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Reconstruction of historical monuments of Picada Café on Tinkercad: developing mathematical skills based on Maker Culture

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Abstract: The goal of this research is to understand whether the process of reconstructing historical monuments using Tinkercad can contribute to develop mathematical skills within the context of Maker Culture. In order to achieve this, an action research approach was employed, whereas the researcher engaged effectively with the participants in order to enhance the teaching and learning process. The activity was conducted with a group of 9th-grade students from an elementary school in Picada Café. The interactions between students and their creative problem-solving approaches were analyzed throughout the project's execution, both regarding mathematics and the project's construction itself. It was observed that the students developed a range of maker skills through DIY experiences, actively taking on roles as creators of their own projects. The project facilitated the development of mathematical skills such as logical reasoning, collaborative teamwork, and effective problem-solving, among others.

Keywords: Maker Education. Tinkercad. 3D Modeling. Mathematics Teaching. Elementary School.

Reconstrucción de monumentos históricos de Picada Café en Tinkercad: desarrollando habilidades matemáticas basadas en la Cultura Maker

Resumen: Esta investigación tiene como objetivo comprender si el proceso de reconstrucción de monumentos históricos, utilizando Tinkercad, puede colaborar para el desarrollo de habilidades matemáticas basadas en la Cultura Maker. Para ello, se realizó una investigación-acción, en la que el investigador interactúa de manera efectiva con el investigado y busca colaborar para la mejora del proceso de enseñanza y aprendizaje. La actividad se realizó con un grupo de estudiantes de 9no curso de un colegio público localizado en Picada Café. A lo largo de la construcción del proyecto se analizó la interacción entre los estudiantes y las formas creativas encontradas para resolver los diferentes problemas enfrentados, tanto relacionados con las matemáticas como con la construcción del proyecto en sí. Se observó que los estudiantes desarrollan muchas habilidades "maker" siendo protagonistas en la construcción de sus propios proyectos. A lo largo del proyecto, los estudiantes desarrollaron habilidades matemáticas como razonamiento lógico, trabajo colaborativo, resolución de problemas, entre otras.

Palabras clave: Educación Maker. Tinkercad. Modelo 3D. Enseñanza de las Matemáticas. Enseñanza Fundamental.

Reconstrução de monumentos históricos de Picada Café no Tinkercad: desenvolvendo competências matemáticas com base na Cultura Maker

Resumo: Esta pesquisa visa compreender se o processo de reconstrução de monumentos históricos, utilizando o Tinkercad, pode colaborar para o desenvolvimento de competências matemáticas com base na Cultura Maker. Para isso, realizou-se uma pesquisa-ação, na qual o pesquisador interage efetivamente com os pesquisados e busca colaborar para o aprimoramento do processo de ensino e aprendizagem. A atividade foi realizada com uma turma do 9º ano do Ensino Fundamental de uma escola municipal de Picada Café. Ao longo da construção do projeto, analisou-se a interação entre os alunos e as formas criativas encontradas para resolver os diferentes problemas enfrentados, tanto relacionados à matemática quanto à construção do projeto em si. Observou-se que os alunos desenvolveram muitas habilidades *makers* ao colocar a mão na massa, sendo protagonistas na construção de seus próprios projetos. Ao longo do projeto, os alunos desenvolveram competências matemáticas como raciocínio lógico, trabalho colaborativo, resolução de problemas, entre outras.

Palavras-chave: Educação Maker. Tinkercad. Modelagem 3D. Ensino de Matemática. Ensino Fundamental.

1 Introduction

The extension project “Cultura *Maker* em práticas escolares da educação básica”, which has been developed at the *Caxias do Sul Campus of the Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul (IFRS)* since 2021, arose from the need to develop new skills for elementary school students in public schools due to the technological advancement in many branches of society.

We understand that it is essential to provide students with opportunities to develop skills such as creativity, problem-solving, teamwork, in addition to participating in multidisciplinary projects and playing a leading role in building projects of their interest.

Technology also brought changes to Mathematics classes, making it necessary to rethink the way we teach Mathematics and the problems dealt with in the discipline (Borba, 2009). The use of technologies in mathematics education assumes a more active role for the student (Silva & Penteado, 2013) and should not involve the simple use of technology to carry out activities that could be done without it. However, one should use technological resources intentionally in order to collaborate by producing mathematical knowledge and student development (Rosa, 2018).

Whenever the students are working in mathematics classes with the production of an artifact using digital technologies, they can build mathematical concepts during the production (Valente & Blikstein, 2019) in a more active, creative, and motivating way.

With that in mind, the extension project develops activities based on the Maker Culture, seeking to explore these new skills arising from technological advancement and, at the same time, provide opportunities to develop mathematical knowledge more actively and dynamically with students in the final years of elementary school, in partnership with municipal schools.

The activities are developed alongside each school, based on conversations with teachers and management, based on the reality of the school itself and the students, seeking to enable them to create their own projects, thus collaborating for their development in various aspects.

In 2022, a partnership was developed with a municipal school in Picada Café, aiming to collaborate in developing a project already started with a 9th-grade elementary school class by the mathematics teacher. This project's subject was the historical heritage of the city of Picada Café, and proposed that students reflected on their relationship with mathematics. From there, they faced some questions of which some are highlighted down below:

- How is a floor plan made? What is it?
- Which Picada Café buildings are considered historical heritage?
- How to build a model from a floor plan?
- How to reduce the actual measurements?

Based on these questions, the students had a lecture with a land surveyor, in which they were able to learn a little bit about this profession, in addition to experiencing how land is measured. In addition, they visited the *Museu Municipal Professor Laurindo Vier* (located in Santa Maria do Herval), which houses the *Memorial da Arquitetura Germânica*, one of the world's largest collections of German-style models. This visit served both as an inspiration and a source of knowledge for the future production of listed sites or historical significance in Picada Café. After that, they visited the *Mini Mundo* (located in Gramado), which has miniatures of various buildings from different parts of the world. They also had a lecture with a civil engineer, so they could understand the concept of a floor plan and the rules established for design.

Therefore, based on this experience and acquired knowledge, the students decided to reproduce models of four historical monuments in the city of Picada Café: *Casa Comercial Christian Kuhn, Casa de Cultura Joaneta, Capela Nossa Senhora da Visitação, EcoVias.*

The class was divided into four groups with an average of five students per group. They visited those monuments, took pictures, took measurements, drew the floor plan of the buildings, prepared scales consistent with the size of the models, and started to produce them, using a variety of inexpensive materials. Throughout the process, students applied various mathematical concepts to real situations, thus contributing to a better understanding of the concepts and their applicability beyond school.

The math teacher who initiated this project in the class, sought help from the project conducted at IFRS in order to teach students how to use the Tinkercad platform, a free online 3D modeling program, in order to build physical models, 3D projects of historical monuments, since the modeling process, in addition to learning mathematical concepts and other skills such as computational thinking, collaboration, self-expression, among others (Bhaduri, Biddy, Bush, Suresh & Sumner, 2021).

Therefore, this research aims to understand whether the process of rebuilding historical monuments, using Tinkercad, can collaborate to the construction of mathematical knowledge and the development of mathematical skills based on the Maker Culture. It should be noted that, according to the BNCC (Brasil, 2018, p. 267), the specific competencies of the mathematics discipline for the 9th grade of elementary school are:

> 2. The development logical reasoning, the spirit of investigation, and the ability to produce convincing arguments, using mathematical knowledge to understand and act in the world.
> 3. The understanding of relationships between concepts and procedures from the

> different fields of Mathematics (Arithmetic, Algebra, Geometry, Statistics, and Probability) and other areas of knowledge, feeling confident about their ability to build and apply mathematical knowledge, developing self-esteem and perseverance in the search for solutions. [...]
> 5. The utilization of mathematical processes and tools, including available digital technologies, to model and solve everyday social and other knowledge problems, validating strategies and results.
> 6. The confrontation of problem situations in multiple contexts, including imagined situations, not directly related to the practical-utilitarian aspect, expressing their answers and synthesizing conclusions, using different registers and languages (graphs, tables, diagrams, in addition to text written in the mother tongue and other languages for describing algorithms, such as flowcharts, and data). [...]
> 8. The cooperative interaction with their peers, working collectively in the planning and development of research to answer questions and in the search for solutions to problems in order to identify consensual or non-consensual aspects in the discussion of a given issue, respecting the way of thinking colleagues and learning from them (Brasil, 2018, p. 267).

The contextualization about the emergence of the Maker Movement and its development, the arrival of the movement in education, the relationship between technology and Mathematics Education, and a brief explanation of the Tinkercad program will be made in this article, as well as a description of the methodology used, the results obtained and the final considerations.

2 The Maker Movement

The Maker Movement has gained considerable traction in various domains in recent years, with education being one of its main focuses, emphasizing the active involvement of students in the learning process (Aleixo, 2021; Aleixo, Silva & Ramos, 2021; Gavassa, 2020; Rodrigues, Palhano & Vieceli, 2021). This movement originated in the United States, is underpinned by several pillars, including the "Do It Yourself" (DIY) culture, which revolves around the concept of crafting, producing, or rectifying items using one's own hands, driven by experimentation and self-directed initiative. As a result, the Maker Movement serves as a modern-day extension of the DIY ethos, incorporating technological elements such as electrical circuits, 3D printing, and computer software (Aleixo, Silva & Ramos, 2021; Blikstein, Valente & Moura, 2020; Bullock & Sator, 2015; Gavassa, 2020).

The creation of the Make Magazine, in 2005, and the Maker Faire, in 2006, also contributed to popularizing the Maker Movement, both sharing "do-it-yourself" practices (Aleixo, 2021; Blikstein, Valente & Moura, 2020; Gavassa, 2020; Rodrigues, Palhano & Vieceli, 2021).

The hacker movement and the development of FabLabs are also part of the Maker Movement's foundation. According to Aleixo (2021, p. 33), the hacker movement emerged in the 1960s and advocated that "all information is free, accessible and open", whereas hackers were considered people who "discovered innovative solutions to solve problems". The first FabLabs appeared in the early 2000s, initially developed at the Massachusetts Institute of Technology (MIT) Media Lab, and became spaces where makers could work on their projects using different tools, machines, and devices, in addition to sharing their ideas and experiences, thus helping each other to achieve their goals (Blikstein, Valente & Moura, 2020; Gavassa, 2020).

In "The Maker Movement Manifesto", also called the Maker Manifesto, Hatch (2013) exposes a set of attitudes and principles of the Maker Movement, highlighting that we are born to “do” things that human beings need to do in order to feel fulfilled; things like creating and sharing their creations. In addition, Hatch (2013, p. 20) states that "the making process brings about a natural interest in learning" and learning is also essential to a person’s development as a maker.

Therefore, Aleixo (2021, p. 34) defines the Maker Movement “as the possibility of building, repairing, modifying and manufacturing objects, machines, projects, and processes with one's own hands, preferably in a collaborative way”. In addition, according to Rodrigues, Palhano and Vieceli (2021), the maker culture also promotes problem-solving creatively as long as makers can create objects in order to solve situations of their reality or of the community in which they are inserted, thus being able to develop collaborative work in teams.

Although the Maker Movement has not been developed specifically for school environments, its application in the classroom can be a great way to explore the contents provided in the school curriculum, also promoting the development of group work and collaborative learning, the use of technology more consciously, creativity, autonomy and the protagonism of students, thus making them the center of the learning process (Paula, Martins & Oliveira, 2021).

3 Maker Education

When it comes to education, the Maker Movement gained prominence mainly from the ideas of Seymour Papert and his constructionist approach, with Papert considered the "father" of Maker Education (Gavassa, 2020; Machado & Zago, 2020; Valente & Blikstein, 2019; Vieira, 2020).

Papert (1994) states that students learn better when they are protagonists of their learning process and when they can learn in a contextualized way with reality, focused on practicing, creating and doing things with their own hands. Since Papert was a mathematics educator, he also reflects on the teaching of the discipline, by stating that students' prejudice and difficulty in mathematics does not mean that it is a complex subject, in fact, but that it is often taught abstractly without contextualization. Thus, Papert (1994) points out that some ways to overcome this perspective regarding the discipline would be to use mathematics in a less formal, more concrete way, inserted in students' creations and, mainly, to associate mathematics with computers.

In that regard, Papert's constructionist method approaches the Maker Movement by arguing that students have more meaningful learning when they engage in creation processes, exploring and building objects of interest and developing the ability to solve multidisciplinary problems that may suddenly arise in their projects (Aleixo, 2021; Resnick, 2020; Valente & Blikstein, 2019).

According to Resnick (2020), the Maker Movement in education can provide creative learning experiences and prepare children for life in the society of the future, as long as "the most valuable learning experiences occur when you are actively involved in developing, building or creating something" (Resnick, 2020, p. 34).

With the changes resulting from technological advancement, new skills, such as creativity and problem-solving, for example, will be necessary and even more valued in the society of the future (Resnick, 2020). The Maker Education is a way to develop these new skills and also to assure student learning, as long as the student produces knowledge through collective work aimed at solving problematic situations, in the maker culture, thus awakening autonomy, creativity, critical sense and protagonism, fundamental factors to promote meaningful learning (Vieira, 2020, p. 42).

The Maker Education is also pointed out as an option for change as opposed to traditional education, as long as it makes the student's learning process more valuable than its final result, thus providing a learning process with mistakes and successes throughout the experiences carried out by the students (Gavassa, 2020; Rodrigues, Palhano & Vieceli, 2021). By favoring the learning process and students' experiences, education with a maker perspective enables the development of self-confidence, independence, creativity, teamwork, protagonism, learning to deal with challenges and solve problems (Blikstein, Valente & Moura, 2020; Gavassa, 2020; Machado & Zago, 2020).

> Therefore, promoting the maker culture at school is essential for promoting quality education, with students producing knowledge, leaving the passivity of the classroom without meaning, with an expository and repetitive methodology (Vieira, 2020, p. 43).

It is important to emphasize that the Maker Education should not be seen as an extra, optional activity, isolated from the classroom, but instead, be part of the curricular subjects, allowing students to be creative and protagonists throughout the school experience, not just in isolated moments (Blikstein, Valente & Moura, 2020; Valente & Blikstein, 2019). With that said, it is clear that implementing the maker culture in schools challenges everyone, especially teachers, who must have an excellent command of knowledge, be open to changes and new perspectives, have flexible planning, put themselves in the role of mediator, facilitator of learning, in addition to rescuing students' interest and motivation to engage in their learning process (Gavassa, 2020; Rodrigues, Palhano & Vieceli, 2021).

4 Technology in Mathematics Teaching

The use of technologies in contemporary society is expanding every day, making society increasingly digital, connected, with easy access to information, causing enormous changes in people's daily lives (Aleixo, 2021; Dias, Evaristo, Roris Filho & Terçariol, 2021; Valente, Blikstein & Moura, 2020). Thus, it is evident that students need to be prepared to deal with this new reality, learning to use technology more consciously and actively.

In that regard, educational spaces need to adapt in order to meet these new demands, incorporating technology into pedagogical and curricular activities in the classroom, aiming to form critical citizens who know how to solve problems and are creative and flexible to adapt to the transformations that have occurred in society. (Aleixo, 2021; Valente, Blikstein & Moura, 2020).

According to the Referencial Curricular Gaúcho, focused on the area of Mathematics,

> digital technologies, which are constantly changing, bring a concern to the school context because they demand a new approach from the school, while at same time providing the opportunity to abandon an obsolete model, reflecting on a contemporary methodology, which promotes participation students, the humanization of school processes and the implementation of active methodologies, in which the pedagogical project contemplates the new school reality, with countless alternatives for interactions, experiences, teaching through research, discoveries, and challenges (Rio Grande do Sul, 2018, p. 31).

The *Base Nacional Comum Curricular* — BNCC (Brasil, 2018) also points out the conscious and critical use of technologies as one of the general competencies of Basic

Education, stating that at school students should

> understand, use, and create digital information and communication technologies in a critical, meaningful, reflective, and ethical way in the various social practices (including school ones) to communicate, access and disseminate information, produce knowledge, solve problems, and exercise protagonism and authorship in life personal and collective (Brasil, 2018, p. 9).

According to Borba (2009), technology has also brought changes to mathematics itself and the way it is taught, requiring curricular adaptations, not only because the answer to many common mathematics problems can now be found on the internet but also because technological advancement is changing human beings ourselves and the way we understand and see the world around us.

In that sense, one possibility to bring technology into the mathematics classroom is to work with technological resources that require mathematical concepts (Valente & Blikstein, 2019) and involve the construction of a product, because whenever students are producing something using digital technologies, they have the opportunity to opportunity to reflect, build knowledge and develop as human beings in general (Rosa, 2018).

The utilization of technologies can raise the level of the learning process since learners can explore, create, and reflect in a very stimulating and innovative environment" (Valente & Blikstein, 2019, p. 256), maximizing the possibilities of constructions, connections between concepts, and stimulating creativity.

According to Papert (1994), whenever students are developing projects using technological resources, they not only develop technical mathematical skills but also start to see mathematics differently, starting to use it intentionally, as a tool or way to help the elaboration of personally important and relevant projects, thus becoming "fluent" in the use of mathematics and putting aside possible prejudices with the discipline.

It is clear that it is necessary to critically reflect on the use of technologies in the classroom because, as stated by Aleixo (2021, p. 22), "the insertion of DT (digital technologies) in isolation does not create results and cannot be considered a salvation for educational problems". The use of technological resources needs to be done intentionally, integrating student activities with curriculum subjects, aiming at student learning, in addition to developing creativity, curiosity, persistence, teamwork, among other skills (Souza & Costa, 2020; Valente & Blikstein, 2019; Valente, Blikstein & Moura, 2020). According to Rosa (2018, p. 257), working with technologies in the classroom "is not characterized as use for the sake of use, but an articulating act under an intentionality that conceives the technological resource as a participant in the production of knowledge".

Furthermore, although children and adolescents "are digital natives", they

> only interact with technologies, as opposed to creating with them. If we want children to grow up as creative thinkers, we need to provide them with different ways of engaging with screens, offering them more opportunities to create their own projects and express their own ideas (Resnick, 2020, p. 41).

Therefore, one possibility to provide students with the creation of their own projects is using Tinkercad.

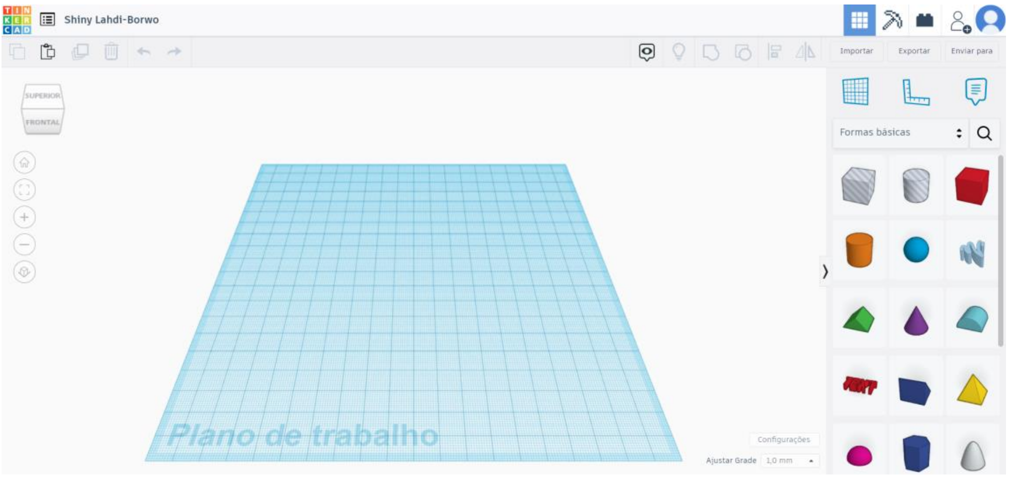
5 Tinkercad

Tinkercad, developed by AutoDesk, is a free web application tailored for 3D design, electronics and coding (Tinkercad, 2022). The application is accessible through a computer, notebook, or tablet with internet connectivity. However, Tinkercad cannot be employed on mobile devices for project creation due to incompatible screen sizes regarding the application's viewport. The web-based platform also facilitates the sharing of projects, whereas the users have the option to share their projects, thus enabling others to either edit a copy without altering the original project or collaborate directly on it. This facilitates the collaborative simultaneous teamwork.

The electronics resource provided by the platform allows to reproduce and simulate electronic circuits by using numerous tools, such as Arduino UNO, batteries, motors, LEDs, resistors, among others. With the coding feature, students can program their 3D projects and circuits using code blocks, presenting a more straightforward and accessible programming language.

When it comes to developing the activity of reconstructing historical monuments, only the resource of 3D projects was used. This resource has a checkered work plane with a default scale set in millimeters, in most of the preview screens, in which all the objects required to build the project are added. All the tools used for construction are available on the right side of the screen, organized into different items such as basic shapes, creatures and characters, vehicles and machines, structures and settings, among others. Among these objects, it is possible to find basic geometric solids and accessories for characters, doors, windows, tires, trees, among other options. Figure 1 shows the initial window of the work plane as soon as a new 3D project is created.

Figure 1: Tinkercad work plan



Source: Tinkercad (2022)

When adding an element to the work plane, it is possible to edit its dimensions, rotate the part in all directions, choose colors, modify the height of the part in the plane, among other settings. There is also a resource called "hole" used to make cutouts in objects. In order to use this resource, it is necessary to adjust this element in the original object and then group them.

The visualization modes are featured on the left side of the screen. The cube gizmo in the upper left corner, allows to rotate the view of the work plane, making it possible to visualize the elements of the work plane better and fit them more assertively.

From the construction of their 3D projects in Tinkercad, students can work on concepts such as scale, distance, geometry, among others, which are very important when using technologies in the areas of Science, Technology, Engineering, and Mathematics (Valente & Blikstein, 2019). According to Papert (1994, p. 22), offering students "the opportunity to learn and use Mathematics through a non-formalized way of knowing, encourages" its use in a more formalized way, thus making the discipline more interesting.

Tinkercad's environment is intuitive and, at the same time, enables the creation of the most diverse projects, considering the numerous tools it makes available for construction. Tinkercad can be a tool that, if used critically and prioritizing the student's development, allows the development of skills such as logical reasoning, creativity, teamwork, problem-solving, among others. In addition, the interface is also quite attractive, thus motivating students to explore the various tools (Dias *et al*., 2021).

6 Methodological path

In order to comprehend whether the process of rebuilding historical monuments using Tinkercad, can contribute to the construction of mathematical knowledge by developing mathematical skills based on the Maker Culture, an action research, in which the researcher is not just an observer, but also effectively interacts with those surveyed, was conducted (Barros & Lehfeld, 2007). Action research in education contributes to the development of teachers and researchers, seeking to improve their practice and thus improve the teaching and learning process (Tripp, 2005).

The activity was developed with a group of 9^{th}-graders in a municipal school in Picada Café and taught by the scholarship holder of the extension project, who is an undergraduate student in Mathematics. The students were already conducting an activity in the Mathematics discipline that involved visiting and building models of the city's historical monuments using the appropriate scale. The recreation of these monuments virtually using Tinkercad was proposed from this.

As long as none of the students knew the program, the activity was divided in two stages. At first, students should build a character (SpongeBob) in Tinkercad based on a script sent to them, in which the step-by-step construction of the character was described using images of Tinkercad icons that the students had to select. In addition, the dimensions of each object (feet or hands) and geometric shapes (cobblestones, cylinders, triangular prism, sphere, and paraboloid) were also featured. It is noteworthy that symmetry concepts such as rotation, translation and reflection, were also explored during the construction of the character, in addition to using concepts of spatial geometry. Recreating this character as a way to engage students in this activity, was the viable choice in addition to the fact that, from its construction, it would be possible to know all the available tools and understand how the program works.

Secondly, the students should start recreating the monuments, using the forms and tools available and creatively explored by them. In addition, they should follow a scale, reconstructing the monuments proportionally, just as they did with the physical models.

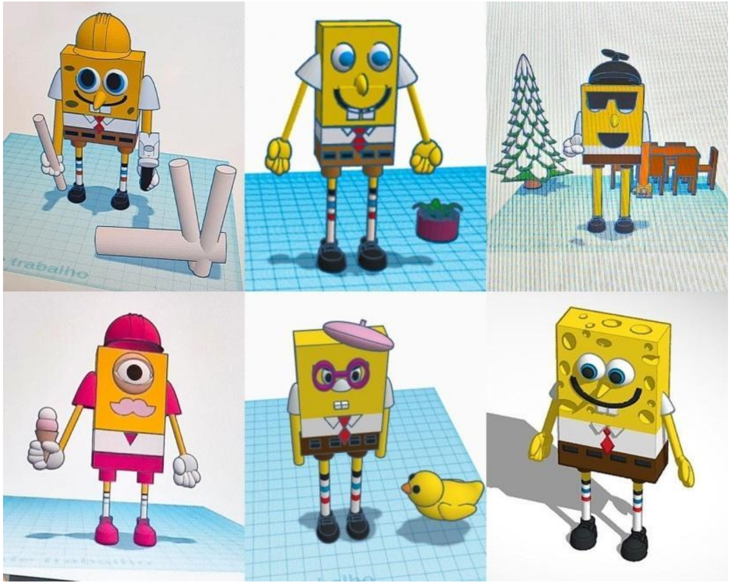
At the end of the activity, the results obtained were analyzed based on the theoretical framework to identify whether the reconstruction of historical monuments using 3D modeling in Tinkercad collaborated to develop mathematical competencies based on the Maker Culture.

7 Results and discussion

In order to promote such competencies, an activity was created in two separate moments, in which the first one was aimed at training the student in the use of the Tinkercad program, and the other one aimed at exploring the mathematics present in the elaboration of the model, thus improving new competences and skills related to the 3D modeling process.

For the first moment, it was proposed that students would build the character SpongeBob in Tinkercad, with the support of a script sent to the class in Google Classroom. As long as they were already familiar with the computer and other tools, the students had no significant difficulties at the beginning of the activity, especially with the script's support to understand the operation of the tools in the application. Already in this first stage of the activity, the students did not limit themselves to the script and developed their own characteristics for their characters in a very creative way, assigning professions to SpongeBob, building different scenarios, adding accessories, among other adaptations, as shown in Figure 2. The last image in this figure is the one described by the script.

Figure 2: SpongeBobs created by students



Source: Self elaboration (2022)

In Maker Education, it is necessary to allow the student to customize their projects so that they are not trapped in the script of the proposed activity. According to Papert (1994, p. 173), children "should be limited only by their imaginations and technical skills". It is essential to give them space to be creative and to learn even more.

The second stage of the activity started in the second shift of classes, which involved the recreation of historical monuments. In that regard, the students should use a scale with the previously calculated measures to construct the physical model. Thus, they used the floor plans already produced by them as support for the construction in Tinkercad.

Scale construction was the first problem faced by the students. The Tinkercad worksheet has a scale of one millimeter, and their measurement notes were in centimeters. Initially, the students tried to multiply all the measurements by ten, transforming them into millimeters and then adding the new measurements to the application. However, they realized that the construction was too big for the Tinkercad work plan. Then the students tried to modify the size of the work plan in order to adapt it to the size of the building, but they didn't succeed. After reflecting on the possibilities, the students decided to use a scale of 1:10, representing each centimeter of the floor plan by one millimeter in Tinkercad so that the construction would remain proportional and be better organized in the application's work plan.

The role of the teacher is emphasized here (in this activity, the scholarship holder assumed the role of the teacher) during the development of this activity, which was not about giving ready-made answers to the students, but about creating an environment for discussion in which they had the opportunity to freely opine and suggest possibilities to solve the problems encountered. This is aligned with what Valente and Blikstein (2019, p. 260) state about the teacher being the one who must create "conditions that promote interaction with objects being produced, and help students to understand the concepts and strategies used", thus helping them to build new knowledge. Nonetheless, highlighting the construction process and not just the final product, is important, thus valuing the "learner's experience that allows them to learn from their mistakes and successes" (Gavassa, 2020, p. 39).

In the sequence, the students encountered another difficulty while starting to build the monuments. The class was divided into four groups of about five students each, but they used only one computer per group, which slowed down the building process, as long as only one student could use the mouse at a time. So they started exploring the application, trying to figure out a way to share the project so they could work on more computers, editing the same project simultaneously. One student could share and teach other classmates to do the same. So they went to work building the project as a team, with two or more computers per group.

The groups explored almost all the tools available in the application creatively, solving all the problems they encountered throughout the project. One of the groups, for example, used the tool to create a hole in other pieces to build a window. However, the students realized that the "hole" element would not only create the window's shape, but also leave a texture very similar to glass, if they did not group the elements, so they built the window glass that way, thus making the project more realistic.

It should be noted that creativity is not limited only to the customization of projects; it is also used to solve problems whenever the student develops simple solutions to complex problems. Whenever students become "creative beings", according to Aleixo (2021, p. 77), they stop assuming the function of mere receivers of information and become "questioners of ideas and inventors of artifacts; beings who build knowledge". Creative thinking is being increasingly valued and, according to Resnick (2020),

> creative thinking has always been, and always will be, a fundamental part of what makes life worthwhile. Living as a creative thinker can bring not only financial rewards, but also joy, fulfillment, purpose, and meaning. Children deserve nothing less than this (p. 6).

In addition, it should be noted that even if the activities were conducted in groups, the students were not limited to helping only their colleagues in their group. Each discovery was shared with everyone else in the room, thus collaborating to improve all the projects. According to Resnick (2020, p. 86), "most thoughts are done in connection with other people, we share ideas, get reactions, complement their ideas"; thus, students learn even more.

The community behavior of students who share when making a discovery so that everyone can enjoy it, values human relationships and is one of the attitudes described by Hatch's Maker Manifesto (2013). According to Hatch (2013), creating something brings us much satisfaction, but sharing our creations is even better because "sharing" is what ensures the "magic" of maker activities. Furthermore, whenever students work together, they develop further and learn to communicate their ideas (Resnick, 2020). If students feel comfortable sharing their ideas and working together, they are "more likely to try new things and take risks, which are a fundamental part of the creative process" (Resnick, 2020, p. 98).

Throughout the activity, students developed creativity, protagonism, teamwork, dealt with challenges and solved problems, learned from their mistakes, among other actions, thus developing various skills related to the Maker Movement that had been pointed out by Aleixo (2021), Resnick (2020), Valente and Blikstein (2019), Gavassa (2020) and Vieira (2020).

Some groups couldn't finish their projects in the second class and missed a few details missing, so the Mathematics teacher gave them another moment to finish them up. All of them succeeded recreating the historical monuments and said they greatly enjoyed the application experience. Figure 3 shows two of the projects built by the students.

Figure 3: Reconstruction of historic monuments (Casa da Cultura and EcoVias)

Source: Self elaboration (2022)

After finishing the physical models and 3D projects, the school held a Cultural Exhibition so that all students could share their projects conducted throughout the year. Thus, the 9th-graders exhibited their physical models, several photos of their activities (from lectures attended, visitation of monuments, production of physical models to 3D projects), the floor plans built, in addition to adding a QR code so that people could access the virtual projects, in which they did the three-dimensional modeling in Tinkercad.

Figure 4: Presentation of physical models and 3D projects at the Cultural Exhibition

Source: Research collection (2022)

The students' projects were 3D-printed at the end of the project. As long as they had no experience with 3D printing, some constructions were hard to print, such as elements that were not well fitted or parts that were tilted, among other problems. Besides, some designs also needed to be adapted in order to fit the printer.

The printing process was performed on three Anycube I3 Mega printers and a GTMax Core A3 using two types of filament: polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS), at the IFRS Manufacturing Laboratory - Campus Caxias do Sul. One of the filaments was only made because of color (to be closer to the original project) and time available to perform this activity, which was only one week.

In order for the constructions to be printed in color and in great detail, it was necessary to dismember all the elements of each project, separating the parts that would be printed in different colors. The average printing process for each project lasted approximately 12 hours. After being printed separately, the pieces were glued together according to the student's original project. The result of one of the printed projects is shown in Figure 5.

Figure 5: 3D printed historic monument

Source: Self elaboration (2022)

Unfortunately, due to time, students could not visit the facilities of *IFRS - Campus Caxias do Sul* in order to learn how to use 3D printers. However, the 3D models printed by the project were taken to Picada Café and exhibited during their graduation. The students were impressed when they saw their virtual projects materialized.

8 Final thoughts

The students succeeded completing the 3D designs of the Picada Café historical monuments on Tinkercad, in addition to the physical models. During the hands-on construction process, students developed protagonism, autonomy, creativity, teamwork, problem-solving, among other skills related to the Maker Movement, experiencing the creative learning proposed by Resnick (2020).

By constructing 3D projects, students learned how to use the Tinkercad platform and created their own projects. They also explored mathematical concepts such as scale, distance and length measurement units, among others. In line with what Rosa (2018) points out, by using a technological resource such as Tinkercad, which requires mathematical concepts to build their own product, students had the opportunity to build knowledge and develop themselves more broadly as individuals.

Whenever the students were faced with problems throughout the 3D modeling process, they intentionally used mathematics to help build projects, applying mathematical concepts, which were previously considered abstract, in real situations, thus contributing to a change of perspective in regarding mathematics, seeing it as part of everyday life, present in various spheres.

It is noteworthy that, throughout the construction of the project, students developed mathematical skills identified in the BNCC (Brasil, 2018) and in the Referencial Curricular Gaúcho (Rio Grande do Sul, 2018), thus developing logical reasoning, interaction, and collaborative work among colleagues in order to solve real problems, using mathematical knowledge, building relationships between mathematical concepts, and using digital technologies to model and solve problems.

Although the mathematics used in the model is the same as in the 3D modeling performed in Tinkercad, other skills were developed, besides spatial thinking, computational thinking, problem-solving and creativity (Bhaduri *et al.*, 2021)

Furthermore, students learned to model three-dimensional objects using the Tinkercad program, by discovering a new use for technology and being able to collaborate for the development of protagonism instead of using these resources passively. Thus, it was possible to carry out an activity in which they used technology more consciously, using these resources to learn even more, as proposed by the BNCC (Brasil, 2018).

The Tinkercad environment made the activity even more enriching, whereas students could learn by "playing", by using their creativity and by bringing their projects to live with their own hands. The use of technology to develop the activity enabled countless options of colors, objects, formats, and tools in the construction of the projects based on the Maker Culture, thus expanding the possibilities of construction when compared to the physical models, also enabling the students to expand the creativity, as pointed out by Valente and Blikstein (2020) regarding the use of technology in maker activities.

Therefore, in addition to mathematical knowledge regarding the project to reconstruct historical monuments in Tinkercad, students were able to develop various skills related to Culture Maker, which encouraged them to be protagonists and get their hands dirty to create more projects of their interest, besides working as a team, developing creativity and solving problems.

With this article, it is expected to encourage more activities related to Maker Culture in schools, including those related to the use of technology in order to expand construction possibilities, thus seeking to develop mathematical skills and train students to prepare for the 21st century.

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