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MAKER EDUCATION: WHERE IS THE CURRICULUM?

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ABSTRACT

The Maker Movement has been inspirational to many educational institutions, contributing to the growing interest in implementing maker education in K-12 and higher education. However, the examples of this implementation show that many maker activities are not yet integrated within the curriculum. The objective of this article is to understand how maker education can be integrated into the K-12 curriculum. Methodologically, this paper uses a qualitative approach, describing case studies in schools implementing maker education. Based on these experiences, it was possible to categorize the material collected into two groups of activities: those developed in schools, but not related to the curriculum; and those related to one or two subjects in the curriculum. Finally, based on these cases, the paper suggests how the implementation of maker education can be carried out in K-12 education. The focus should not only be the teaching of disciplinary content through maker approaches, but be able to create conditions for the student to become aware and understand the curricular topics that are incorporated in the products they build.

KEYWORDS: Maker movement; Maker activity; STEM-rich; K-12 education; Educational technologies.

EDUCAÇÃO MAKER: ONDE ESTÁ O CURRÍCULO?

RESUMO

O Movimento Maker tem inspirado instituições educacionais, contribuindo para o crescente interesse pela implantação da educação maker tanto no ensino básico quanto no superior. No entanto, os exemplos dessa implantação mostram que as atividades maker não estão ainda integradas ao currículo. Portanto, o objetivo deste artigo é entender como a educação maker pode ser integrada ao currículo do ensino básico. Para tanto, foram utilizadas a abordagem documental e visitas às instituições que estão implantando a educação maker. Com base nessas experiências, foi possível classificar o material coletado em dois grupos de atividades: as que estão associadas a uma ou duas disciplinas do currículo, e as que não estão relacionadas ao currículo. Com base nesses estudos de caso, discutimos como a

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implantação da educação maker pode ser feita no ensino básico. O foco dessa educação não deve ser apenas o ensino de conteúdos disciplinares por meio da educação maker, mas também ser capaz de criar condições para que o aluno tome consciência e entenda os conceitos curriculares presentes nos produtos que constroem.

PALAVRAS-CHAVE: *Movimento maker; Atividade maker; STEM-ampliado; Educação básica; Tecnologias educacionais.*

EDUCACIÓN MAKER: ¿DÓNDE ESTÁ EL CURRÍCULUM?

RESUMEN

El Movimiento maker ha sido observado por las instituciones educativas, contribuyendo al creciente interés en implementar la educación maker en la educación básica y superior. Sin embargo, los ejemplos de esta implementación muestran que las actividades maker aún no están integradas con el currículum. El propósito de este artículo es comprender cómo la educación maker puede integrarse en el currículum. Con este fin, se utilizó el enfoque documental y la visita a las instituciones que están implementando la educación maker. Con base en estas experiencias, fue posible clasificar el material recolectado en dos grupos de actividades: las desarrolladas en las escuelas, pero no relacionadas con el currículum; y los relacionados con una o dos asignaturas del currículum. Finalmente, con base en los estudios de casos descritos y las lecturas realizadas, se describe cómo la implantación de la educación maker puede llevarse a cabo en la educación básica. El enfoque de esta educación no solo debe ser la enseñanza de contenido disciplinario a través del maker, sino también ser capaz de crear condiciones para que el estudiante tome conciencia y comprenda los conceptos curriculares que están presentes en los productos que construyen.

PALABRAS CLAVE: *Movimiento maker; Actividad maker; STEM-ampliado; Educación básica; Tecnologías educativas.*

1 INTRODUCTION

Technology and science education have converged and diverged over the course of the last century. This history, which is forgotten in current educational debates, can assist in illuminating the role of *maker* education in schools. Historically, technology education focused on vocational training, including carpentry and industrial trades (see, for example, DE VRIES, 2018). Even higher education in engineering, during the first half of the twentieth century, was essentially practical, and contained a large number of "hands on" classes. The "scientific" engineer, who must study calculus and physics before learning to build objects, is a creation that originated in the second half of the last century (TRYGGVASON; APELIAN, 2006). Major schools of engineering in the beginning of the twentieth century were temples for the practical "hands on" engineer. However, these same schools, as of the 1970s, worshiped engineering theory and "science" above all else.

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The same occurred in K-12 education. Courses such as carpentry, sewing, and the "manual arts" were considered a refuge for students who did not perform well in subjects such as mathematics, reinforcing the idea that intellectual work is superior to manual labor. Nevertheless, as of the 1980s, many researchers noticed that the seclusion of technology in "manual" classes, and the glorification of "pen and paper" science and mathematics contradicted new cultural, social, and economic trends being established. The UK, in 1989, created a curriculum for technology in education, and researchers began to notice that scientific and technology education had fundamental differences: while science tries to find one equation that would solve many problems (convergent), engineering tries to discover diverse solutions for a single problem (divergent) (ATKIN, 1990).

The inclusion of engineering and technology into K-12 education, therefore, faced a turbulent environment for decades, trying to impose a traditional model that prioritizes convergent thinking to a type of divergent content, encountering few viable solutions. Bullock and Sator (2015, p. 71) claim: "Current science curricula fail to frame the relationship between science and technology as a symbiotic relationship and thus fail to understand that technology education creates a space for science education, and vice-versa".

Maker education, which focuses on the implementation of activities that combine science and technology (both in terms of space, and curricular themes), is a new chapter in this history. Nevertheless, this education is based on a series of digital technologies, which for decades have been difficult to integrate into the classroom. A study by Iannone, Almeida and Valente (2016) points to the fact that these technologies are present particularly in administrative settings and in computer labs, and are already part of the lived experience of many teachers and students. However, they cannot be found in the classroom, nor were they incorporated into curricular practices. This reality currently impacts the implementation of maker education. Nonetheless, considering that technology is a part of contemporary society, which is increasingly digital, mobile, and connected, it is impossible to think of them as not being a part of pedagogic and curricular activities in the classroom. The historic and cultural moment of the beginning of this century brought maker education to the schools' doorstep.

This article aims to understand how maker education can be integrated into K-12 curriculum, considering the particularities of "divergent" content (typical of maker activities) combined with other forms of knowledge from other disciplines, and different ways for organizing curriculum. In order to do so, data collected during previous studies were used to

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answer the following questions: How to characterize maker education? What is the concept of curriculum that can be used in the development of maker activities? How to assist in the development of concepts related to “STEM-rich” (BEVAN, 2017)? How to implement maker education in K-12 education?

In order to answer these questions, documents and examples of maker education activities and spaces visited by the authors were used, as well as the authors’ experiences in the development of maker spaces, and conducting workshops for teacher development. The article is divided into five sections, and the first of them addresses the connection between curriculum and maker activities. The following sections focus on the integration of maker activities into the curriculum, presenting and discussing practical examples; the implementation of maker education in K-12 education; and, finally, the conclusion.

2 THE PILLARS FOR MAKER EDUCATION AND THE CURRICULUM

In this section we present topics concerning the origins of maker education, its vision of the curriculum, and the relationship between maker education and STEM-rich.

2.1 The origins of maker education

The Maker Movement, basing itself on the “Do-it-Yourself” (DIY) culture, is but one of the pillars for maker education. This movement has at its core the idea that people can build, fix, modify, and fabricate the most diverse array of objects and projects. The collective of Makers gathers its members in physical spaces, equipped with traditional objects and digital fabrication tools, known as makerspaces, hackerspaces, FabLabs, FabLearn labs, and other such designations.

FabLabs are an important pillar for the maker movement. During the beginning of the 2000s, Neil Gershenfeld and his collaborators from the Massachusetts Institute of Technology (MIT) Media Lab created a space for digital fabrication with relatively low costs, and began to take the model outside MIT’s campus. In these spaces, through access to digital fabrication tools, students studied the “boundary between computer science and physical science” (GERSHENFELD, 2012, p. 46). Since then, the network of FabLabs has expanded to

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communities, museums, libraries, science fairs, and has finally reached institutions of education.

Maker education has other historic pillars – the Maker Faire and the MAKE Magazine, created in the USA in 2006, popularizing the practice of DIY; the FabLearn project, which disseminated communities of maker educators, and, since 2010, created the first maker spaces in schools in a dozen of countries (MARTINEZ; STAGER, 2013). However, the idea of hands-on and "Do-it-Yourself" in education is not new: it was proposed by educators such as Dewey (1916), Freinet (1998), Montessori (1965), and Freire (2008), who discuss pedagogical approaches based on "hands on" using technologies from their time period, such as letters, wood, etc. Pedagogy based on "hands-on" utilizing digital technologies was proposed by Papert and collaborators (who coined the term "constructionism"), which is based on the idea that knowledge is developed when the learner is engaged in the production of an object of their interest (PAPERT, 1986). Digital technologies, particularly computers, play a central role for they "provide an especially wide range of excellent contexts for constructionist learning" (PAPERT, 1991, p. 8). Constructionism's intellectual tradition is, therefore, another important pillar, as it prepared the theoretical grounds for maker educators to develop a deeper understanding of their own practices.

Yet the fact that maker learning has many historic pillars resulted in its never being properly defined. This created a wide range of possibilities, from the use of simple objects, such as sticks, cardboard, glue, etc., to the use of fabrication tools, such as laser cutters, digital CNC routers, and 3D printers. This wide range of possibilities and resources offered by the maker movement has provided different scenarios for schools to incorporate these ideas. Many researchers have observed that the production of objects or the development of learning based on constructionist methodologies, such as those offered by maker activities, can provide the conditions for learners to be creative and critical, as well as capable of solving problems and working in groups (MARTINEZ; STAGER, 2013; HALVERSON; SHERIDAN, 2014; KURTI; KURTI; FLEMMING, 2014; BLIKSTEIN; WORSLEY, 2016).

Nevertheless, there is still the challenge of connecting maker activities to the curriculum, seeking not to forget the richness of the process of constructing objects, without losing sight of the need to generate learning, as argued by Valente and Blikstein (2019). This requires not too "enchanted" with the infinite number of possibilities and resources available for these activities, forgetting the initial educational objective.

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Furthermore, Valente and Blikstein (2019) argue that there is a huge diversity of objectives within maker education, despite its apparent unicity. In this study, the authors note that even neighboring schools had diverse objectives. In one school, the objective was not necessarily to work on curricular content, but rather to increase the students' self-esteem. The social and cultural contexts in which these students lived was highly unfavorable, which resulted in their low self-esteem regarding their ability to execute tasks successfully and learn. Therefore, the teacher's concern was to create an environment in which students were capable of creating something successfully, and sharing their product with colleagues and family members. In another school in this same district, the objective of the activity was to develop something with high aesthetic value, a professionally finished product. Therefore, in some situations, it is important to consider the students' and the communities' circumstances and needs. Thus, maker education is not always aligned with objectives in the school's curriculum, but when it is, one must be clear that action does not necessarily entail learning: there is a need for explicit elements of the educational design to connect maker education and the curriculum.

2.2 Vision of the curriculum

In Brazil, the National Curricular Parameters (*Parâmetros Curriculares Nacionais* – PCN) (BRASIL, 1997), the National Curricular Directives for K-12 Education (*Diretrizes Curriculares Nacionais para a Educação Básica* – DCNEB) (BRASIL, 2013), and, more recently, the National Common Core Curriculum (*Base Nacional Comum Curricular* – BNCC) (BRASIL, [n.d.]) were created with the objective of guiding K-12 schools. One of BNCC's competencies, digital culture, is to provide the opportunity for activities with technologies in the sense of stimulating students' curiosity, as well as "creative, logical, and critical thinking, through the development and strengthening of their ability to ask questions and to evaluate responses, to argue, to interact with various cultural productions" (BRASIL, [n.d.], p. 58). Thus, the pedagogical process must consider the development of distinct languages, methodologies, and multi-directional interactions between learners, teachers, teaching material, and the use of digital technologies, which should be part of the curriculum and the school's pedagogic plan.

The possibility of giving new meaning and adapting the curricula is shared by different authors, such as Gimeno Sacristán (1998; 1999; 2000), who understands curriculum as a social

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praxis that encompasses content, method, procedures, cultural tools, previous experiences, and activities. For this author, the school coexists with an official curriculum, that is prescribed, and with a real curriculum, which is established in the formative context and is experienced through concrete practice in the relationship between teachers and students, and amongst students. However, both prescribed curricula and the real curricula, according to Freire (2008) and Pacheco (2000), should involve the social, the political, and the cultural. Pacheco (2016) emphasizes that knowledge, conceptualized as a historic product, is at the core of curriculum.

Since the real curriculum is a fundamentally deliberative space, according to Pacheco and Paraskeva (1999), it is part of a project that involves intention and praxis, which implies a *continuum* of decision making, and, therefore, an unfinished process that integrates options, and values, attitudes and techniques. Value and attitude dimensions contribute to guaranteeing that curriculum experienced in the classroom is not neutral.

It is important to assume that curricula in maker education are not neutral. Everyone is a "curricular actor", as suggested by Macedo (2013), who understands the curriculum as a procedural concept, and curricular scenarios function as "curricular moments". In other words: "time-spaces in which all and any social actor involved in curricular 'things' are heard as important for the democratization of the socially invented artifact" (MACEDO, 2013, p. 429).

In this sense, the concept of curricular acts is relevant to understand the learning contexts created in maker spaces, for curriculum should not be something developed by educational authorities to be applied by educators. The activities to be developed in maker spaces should be thought of as curricular acts so that learning, meaning negotiations, and meaning making originate in the social interaction with people, with materials, and with the technologies present in that space. Curriculum is not defined from the start and imposed, but is based on the teacher's pedagogic intentions, and reconstructed through the students' and teacher's actions.

For maker education to support curricular acts and interdisciplinarity, it is important that the integration of maker activities into the discipline's curriculum take place in a manner that is substantiated, and not based on fad. First, technology should have an auxiliary role for the *carrying out of something that cannot be done using conventional methods*. Second, it is important to match the technology to the educational proposal. In other words, *it is not realistic to use various technologies to address content that does not demand a given equipment.*

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Figure 1 illustrates a balance that must guide the development of educational maker activities: on the one side of the balance is the **curriculum** that, to be put into practice, involves teacher training, scientific development, and the knowledge to be addressed. On the other side of the balance is the **maker** activity, which involves creation, technology development, and the real world. The metaphor of a balance indicates that both of these components must be in equilibrium – one must not loose on the side of curriculum, nor on the maker side.

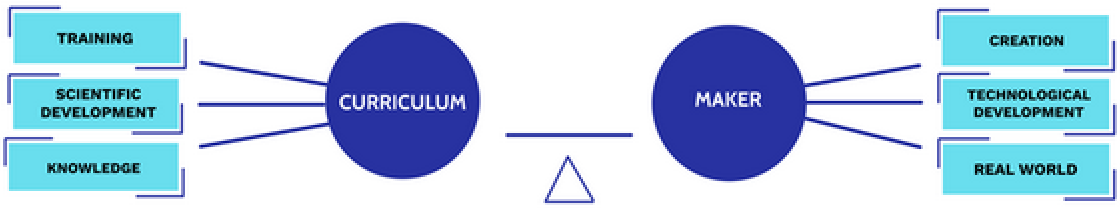

Figure 1 – Balance between Curriculum and Maker.
Source: The authors

To find equilibrium on this balance means to consider training and creativity, simultaneously developing scientific and technological aspects. Projects that involve digital fabrication and advanced technology are almost exclusively related to activities in the STEM disciplines, though authors such as Bevan (2017) have considered activities in other disciplines (STEM-rich).

2.3 The relationship between maker education and *STEM-rich*

One of the arguments used to justify the implementation of maker education in US K-12 education is the possibility of supporting the curricular integration of the sciences, technology, engineering, and mathematics, what is known as STEM. Though the integration of *STEM* disciplines is desired, it does not occur satisfactorily, as seen in a report by the National Research Council (2014).

Maker education has been considered a solution to integration (BLIKSTEIN, 2013; HALVERSON; SHERIDAN, 2014; RILEY, 2015; ROSE, 2014; SHERIDAN et al., 2014). In addition to this integration into maker education, there are conditions needed for students to be protagonists, develop projects using traditional objects and technologies, and able to work on authentic projects in flexible and collaborative spaces (VUORIKARI; FERRARI; PUNIE,

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2019). In addition to STEM disciplines, maker education has allowed for activities in the arts (PEPPLER, 2016) and design (MARTIN; DIXON, 2016), broadening the scope of disciplines, what Bevan (2017) coined as STEM-rich.

Another important aspect is that the activities taking place in maker spaces can contribute to the learners' personal and social development. Clapp and colleagues (2017) identified that students take on a more proactive role regarding real world problems and develop character – they can take risks, learn to handle failures and achieve success, and develop a mentality that includes creativity, curiosity, persistence, social responsibility, and group work.

Finally, there is an increased concern in maker education with the equal participation of all students. In 2013, Buechley identified that 89% of the authors, and 81% of the readers of the Maker Magazine were men (BUECHLEY, 2013). Particularly in the USA, this issue has been the research focus of many groups and authors, so that maker education does not become elitist, catering to a privileged group of students (BLIKSTEIN; WORSLEY, 2016; VOSSOUGHI; HOOPER; ESCUDÉ, 2016; CALABRESE BARTON; TAN, 2018). The objective is to be able to value the cultures, experiences, and values students bring to the learning and teaching process.

In the following sections we will present and discuss examples of how curricular themes can be identified in activities students develop during maker education.

3 INTEGRATION OF MAKER ACTIVITIES AND THE CURRICULUM

In this section we will discuss examples of educational activities executed in schools, being that one case is not related to the curriculum, and the other concerns STEM-rich.

3.1 Maker activities that are not related to the curriculum

The maker activity discussed in this section was reported in Moura (2019), and observed during a visit to a US institution of public education in the suburbs of the city of Palo Alto, in California, described as a case study ("The boats in an aquarium.")

During one of his educational activities, the technician responsible for the maker space promoted a competition for a group of students between 5 and 6 years old. As they entered the school's maker space, the students came upon an aquarium filled with water, in the middle of

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the classroom. Once students were sitting and facing him, the technician began to explain the dynamic of that day's activity. Each student would build a boat and, in order to do so, they would be given a few materials that are easily manipulated, present in the maker space, such as different types of paper, plastic, yarn, glues, and recycled materials. Due to the students' age range, and because this was an activity planned to be executed during a single class period, other options were not considered for this activity, such as the use of a 3D printer. The technician further explained that, after having constructed their boat, each student would go up to the aquarium and test their vessel. The boat had to hold a large number of marbles without sinking. The "winner" of this task would be student who constructed a boat that could hold the largest number of marbles.

Students then set off to begin the activity. They constructed their boats and would walk up to the aquarium to test it. They would deposit the boat in the water, and then place marbles in the boat, counting them, up to the moment their boat sunk. Instructions to use different materials, or to not place too many marbles on the boat at once, were constantly iterated by the technician. He also questioned the students as to why some of their projects were not successful. By the end of the activity, one the kids, a girl, was declared the champion, having placed 12 marbles on her boat, which was built out of aluminum paper, ribbons, and pieces of styrofoam glued onto the vessel's edges. At the end of the lesson, the technician asked that students to sit in circle in the patio so that they could discuss the activity. At this time, the technician carried out a debate on the importance of planning before executing a project. Not long thereafter, the school bell rang indicating the end of class, prompting students to run back to their regular classroom. Figure 2 illustrates different moments of the activity. The image to the left depicts the students constructing their boats; in the center image, one can see attempts to make a few boats float; and in the image to the right, one sees the students in a circle talking.

Figure 2 - Maker Activities "The Boat and the Aquarium".
Source: Moura (2019).

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The activity was well accepted and developed by the students, with high levels of involvement. The technician presented this as a fun activity, which was proven true in the students' attitudes. Though this was not made explicit, this activity allowed for students to work on various competencies, such as autonomy when faced with the choice of materials, the commitment to achieve the proposed objective with enthusiasm and dedication, as well as persistence, resilience and versatility. Nevertheless, it is important to take note of two very significant absences: one, of the teacher, and consequently, of curricular content.

A technician in an educational maker space, as a rule, is responsible for maintaining and managing the environment. It is the teacher's responsibility to be ahead of a class in an educational space. Therefore, having been justified or not, the teacher's absence obliges the technician to take on the role of the teacher, having to develop and carry out school activities with the students. To take on this teaching role is inappropriate, as this professional usually does not have any pedagogic training, and, for this reason, is not, and should not be, responsible for providing academic content. As a result of this condition, the curricular content is abandoned. Consequently, Moura (2019) mostly points to how maker activities have not been developed to address curricular content, but rather cognitive, motor, and socio-emotional competencies. On the other hand, in a few maker spaces, one can observe the development of maker activities that are related to the curriculum, including STEM-rich disciplines.

3.2 Maker activities related to STEM-rich

In "Digital Fabrication and Making in Education", Blikstein (2013) presents a project developed by a history teacher who wanted to give classes in the maker laboratory. Though the teacher was not familiar with digital prototyping, aided by the technician in the maker space, she sought to understand the possibilities offered by the resources present in the lab. She then proposed that her students learn about important women in US history (such as Rosa Parks) by building historic monuments in their honor, using a 3D printer and a laser cutter. The math teacher also participated in the project, creating the wooden base for the monuments. The base was marked with a grid of one-inch squares. The teacher then challenged students to construct all objects to scale – thus establishing an authentic and rich connection to his discipline. Figure 3 depicts three of these monuments.

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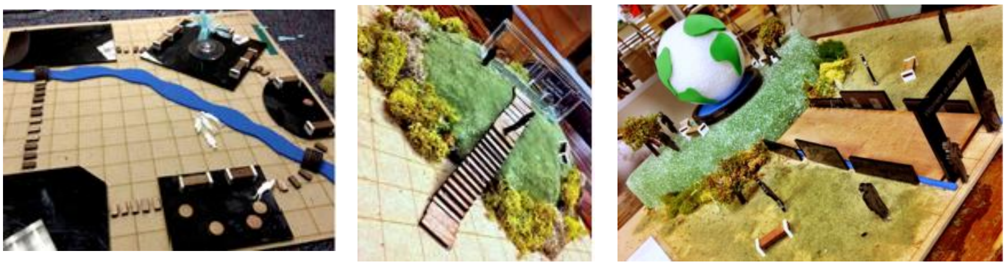

Figure 3 – Three examples of projects from the "Historic Monuments", depicting the one-inch grid suggested by the math teacher to guide the development of objects to scale.
Source: Blikstein (2013).

This is a project that can be described as an educational maker activity that is not completely related to the hard sciences, since it includes, in addition to mathematics, history content. The first step to create a curricular maker activity, thus, is to think of the learning objective – which should come prior to the choice of the technology.

Another project in a Brazilian school focused on the people of ancient civilizations as part of the World History curriculum. The objective was to evaluate various techniques and materials used by different civilizations, relate this information to the society's characteristics, social organization, and historic context, and, based on this information, develop similar objects using fabrication tools in the maker space.

To study major ancient civilizations, the history teacher proposed that the class be divided into groups, each of which would select one of the principal societies in human history to focus on. This selection could be based on region: for example, people who inhabited the Mesopotamian region, such as the Akkadians, Babylonians, Assyrians and Chaldeans. Or the selection could be based on epoch: selecting people from distinct regions but of a similar time period (Chinese, Greek, Roman, Egyptian, etc.). After choosing a group to study, the first of four phases thought of for this activity consisted of studying the culture of the selected group, focusing primarily on the artifacts/objects they used, their materials, technologies, and types of logographic writing. The next phase consisted of creating and producing historic artifacts such as coins, utensils, signs with symbols, and scriptures similar to those that belonged to the given civilization chosen by the group. To complete this task, students were encouraged to use various maker technologies, such as 3D printers, laser cutters, polymer molding, woodworking, and clay, amongst others. During the third phase, the proposal was to create excavations so that the groups could exchange archeological sites amongst each other, and discover from which civilization the produced objects belonged. Finally, during the fourth phase, prompted by the

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teacher, the students discussed the connections between the technologies, materials, and historic context, for example, to understand how the discovery of new material or fabrication techniques changed the civilization's economy and social context. This is an activity that, in so being developed, can be executed in a short time period, for example, of one or two weeks, or over a longer period of time, taking months, depending on the teacher's options and learning objectives.

In these three cases, the important fact to be noted is the role of the teacher in relating or not the activity to the curriculum. In the case of the *Boats in the Aquarium* activity, considering the student's age range, the activity could have been used to explore concepts from the mathematics curriculum, such as the geometric shapes of the constructed boats, trying to identify which are better suited to keep the boat floating. This project could also be used to discuss with students their real or historic references to boats, or scientific concepts, such as buoyancy, or even scientific practices, such as systematic experimentation. The lack of curriculum to be addressed in this activity reinforces the absence of the teacher's participation, for teachers know how to explore the products that the students develop to understand the disciplinary concepts addressed.

4 IMPLEMENTATION OF *MAKER* EDUCATION

The implementation of maker education should be based on four pillars: the development of the maker space; teacher training; the projects being developed; and the student as protagonist. The maker space is the location in which students develop activities. It would be ideal if the school were, in reality, a huge maker space, in which students of different ages and teachers from distinct disciplines could interact and develop projects, exploring various concepts, abilities, and attitudes in an integrated manner. This already takes place in some maker schools – for example, the Acera school - The Massachusetts School for Science, Creativity and Leadership (ACERA, 2020).

Maker spaces in schools can take on various formats. In some schools, there are special rooms with traditional educational materials (glue, cardboard, wood), recycled materials, and digital technologies, such as 3D printers, laser cutters, and CNC routers. In other schools, there are spaces that provide a combination of these same characteristics with materials that can be employed in all subject areas. Finally, there are institutions that create a "maker corner" within

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the classroom. In this final case, the construction of basic objects can begin within the classroom and be complemented with the use of digital fabrication tools. Therefore, the maker space can be understood as a combination of various locations present within a school, such as an art classroom, a science laboratory, and a repair shop (LECORCHICK; SPIRES; GALLO, 2019).

However, it is important to emphasize that digital technologies are a major component of the maker space, as argued by Valente e Blikstein (2019). They maximize possibilities: it is one thing to paint with your fingers, or to use a single color of paint; it is quite another to have a large amount of colors and various types of paintbrushes at your disposal. The quality of the tools and the materials expand the possibilities for construction. In addition, the technologies should serve as more than an aid to the manufacturing of a given product. One can create a vase out of clay, but it is a drastically different task to program a robot to do the same thing (despite the similar final product). In the case of the robot and digital fabrication tools, they must be programmed in order to work, and the program constitutes the representation of the student's knowledge concerning concepts such as scale, distance, geometry, and programming. This representation can be studied and analyzed at the level of the concepts and strategies used, and can be perfected and ameliorated, helping the student achieve a new level of scientific knowledge through a growing learning spiral (VALENTE, 2005).

The teacher, so as to be able to help in the process of constructing knowledge through maker activities carried out by the students, should be prepared and knowledgeable not only of the content of the given subject they teach, and of the use of the technologies available in the maker space, but also as to how to integrate the students' activities with curricular disciplines, and how to challenge the students so that they may continue on their growing learning spiral.

Therefore, teachers become protagonists when they demonstrate a positive attitude in relation to maker education. Despite claiming the contrary, the school does not demonstrate, in practice, a concern in connecting curriculum to real life situations or to the students' interests. The possibility of thinking of the students' activities as "curricular moments", as suggested by Macedo (2013), creates the conditions for teachers, based on their pedagogic intents, to incorporate the students' interests and needs.

The teacher, as the main agent in the schooling institution and the classroom, must be conscious of the fact that, generally, teaching is not committed to creativity, since it is tailored to the textbook, to prescribed curricula, or other things that are extraneous to what is taking

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place at that moment in the classroom. The teacher should not abandon such references or their planning. Nevertheless, proposals for maker education that are prescriptive and excessively rigid serve as "pedagogic crutches".

Learning through action brings back the natural condition of experimentation, of curiosity and creativity, allowing for learners to become involved in activities where they can create things intuitively, going beyond simply interacting with the technology. However, this curiosity should be epistemological, a "relentless inquiry", as proposed by Freire (2000, p. 35). On the other hand, to simply create something meaningful and creative does not justify the teacher's practice. The teacher must also be concerned with methodological rigor (WEFFORT, 1996), and, consequently, with the curricular content involved in the maker activity.

Regarding the projects developed by the students, as mentioned in other sections of this article, they should be integrated into curricular subjects and to the schools' pedagogic plan. Kim and colleagues (2019), in line with Freire (1968), observe that students have a greater chance at engaging with their activities and developing greater interest in learning, if the projects they execute are related to their lived experience and environments. These authors mention that projects can address themes from the schools' community, or the contexts in which students live, for example. Students can then apply the abilities and concepts learned in the maker space to the maintenance of school objects, or objects that improve the school or the places in which they live.

However, Kim and colleagues (2019, p. 10) found maker spaces that studied "pre-constructed lessons, packaged instructions that came with makerspace kits or curricula developed by governing organizations". The interviewed technicians and teachers in these maker spaces claimed that they preferred these lessons, for they were connected to a global FabLab community and to available online resources. Some students also chose detailed designs and creation processes, since this straightforwardness "reduced anxiety and provided a guided opportunity through new makerspace experiences" (KIM et al., 2019, p. 10).

Other maker spaces studied by these authors, which were more broadly conceived, emphasizing personalized projects, demonstrated that the "sense of empowerment and agency [the students] developed through the flexible nature of the open curriculum allowed them to apply their acquired skills outside of the makerspace environment." (KIM et al., 2019, p. 10).

Therefore, the students' actions, or the fourth pillar of maker education, are directly related to the type of pedagogic and curricular approach developed. A pre-formatted curriculum

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allows for the students to have access to the material provided by the maker community, allowing for the student to receive hints as to how to construct their product most efficiently. It seems like the focus in this case is to obtain a product with the least amount of challenges and in the least amount of time. On the other hand, students in a more open approach from the curricular standpoint can develop their personal interests, create products of their interest, be more creative, and more highly engaged in their activities.

The implementation of maker education can follow two distinct paths: one more focused on production, and the other on the students' ideas, concepts, and attitudes. In this sense, it is fundamental to think of the type of education that is being hoped for through this implementation so that maker education does not become a frustrating experience, such as an attempt to place a "squared nail" in a "round hole"; in other words, an innovative pedagogic approach in an archaic educational system.

As argued by Gilbert (2017), maker education based on flexible curriculum, in the model of "curricular moments", with integrated disciplines, teachers working together, and based on projects, have a greater chance of making traditional instructionist teaching even more anachronistic. The question is whether maker education will be truly transformative, or if this type of education will become one more pedagogic "make believe", without bringing about concrete change.

5 FINAL CONSIDERATIONS

The aim of this article was to differentiate between maker activities conducted in school contexts in two different modalities. In one, the activities are explicitly related to the curriculum, and there is an intentional connection to the school's subject-areas. In the other modality, the activities do not have a clear connection to the curriculum. In both situations, and primarily in the latter, though students are "building" and engaged, there is not guarantee that this will translate into learning of disciplinary content. This does not occur satisfactorily without the clear development by the teacher of original learning objectives, and the integration of maker technologies in a way that is relevant and appropriate. To do so the teacher must understand how maker technologies can, in fact, transform the activity and enrich its learning objectives, rather than simply serve as "decorative" aspects of conventional curricula.

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Fads and deceitful revolutions pervade education since the beginning of the 21st century. Theories (such as constructionism) are renamed, essential ideas are systematically trivialized (such as Paulo Freire's pedagogy), and the work developed by innovative educators (such as in maker education) is at risk of being destroyed by traditionalist forces. We believe that the integration of maker education technologies and ideas into the curriculum is a critical step to solidify Papert's, Dewey's, Freire's and others' transformative agenda. By maintaining maker education outside of schools and the curricula, we do not tackle the possibility of democratically offering these opportunities to all students. But we also maintain maker education as an optional, elective activity, which is simply "fun", straying from its role as a transformative agent of the school's core – the curriculum.

Nevertheless, when we bring maker education to the curriculum as a simple adornment to a fixed and inflexible didactic sequence that denies students of their role as protagonists, and the teacher of their role as curricular creators, guides, and organizers, we also do a disservice to the transformation of the school, for these expensive technological beautifications will not bring about more learning, and, possibly, will be hastily discarded.

Therefore, it is our role to guarantee that maker education does not become a fad or catchphrase, but rather a force of true reorganization of the school curricula. Without pedagogic intent, without educational theory to act as a guide for the development of activities, without a concern for the democratization of opportunities, and without an understanding of the mediating and magnifying role of technology, maker education is at risk of becoming an empty and generic brand; a marketing element, rather than of one of emancipation; a tool in the hands of "consultants", not educators. Therefore, once again, we could deny our students one more opportunity of emancipatory education.

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