding of specific topics. Through these virtual spaces, students and researchers can work together and share resources, reducing the cost of trial and error and accelerating the discovery process by combining ideas and methods from different research areas. In this way, they can explore new frontiers and create new knowledge faster than they would be able to if they worked separately. After the training of soft skills, student performance in these interdisciplinary academic spaces would be our future focus of research.

Conflict of Interest

We, the authors of "Self-Organized Maker Education: Action Research at A Interdisciplinary University", hereby declare that we have a potential conflict of interest as researchers who are also subjects or objects of the research discussed in this article.

As researchers engaged in action research, we are aware that our dual roles as researchers and as subjects/objects of the research may lead to potential bias or influence the interpretation of the results. This conflict of interest arises from our direct involvement and personal investment in the research process and findings. We recognize that our personal experiences, perspectives, and biases as researchers and participants in the research may influence data collection, analysis, and interpretation. It is important to note that our understanding and interpretations of the research findings may be shaped by our own experiences and perspectives, which could introduce subjectivity and potential bias into the research.

To mitigate the potential impact of this conflict of interest, we took the following steps: first, we undertook reflexivity measures: throughout the research process, we engaged in ongoing self-reflection and reflexivity, critically examining our own roles, assumptions, and biases. Second, we sought external feedback and underwent a rigorous peer review process to ensure that our interpretations and conclusions were critically evaluated by independent experts. Third, we ensured transparency by detailing our roles as researchers and subjects/objects of the research, including our personal experiences and perspectives, to increase transparency and allow readers to assess the potential impact of our involvement.

By acknowledging this conflict of interest, we recognize the importance of critically examining our own role and biases, and we strive to present an objective and balanced account of research findings.

Author Contributions

Qingqing Xing initiates the main idea and organizes the writing process; Yihan Cai contributes ideas and does part of the writing; Nan Zhu analyzes and visualizes the data; Jing Yu writes part of the paper, Yingbo Liu provides the data and gives administrative support and is the corresponding author; all authors had approved the final version.

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