Maker culture and science teaching: An experience report with biology degree students

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Luiz Paulo Fernandes Lima[1], José Ricardo Barros de Lima[2], Daniel Brandão Menezes[3] and Francisco Herbert Lima Vasconcelos[4]

ABSTRACT

Digital production offers scientific educators and their students a multitude of opportunities, ranging from computational modeling to the production of educational materials. Thus, this report outlines the experiences during a formative phase of maker culture and digital fabrication with students in the third semester of the biology course at the Federal University of Ceará - UFC. The training covered the introduction of maker culture, computational modeling processes and 2D and 3D digital manufacturing, culminating in the conceptualization of projects that could potentially be carried out in the future within a FabLab. Throughout the training, the participants' involvement was palpable, evident in the use of educational materials, responses to the questionnaire and suggestions for future projects. Consequently, we deduce that the results signify a positive reception and lucid understanding among participants about the potential of FabLab and digital fabrication in education.

Keywords: Digital manufacturing, Maker culture, Science teaching.

[1] Ph.D. student in science and mathematics education
Universidade Federal do Ceará
ORCID: https://orcid.org/0000-0002-5250-7669
[2] Ph.D. student in science and mathematics education
Universidade Federal do Ceará
ORCID: https://orcid.org/0000-0002-3029-6290
[3] Postdoctoral researcher in Teaching
Universidade Estadual do Ceará
ORCID: https://orcid.org/0000-0002-5930-7969
[4] Ph.D. in Multilinear Analysis and Educational Assessment in Telematics
Universidade Federal do Ceará
ORCID: https://orcid.org/0000-0003-4896-9024

INTRODUCTION

The implementation of activities focused on active learning has garnered increasing support in primary education institutions, aiming to empower students as protagonists of the educational process. Active methodologies seek to transform the educational environment, effectively fostering the skills and competencies crucial to students' lives, both within and beyond school (Rocha & Farias, 2020; Barbosa & Moura, 2013).

In this context, maker culture has emerged, providing space for students to develop their own projects and actively engage in the learning process. This cultivates collaboration, critical thinking, innovation, and the acquisition of technological and digital skills (Freitas Oliveira et al., 2023).

Within maker culture, students can participate in a variety of activities, ranging from traditional crafts using paper, brushes, and scissors to digital manufacturing of materials using technologies like laser cutting machines and 3D printers. These activities take place in specially designated spaces called makerspaces or FabLabs, equipped with materials for teachers and students to develop activities and create educational products (Gondim et al., 2023).

One of the significant advantages of FabLabs is the opportunity for individuals to create their own learning resources across different domains. This text particularly focuses on natural sciences, where there is a multitude of manufacturing possibilities, from laser designs on cardboard to 3D printing complex structures such as a human heart. Technological innovation has the potential to revolutionize the teaching and learning of science in primary schools (Raabe & Gomes, 2018).

To effectively utilize these spaces, it is essential to train teachers in computational modeling and the operation of FabLab machines. This enables teachers to autonomously design and produce their educational resources, addressing the individual needs of their students and daily learning requirements (Corte Real et al., 2022).

The integration of maker culture into primary education presents numerous teaching opportunities. How teachers guide their classes and how students utilize these dedicated spaces directly influence knowledge acquisition. It is conceivable to produce models of human skeletons or other living organisms, as well as invisible structures like cells, bacteria, and viruses, depending on the specific needs of the moment.

Therefore, this experience report outlines the training on maker culture and digital fabrication conducted with students in the third semester of the biology degree program at the Federal University of Ceará (UFC). The training included presentations on maker culture, computational modeling processes, and 2D and 3D digital manufacturing, culminating in the development of projects for potential future realization within a FabLab.

MAKER CULTURE AND FABLAB

Maker culture experienced significant growth in the early 2000s, propelled by the rise of Do It Yourself (DIY) practices and garnering increasing global support (Blikstein et al., 2020). The establishment of spaces like makerspaces and FabLabs further solidified and expanded this movement, infiltrating various university disciplines and eventually reaching primary education institutions (Gershenfeld, 2012).

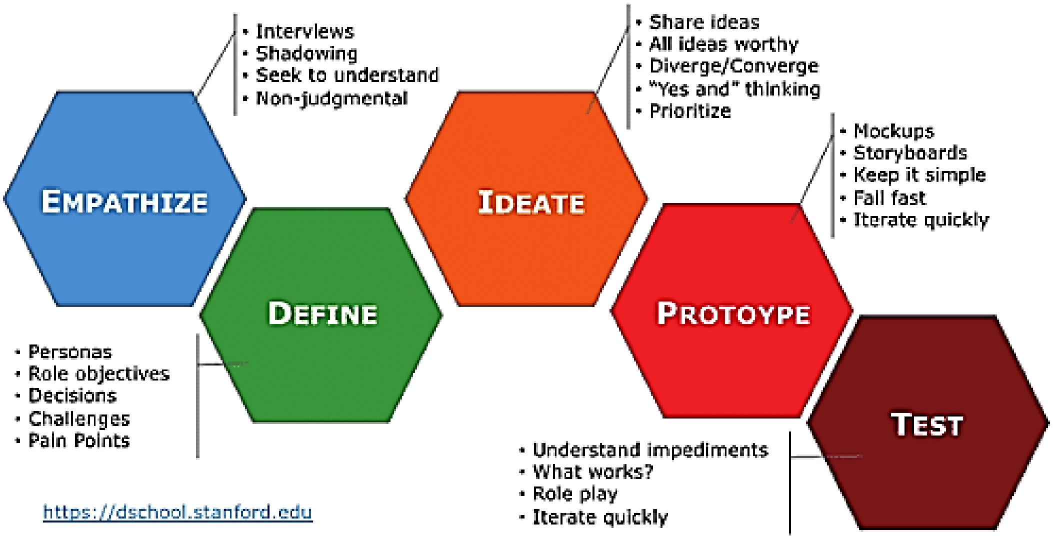
Within this framework, a diverse array of activities places the student at the core of their learning process, fostering active engagement. These activities span from traditional craftsmanship to electronics, facilitating the development of electrical circuits for various applications. Moreover, they encompass programming and robotics, empowering students to both program and construct their own robots. However, the true transformation occurs with the introduction of 2D manufacturing utilizing laser cutting machines, and 3D manufacturing employing specialized printers, which fundamentally redefine the possibilities within makerspaces (Arusievicz et al., 2022).

Digital fabrication (DF) via computational modeling extends beyond merely creating new objects; it also encompasses producing replacement parts or replicating existing items available in the market (Peres et al., 2021). In the educational context, the critical aspect is understanding how DF can be applied. In this regard, virtually anything can be manufactured, from cartographic maps to cellular structures, depending on the needs and objectives of the teacher and their students. Design Thinking (DT) serves as a valuable methodology for guiding these decisions with its specific approach.

DESIGN THINKING AND DIGITAL FABRICATION

Design Thinking is a methodology structured in well-defined stages, closely associated with the maker culture. Its process comprises distinct phases, as can be seen in figure 1: discovery, interpretation, ideation, experimentation and evolution, and can be adopted by both teachers and students in various modeling or manufacturing activities within FabLabs (Brow, 2010).

Figure 1. DT Phases. https://dschool.stanford.edu



During the discovery phase, teachers and students encounter a challenge to be addressed, such as studying the circulatory system without access to a heart model to comprehend blood pathways. In the interpretation and ideation phase, initial solutions to the problem begin to surface. Discussions, idea exchanges, and sketching are common during this stage. Subsequently, in the experimentation phase, computational modeling occurs to determine whether manufacturing will be conducted in 2D or 3D. Various software tools are employed at this juncture to dimension the parts (Educadigital, 2013).

It is during the experimentation and evolution phases that machines are employed to bring the previously developed model to life. For instance, in the case of the heart model, if 3D printing is chosen, parameters such as print size, characteristics like infill and quality, and the selection of the most suitable printing material need to be determined. Finally, teachers and students assess the effectiveness of digital fabrication, identifying any necessary adjustments and reassessing the model or print quality. This phase serves to validate the product, showcasing its functionality in resolving the initially posed problem (Educadigital, 2013).

METHODOLOGY

The training event occurred in mid-October 2023 and brought together 20 students from the third semester of the biology degree program, along with a teacher from the same discipline and three PhD researchers specializing in Science and Mathematics Teaching, with a focus on maker culture and digital fabrication. All participants were affiliated with the Federal University of Ceará (UFC).

Conducted at the FabLab of the Center for Excellence in Educational Policies (CEnPE) - Federal University of Ceará (UFC) Pici Campus, the session lasted three hours. During the event, the fundamentals of maker culture and Design Thinking were discussed, and digital manufacturing tools in both 2D (laser cutting machine) and 3D (3D printer) were introduced, divided into four segments.

Initially, students were presented with several examples of digitally manufactured materials available on the FabLab workbenches, as depicted in Figure 2. These objects ranged from 2D geometric shapes to three-dimensional models of cells, illustrating the wide array of teaching possibilities offered by digital manufacturing across all educational levels. At this stage, the most pertinent aspects of Design Thinking were underscored.

Figure 2. Presentation of the FabLab and the materials developed in it

Following that, the laser cutting machine and the Studio Due V software were introduced, showcasing the modeling of a human eye. The functionality of the digital tool was demonstrated, highlighting its key features in 2D manufacturing and its compatibility with materials such as cardboard and wood scraps for reuse.

Next, participants were introduced to the website Thingiverse and Tinkercad, from which a heart model was selected for modeling and subsequent 3D printing. The printing process using Ultimaker Cura was elaborated upon, covering the specifications of the 3D printer, compatible materials, and various approaches to printing objects, including the heart model.

Lastly, as a concluding step, students completed a questionnaire on Google Forms regarding maker culture, FabLab, and digital manufacturing. Following this, they were paired up to brainstorm potential educational products integrating concepts from Biology and maker education.

RESULTS AND DISCUSSIONS

Firstly, we analyzed the participants' reactions upon entering the FabLab, as depicted in Figure 3, and quickly noticed their awe at the space. It's an environment conducive to relaxation, collaboration, and curiosity, and these attributes were evident throughout the training period.

Figure 3. CEnPE FabLab – UFC Pici campus

Additionally, participants responded to a question regarding their visit to the FabLab, the answers to which are illustrated in Figure 4. Although only 10 individuals completed the questionnaire (see Table 1), it's evident that the overall impression was positive, with some recognizing the significant potential the space holds for education. The more detailed responses indicate that students grasp the significance of such a space in education, particularly in teaching complex concepts that are often challenging to visualize within the confines of a traditional classroom.

Table 1 – Answers to the open question about FabLab.

Leave a comment about your visit to our FabLab.	
Student 1	Very cool.
Student 2	Too much.
Student 3	It really has the potential to improve teaching in the classroom.
Student 4	Cool.
Student 5	It was incredible, visiting this place gave me a lot of ideas.
Student 6	I thought it would be great to get to know another makerspace.
Student 7	Vvery cool. I have a degree but I love education and its applications and I am inserted in the school context, so getting to know the laboratory filled my eyes and brought me a lot of ideas.
Student 8	It was great. The teachers were super receptive and attentive. A very cool place full of interactive things. congratulations.
Student 9	I was delighted with all the material produced. congratulations
Student 10	It was great to see different teaching methods to elucidate more complex content, in addition to the traditional lecture method.

Throughout the training, we elaborated on the processes of computational modeling and digital manufacturing, culminating in the creation of a cardboard eye in 2D and a 3D heart model. We presented digital manufacturing to students as a means of integrating maker culture into classrooms, emphasizing its potential utility for both teachers and students across various educational levels and disciplines. The results of the modeling and printing are depicted in Figures 5 and 6, respectively. For 2D printing, we utilized cardboard sourced from discarded boxes to repurpose material that would otherwise go to waste. In contrast, for 3D printing, we used PLA, a type of plastic known for its lack of odor when melted.

Figure 5 – Human eye manufactured on the laser cutting machine

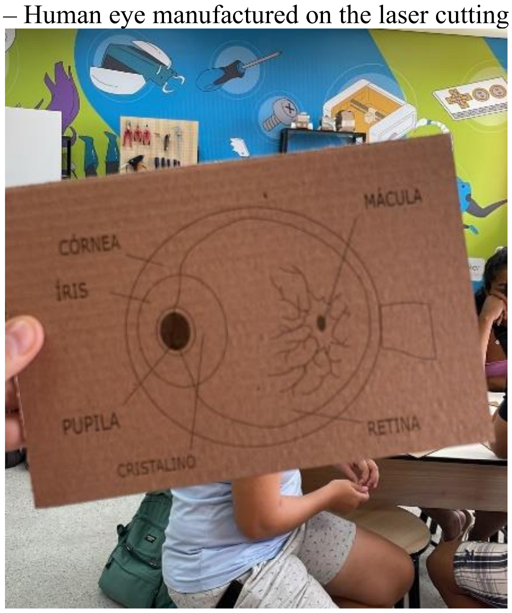
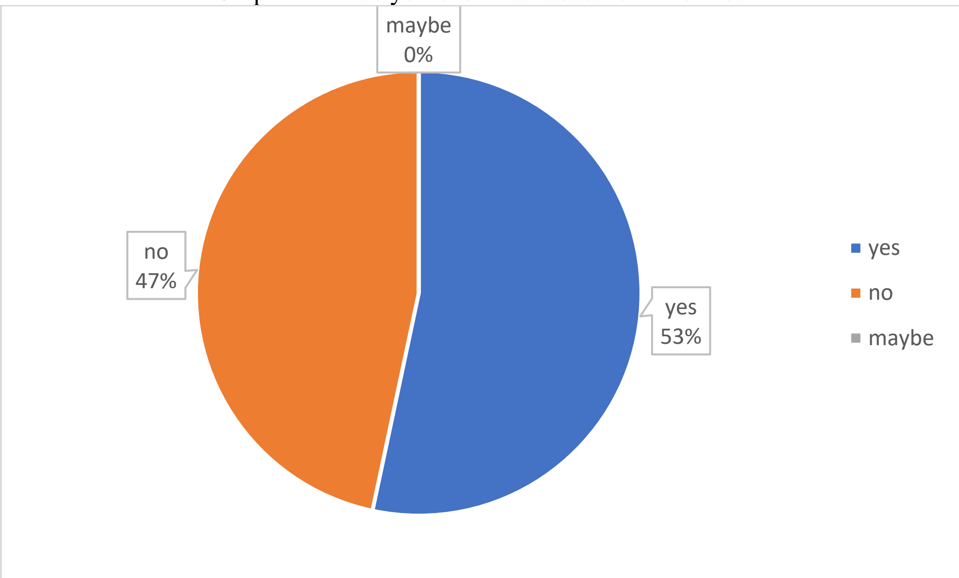


Figure 6 – Human heart manufactured using a 3D printer

Regarding the results of the questionnaire on the utilization of the FabLab, we posed four pivotal questions whose responses hold significant weight in our research on teacher training in maker culture. Out of the 20 students surveyed, 15 provided responses that serve as the data for our analysis.

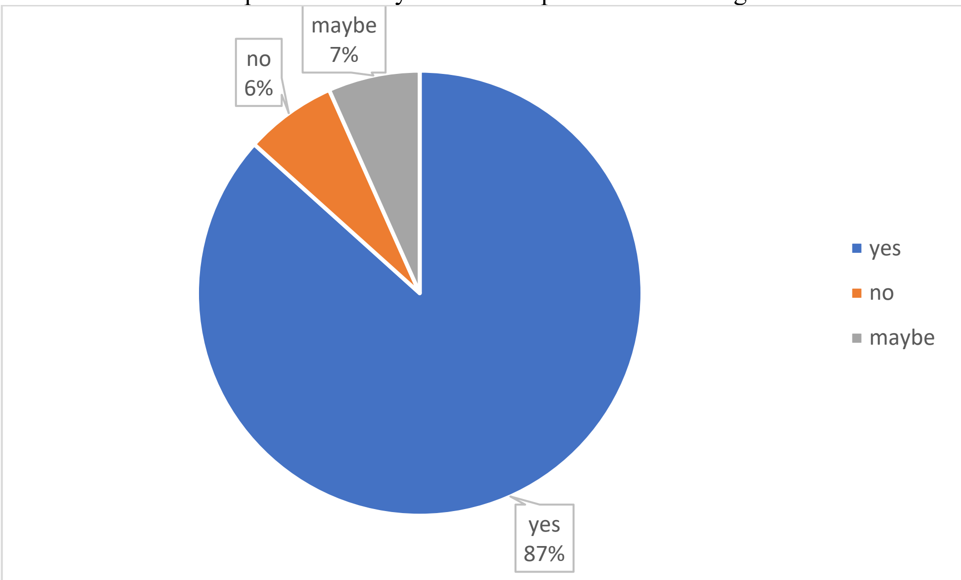
When inquired about their access to a FabLab, slightly over half stated that they had previously accessed one, while the remaining participants had either never entered a FabLab or were unaware of its existence, as depicted in Graph 1. This indicates that makerspaces and FabLabs are not universally recognized among students in the third semester.

Graph 1 – Have you ever had access to a FabLab?

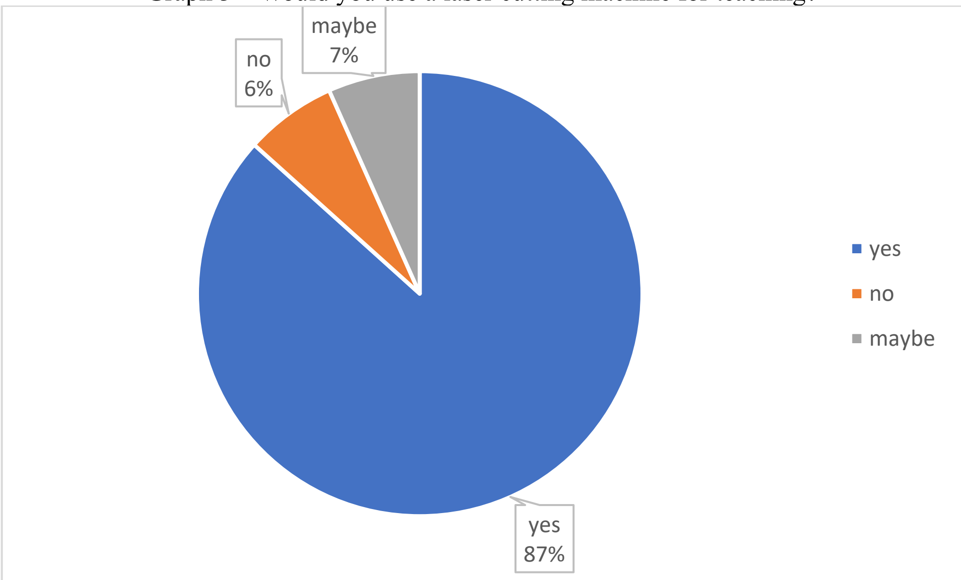


When queried about whether, given the opportunity, they would utilize the laser cutting machine and/or the 3D printer in the FabLab, Graphs 2 and 3 illustrate that the responses were identical. Hence, both maker tools held equal significance, underscoring their importance in the formative phase and digital manufacturing. Only one individual responded with "maybe," and another stated that they would not use either tool.

Graph 2 – Would you use a 3D printer for teaching?

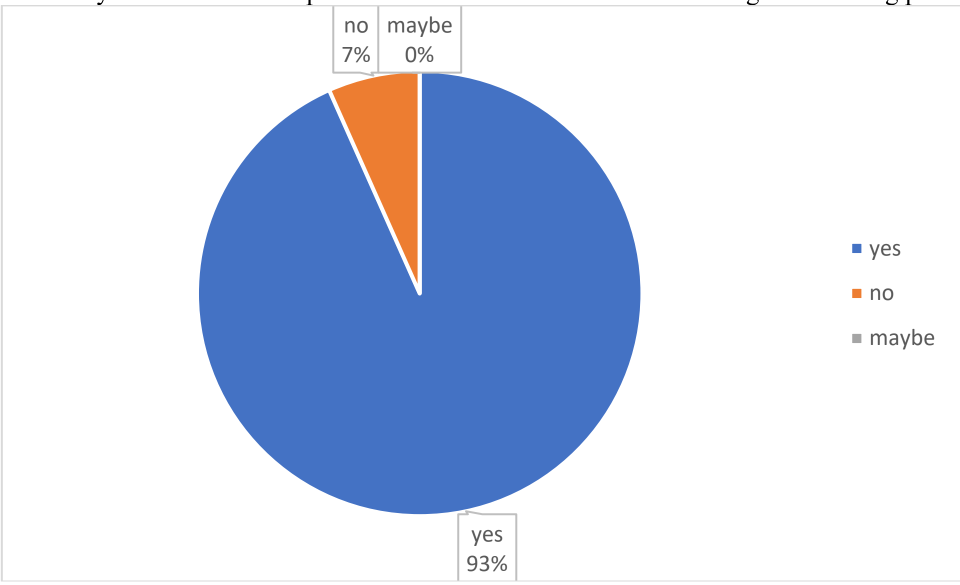


Graph 3 – Would you use a laser cutting machine for teaching?



When questioned about the potential impact of a makerspace on the teaching and learning processes, Graph 4 indicates that the majority responded affirmatively, with only one individual expressing a negative opinion. This data underscores the significance that FabLab and digital manufacturing can have in education, as perceived by the students.

Graph 4 – Do you think a maker space can make a difference in the teaching and learning processes?



After completing the questionnaire, the students were paired up and tasked with integrating biology with maker education, documenting and exchanging ideas with their peers regarding their development of didactic activities involving digital fabrication. The outcomes were as follows, as depicted in Table 2. Only one pair opted not to respond or share their ideas.

Table 2- Possibilities of projects applicable in classrooms relating biology and maker culture.

Teams	Projects
1	Construction of reptile skeleton in mdf for classification.
2	Put together a puzzle of the states of Brazil with their respective environmental conservation units.
3	production of 3D models of insects divided into 3 parts for assembly, like puzzles
4	Using cardboard and a laser cutter, produce various vegetables to classify their parts and types.
5	3D hemoglobin production for blood donation classes.
6	Production of a 2D game (MDF) about parasites and their diseases.
7	Manufacturing of parts (2D, 3D, handmade) to produce a board game about biological warfare (2 teams).
8	Production of cards on a plotter (RPG) about the fauna of the caatinga.
9	Based on the theory of evolution, manufacture various types of skulls in 3D to address the differences between species.

Source: the authors

The outcome of the project proposals indicates that the students grasped the essence of maker culture and were able to envision the myriad possibilities that FabLab and digital manufacturing can offer to education. All participants were encouraged to engage in future activities, with their ideas poised to be implemented within this space.

FINAL CONSIDERATIONS

Upon analyzing the results, we observed a highly positive reception from the participants towards the FabLab and maker culture within the educational context. The environment was wellreceived, fostering relaxation, collaboration, and curiosity—all essential elements for nurturing creativity and collaborative learning.

Participants acknowledged the space's potential for education, emphasizing its significance in teaching complex concepts that are challenging to visualize in traditional classrooms.

The hands-on aspect of the training, involving computational modeling and digital manufacturing, allowed students to apply their newfound knowledge in practice. The utilization of recyclable materials such as cardboard and PLA in 3D printing showcased a sustainable and mindful approach. The majority of participants expressing interest in utilizing both the laser cutting machine and the 3D printer underscores the relevance of these tools in the training context.

The assessment of the potential impact of a makerspace on teaching and learning processes is also promising, with the majority recognizing its positive influence on education.

Furthermore, the outcomes of the project proposals demonstrate that participants were able to grasp the concepts of maker culture and creatively apply them, integrating biology with maker education. The decision to invite all participants to future FabLab sessions, where their ideas could be implemented, indicates sustained interest and engagement with the possibilities offered by the space.

In conclusion, the results suggest a positive reception and a clear understanding among participants regarding the potential of FabLab and digital fabrication in education. This formative experience appears to have ignited students' interest and imagination, suggesting that similar initiatives could be valuable for integrating maker culture into teaching and fostering educational innovation.

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