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Implementation of a STEAM education project in a private portuguese basic school during SARS-COV-2 pandemic

Implementação de um projeto de educação STEAM numa escola básica privada portuguesa durante a pandemia de SARS-COV-2

Implementación de un proyecto educativo STEAM en una escuela primaria privada portuguesa durante la pandemia SARS-COV-2

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Abstract
STEM education is a relatively new area that aims for an integrated and interdisciplinary teaching and learning between scientific disciplines from different fields of science to promote active and creative learning. More recently, the letter "A" for the arts has been added to the acronym because it is believed that it can promote truly transdisciplinary learning. In this work we present our findings regarding an investigation conducted in a private school, during the on-line classes on a discipline called STEAM. The on-line classes happened due to the SARS-CoV-2 pandemic that changed the *in-situ* teaching-learning paradigm to the distance learning model. In this STEAM discipline the students were challenged to achieve certain objectives in several STEAM activities. After all activities were done the students answered a questionnaire regarding the work done. This data was analyzed using a Mann-Whitney U nonparametric statistical test. Some of the students also

participated in interviews regarding the discipline and their enjoyment about the performed activities. The qualitative and quantitative analysis of the data allowed us to conclude that students, in general, recognize the importance of STEAM activities for their integrated learning, but ranked with higher scores the manual construction activities to the detriment of purely virtual activities. In addition, the data allowed us to study the statistically relevant differences in student responses regarding grades and sex. The results may give important guides for teachers who may desire to implement STEAM education programs in the future.
Keywords: STEAM. SARS-CoV-2. Creative learning

Resumo
A educação STEM é uma área relativamente nova que visa um ensino e aprendizagem integrados e interdisciplinares entre disciplinas científicas de diferentes campos da ciência para promover a aprendizagem ativa e criativa. Mais recentemente, a letra “A” para as artes foi adicionada à sigla porque se acredita que ela pode promover uma aprendizagem verdadeiramente transdisciplinar. Neste trabalho apresentamos nossos achados a respeito de uma investigação realizada em uma escola particular, durante as aulas on-line de uma disciplina denominada STEAM. As aulas on-line aconteceram devido à pandemia do SARS-CoV-2, que mudou o paradigma de ensino-aprendizagem *in loco* para o modelo de ensino a distância. Nesta disciplina STEAM os alunos foram desafiados a atingir determinados objetivos em várias atividades STEAM. Após a realização de todas as atividades, os alunos responderam a um questionário referente ao trabalho realizado. Esses dados foram analisados usando um teste estatístico não paramétrico U de Mann-Whitney. Alguns alunos também participaram de entrevistas a respeito da disciplina e do quanto gostam das atividades realizadas. A análise qualitativa e quantitativa dos dados permitiu-nos concluir que os alunos, em geral, reconhecem a importância das atividades STEAM para a sua aprendizagem integrada, mas classificam com pontuações mais elevadas as atividades de construção manual em detrimento das atividades puramente virtuais. Além disso, os dados nos permitiram estudar as diferenças estatisticamente relevantes nas respostas dos alunos em relação às notas e ao sexo. Os resultados podem fornecer guias importantes para professores que desejam implementar programas de educação STEAM no futuro.

Resumem
La educación STEM es un área relativamente nueva que tiene como objetivo la enseñanza y el aprendizaje integrados e interdisciplinarios en todas las disciplinas científicas de diferentes campos de la ciencia para promover el aprendizaje activo y creativo. Más recientemente, la letra “A” de las artes se ha agregado al acrónimo porque se cree que puede promover un aprendizaje verdaderamente transdisciplinario. En este trabajo presentamos nuestros hallazgos sobre una investigación realizada en un colegio privado, durante las clases online de una disciplina denominada STEAM. Las clases en línea sucedieron debido a la pandemia SARS-

CoV-2, que cambió el paradigma de enseñanza-aprendizaje in loco al modelo de aprendizaje a distancia. En este curso de STEAM, los estudiantes fueron desafiados a lograr ciertos objetivos en varias actividades de STEAM. Después de realizar todas las actividades, los estudiantes respondieron un cuestionario referente al trabajo realizado. Estos datos se analizaron mediante una prueba estadística U de Mann-Whitney no paramétrica. Algunos alumnos también participaron en entrevistas sobre la disciplina y cuánto les gustan las actividades realizadas. El análisis cualitativo y cuantitativo de los datos permitió concluir que los estudiantes, en general, reconocen la importancia de las actividades STEAM para su aprendizaje integrado, pero califican las actividades de construcción manual con puntajes más altos que las actividades puramente virtuales. Además, los datos nos permitieron estudiar las diferencias estadísticamente relevantes en las respuestas de los estudiantes en cuanto a calificaciones y género. Los resultados pueden proporcionar guías importantes para los maestros que deseen implementar programas educativos STEAM en el futuro.

Palabras-clave: STEAM. SARS-CoV-2. aprendizaje creativo

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INTRODUCTION

The word STEM, an acronym for Science, Technology, Engineering and Mathematics, appeared in the 1990s in a report by the National Science Foundation (NFS - National Science Foundation) (SANDERS, 2008). In terms of Education, it symbolizes an integrated and interdisciplinary approach between scientific subjects from different science fields to promote creative learning. Although many documents were written about the importance of STEM in school curricula, not much has been done to effectively ensure the implementation of this type of education. According to Park, Wu & Erduran (2020), STEM education and the "Nature of Science" (NOS) are two of the most important topics that guide research in education nowadays. Also, according to these authors, both STEM education (which integrates disciplines in the areas of technology, engineering and mathematics with the sciences) and NOS can be seen as extensions of what should be taught in science classes and still constitute educational efforts used for science teaching, since traditional, content-oriented teaching has failed to teach authentic scientific practices.

According to Bybee (2013, p. X) the meaning of STEM changes according to the environment in which it is applied. Within the school context, the author considers that STEM education should contribute on three main fronts:

1. Develop a literate and qualified society in Science, Technology, Engineering and Mathematics.

2. Ensure that students and teachers have developed 21st century skills within an integrated school environment.

3. Generate a research and development force focused on STEM innovation.

English (2017) believes that STEM education should be implemented according to several factors, such as for example the curriculum, location of the educational institution, school context and political vision. Moreover, the author supports the idea that the pedagogical practice supported by STEM teaching allows students' mathematical learning to be enriched in activities considered “easy entry” (low floors), which means that students can engage in the activity with a minimum of knowledge of mathematics. However, these are wide enough to allow the student to reach levels of thinking, reasoning and learning, normally beyond what is supposed for their age group and school year. According to Lowrie, Fitzgerald & Downes (2018), the STEM practice enables students to equip themselves with the necessary tools such as knowledge, skills and values that allow them to achieve success in today's world of constant and sudden changes. The authors also argue that STEM education should be a world priority and exemplify the Australian government's interest in this theme from various political initiatives. This view is in line with the report by the Organization for Economic Development and Cooperation (OECD, 2014) which states that STEM education is an enabling path for students to become a member of society, able to adapt and be innovative in face of global changes.

Lowrie, Fitzgerald & Downes (2018) and English (2017) support the idea that each school should approach STEM teaching differently, however, the former allege that there is evidence that identifies certain characteristics that must be present for a STEM teaching program to be successful, especially the teaching mindset or even a pedagogical disposition towards a STEM education.

The STEAM teaching model we used in this research is based on the view described by Bybee (2013):

“While understanding the concepts and processes of traditional disciplines certainly contributes to citizens’ intellectual growth, I argue that future citizens need educational experiences that transcend the traditional boundaries of science, technology, engineering, and mathematics disciplines. It is not enough to assume that if students know enough biology, for example, they will make healthy choices. (...) If we want students to learn how to apply knowledge, their education experiences must involve them in both learning the knowledge of STEM disciplines and reacting to situations that require them to apply that knowledge in contexts appropriate to their age and stage of development. It really is not complicated. STEM initiatives have the potential to provide these educational opportunities.” (Bybee, 2013, p. IX, X).

However, we propose a STEAM education rather than STEM education. The letter "A" stands for Arts and there is no agreement in the literature on how art should be implemented. According to Quigley, Herro & Baker (2019, p. 144) the first theoretical framework for STEAM education was created in 2006 by Georgette Yakman, founder, researcher and CEO of "STEAM Education". In this framework, Georgette Yakman advocated that science could be understood from the knowledge of technology and that art would be fundamental to this comprehension (Yakman, 2008). Thus, Georgette Yakman proposed the framework in which all disciplines were integrated (Yakman, 2015), but privileged science and technology over engineering and arts, although she connected them all through mathematics.

Quigley, Herro & Baker (2019, p. 144) are cautious in adopting such a framework because they consider that in practice, art is a captivating component of disciplines and not an integral component in problem solving, thus becoming something to be applied later. However, Bequette & Bequette (2012) argue that when the arts are seen as an end goal and not just a gateway to the topics associated with the STEM disciplines, considered more important, the STEAM curricula that are carefully developed can promote truly transdisciplinary learning (p. 43) and that "art, like engineering, is concerned with finding answers to problems and seeking visual solutions using the design process. Art, like engineering, subscribes to the idea that design thinking is a complex cognitive process (...)" (p. 44).

We agree with this idea when we propose STEAM activities to our students, but that is not always easy to achieve. Daily, it was found there is an almost invisible barrier, that no one speaks about openly or explicitly, about the fact that the art discipline is sometimes overlooked or considered of lesser importance by science teachers, by students and sometimes even by society. This is easy to understand when we realize that in the majority of schools in Portugal, the weekly workload of Visual Education is only one hour, while physics, chemistry and natural sciences have two and a half hours (or more) and mathematics has at least four or five hours per week. If the subjects were considered equally important, the workloads would be equivalent.

Kobayashi (2019, p. 177-178) goes beyond this interpretation and argues that an "A" in STEM offers an opportunity to change our interpretation of education, narrowing the differences between STEM areas through an emphasis on art. Mathematics can be seen as "art", stating that mathematics can be considered a creative endeavor, providing opportunities to perceive and build patterns that help us understand ourselves, as well as the complex universe in which we were born and that the "A" of art in STEAM becomes the "A" of "aesthetics" as the basic art of being alive and awake in the world, this being the goal of education. This interpretation given by Kobayashi, although quite profound, can cause controversy. In this view, we can categorize almost everything as art, even because mathematics is part of the various areas of science. Besides, in this interpretation one could argue that the universe itself is the most primitive form of art, and everything inside the universe could also be considered art.

We can say for sure that our vision of STEAM education for our students is much simpler than most of the authors have presented. Our research concerns a new curricular discipline called STEAM, where we try to integrate the knowledge of the different scientific areas and arts, promoting interdisciplinary teaching aiming to achieve transdisciplinary learning. We know we are just at the beginning of a new educational paradigm, and we still must explore the possibilities and educational opportunities for improving the teaching and learning process. The discipline of arts is a fundamental element in some concepts applied by students in enriched contexts and in their creativity during the conception and development of the activities proposed in the classes.

In this work we investigate how the students classify in terms of how they liked the activities implemented during the online STEAM classes. We also investigate if there are any statistical differences between the results regarding the sex and the grade of the students.

STEAM AS A DISCIPLINE

In the Portuguese private school where this investigation was done, the STEAM project is applied to students from Preschool Education to the end of the 8th year of Basic Education. The general objectives of the STEAM project are to involve students in a STEAM learning environment, to promote the integration between these five disciplines to be a cohesive learning experience, and to develop a new shared and applied learning model in the understanding, identification, and resolution of real-world transdisciplinary problems.

Education in STEAM subjects, with an emphasis on student engagement, encompasses the development of "21st century skills", such as: effectively managing your own work; acquire new skills and information about your own development; be able to solve small problems; think critically about tasks; being able to communicate and debate different ideas; to work in collaboration with others. Also, within the general objectives, students must be able to work in an interdisciplinary way, with understanding and recognition of the interdependence between disciplines in the STEAM area. To achieve this kind of education, the students were introduced to several concepts about robotics and Information and Communications Technology (ICT) for educational purposes: the basic principles of exploring tools such as Scratch, LEGO Education, Micro:bit, Minecraft Education and Paint 3D. Knowing how to use new technologies enables students to develop small personal and team projects.

In the 1st Cycle of Basic Education, the project's primary goal is to explore curricular projects related to LEGO Education WeDo 2.0, using the Minecraft game and the Scratch program. For students of the 2nd and 3rd Cycles of Basic Education, the STEAM project acts as an enrichment and enhancement activity, centered on curriculum for consolidation and deepening the understanding of this curriculum.

More specifically for the 7th and 8th grades (3rd Cycle) in which this investigation is based, the students had weekly one hour of STEAM discipline and used different software such as MS Paint 3D, Minecraft, programming activities (micro:bit and javascript based coding), in addition to carrying out various activities involving low cost materials, in which they could reinforce teamwork and the exercise of some of the skills described above. Even though the main purpose of the STEAM discipline was to enhance and deepen the understanding of the curriculum, this project was also used to widen the students' understanding of science and the real world by exploring activities that were not necessarily correlated to the curriculum of the scientific disciplines or arts.

Also, the activities were implemented considering the idea that art would be present throughout the teaching process and that students would not necessarily apply techniques and concepts learned in Visual Education to achieve the intended objectives of each activity. Many of these activities included art in their development and in the final product. In the various interdisciplinary works in which teachers from different areas participated, there was feedback inherent to scientific discipline and feedback inherent to art.

METHODOLOGY

THE RESEARCH PROBLEM

Due to the pandemic (SARS-CoV-2) in 2020, in-person classes were suspended, and the teaching model changed to distance learning. With that, the activities that the students were carrying out in the STEAM discipline had to be interrupted and new activities for the STEAM discipline were proposed to the students, considering the emergency situation that the country and the population found themselves in.

The STEAM activities proposed to the students before the pandemic was different for the 7th and 8th grades, so two questions arose from these activities:

- Are the statistical results for the median the same for the 7th and 8th grades?
- Are the statistical results for the median the same for the males and females?

To know the answer, we performed the Mann-Whitney U Test, a nonparametric statistical test that enables us to compare results between two groups, even when our distribution is non normal and our sample is not random. The test was made using IBM SPSS STATISTICS version 26.

THE SAMPLE

The sample of this investigation was the students attending the 7th and 8th grade, with ages between 11 and 14 years old. We only accepted students who freely agreed to participate in this study, coming from four different classes, namely 7th A, 7th B, 8th A and 8th B (Table 1).

Table 1 - Number of students of each class by sex

	7th A	**7th B**	**8th A**	**8th B**
Male	**10**	**10**	**14**	**14**
Female	**7**	**8**	**12**	**11**
Total	**17**	**18**	**26**	**25**

Font: The authors. In the case of the 8th B class, initially there were 13 boys, but in the middle of the school year another boy entered the class and raised the total number to 14. It is possible to see that there was some equity in the distribution of boys and girls in each class.

At the beginning of the school year, all students received an Acer-branded hybrid portable computer, featuring an Intel® Pentium® CPU N4200, with 4.00 GB of RAM memory and a 11.6-inch touch screen running Windows 10 operating system. The computer was part of the mandatory school material that should always be with students in the classroom so that they could use it whenever necessary.

Regarding the STEAM subject, except for three students, one from the 7th B and one from the 8th A who were new to the school and one student from the 8th B who entered the 2nd period, all the others have already had classes in previous years with this discipline. Thus, for most students who were part of the sample of this investigation, the STEAM course was not new.

DATA COLLECTION

For this qualitative study, we designed several tools for data acquisition. So, data was collected from a questionnaire, interviews to students and field observation.

The field observations were made during the on-line class by the teacher of the discipline who is one of the authors of this work. These field observations were gathered by handwritten notes taken during the classes from conversations with the students and refer to the results and final products sent by the students at the end of the assigned works.

At the end of the school year, the students that volunteered to participate in this study answered, anonymously, a questionnaire regarding how they would rate each activity they had done during the on-line classes, by grade and sex. To rate the activities, they had to choose an integer number from 1 up to 6 for a Likert scale, in which the meaning of each number in described below:

1 - Really did not like the activity;

2 - Did not like the activity;

3 - Disliked the activity a little bit more than I liked it;

4 - Liked the activity a little bit more than I disliked it;

5 - Liked the activity;

6 - Really liked the activity.

The interviews were of free choice for each student and nine of them in total, four from the 7th grade and five from the 8th grade, agreed to participate. The interview was a standardized open-ended allowing interview and also some informal conversation. The questions made during the interviews were related to the STEAM classes, the activities done and students´ general feelings regarding the subject.

THE STEAM ACTIVITIES

Circulation restrictions imposed by the state of emergency due to the pandemic led to the proposal of activities that could be carried out with home resources, as it could be difficult for students to obtain materials for the activities. It was also considered that the teacher had a short time interval to prepare and adapt the new activities. Therefore, we took the decision to give preference to activities that could be performed by both 7th and 8th grade students, using low-cost materials accessible to everyone, or activities that could be performed on the computer. Because the students were mainly in front of the computers all day long for all the classes, we minimized the number of virtual activities as they require more hours in front of the computer.

For each activity, students should prepare a plan, present a schematic drawing (if it was inherent to the activity) and identify the scientific concepts relevant to the activity. This last request aimed to show students the applicability of the science taught, so that students understand the meaning of what is intended to teach and thus link science to daily practice. With this teaching dynamic, we sought to minimize one of the reasons why students do not choose the STEAM area in higher education, which is the non-perception of the purpose of STEAM teaching, when they fail to identify the applicability of a particular subject or topic in different contexts. When that happens the STEAM area is considered by students as rigid, aimed at obtaining a specific answer, without the possibility of exploring or offering conditions to develop a certain theme (HOLMEGAARD, MADSEN and ULRIKSEN, 2014).

A novelty that was immediately implemented was the possibility for family members to participate in the activities. This choice was made for a few reasons:

- By understanding that the students would need help, since in the classroom they had the help of teachers and peers.
- By understanding that in a moment of social isolation, having the family more present could be helpful to minimize possible damage caused by distancing and change in lifestyle.
- By understanding that it would be better for students to have explicit permission to receive help from family members rather than not having such permission and end up being helped anyway.

In addition to the above considerations, we believe that because the students develop the work in the family environment, this could be a good opportunity to promote an understanding of the scientific contents with the families and to know the scientific process to reach knowledge. In the future, this can be an important help for choosing the STEAM area, since the environment and the influence of parents are two important factors when students choose their careers in the STEAM area (HOLMEGAARD; ULRIKSEn and MADSEN, 2015; REGAN and DEWITT, 2015).

In the following, we will describe schematically the seven activities proposed to the students in this study, carried out during the pandemic: five of them are building activities and two of them are virtual activities.

ACTIVITY 1 - FREE ACTIVITY

Since the situation in which everyone found themselves was unprecedented, it was decided that the first on-line activity would be a free activity in which students would have the autonomy to choose what they wanted to do, considering that the activity was within a STEAM perspective and that they had the necessary materials to carry it out.

The students were provided with some internet sites where they could get inspiration to later develop their own activity.

The students were required to take photographs of the development of the activity and make a video to show the final product developed.

ACTIVITY 2 - STONE, BOAT AND WATER

This activity was carried out by the students over a two-week time interval and aimed to answer the following question: “A small boat floats in a swimming pool. Inside the boat there is a stone. What will happen at the pool water level if the stone is removed from inside the boat and thrown into the pool: will the water level go up, go down or stay the same?”

In this activity, the students had to plan the activity, as follows: indicate what material would be used to represent the boat; what material could represent the stone; and what to use instead of a real pool. In addition, it would be necessary for them to indicate the scientific concepts present in the activity and make a prediction of what would happen at the water level when the stone was removed from inside the “boat” and placed inside the “swimming pool”. Finally, they should compare the results with their predictions.

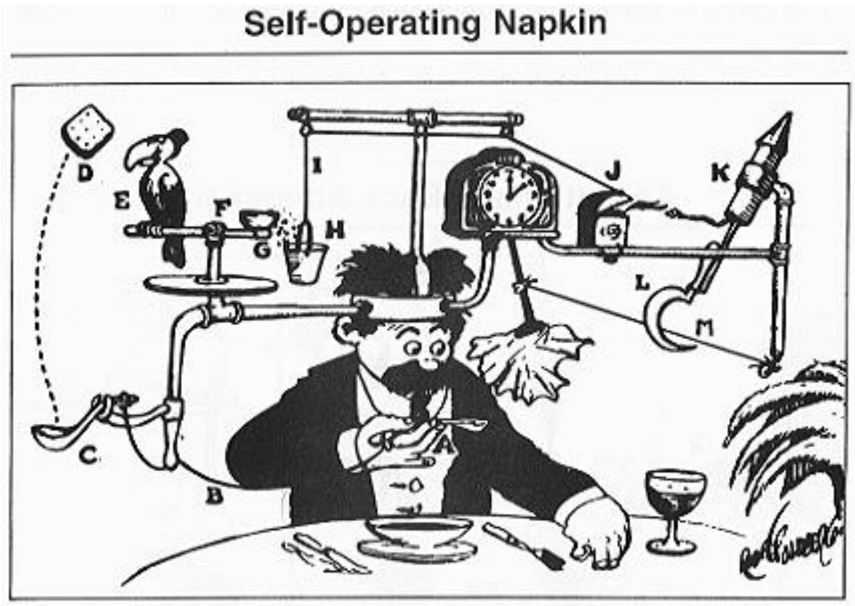
ACTIVITY 3 - CHAIN REACTION

This activity was done by the students over two weeks and aimed to assemble a Rube Goldberg machine (GOLDBERG, 2018) in which a marble falls into a glass, and/or a domino piece pushes another and/or an object is dropped.

Rueben Garret Lucius Goldberg (1833-1970) became known as an inventor, sculptor, author, engineer and cartoonist and left a mark on history for his extraordinary achievements. Rube Goldberg was best known for Professor Butts' crazy contraptions. These inventions, also known as Rube Goldberg Machines, would solve a simple task in the most complicated, inefficient, and hilarious way possible (GOLDBERG, 2018).

Goldberg's Self-Operating Napkin cartoon (figure 1), originally published by Collier's Weekly in 1931, also printed on a thirty-two cent US postage stamp in 1995, is a good example of this (TUMEY, 2014).

Figure 1 – Professor Butts and the Self-Operating Napkin



Font: (Tumey, 1931)

ACTIVITY 4 - LET'S CODE: SNOWMAN

In the week-long “let's code: Snowman” activity, students were introduced to the concept of inline programming using a JavaScript library called p5.js, which allows the user to create images, animations and interactions with very simplified lines of code (Mccarthy; Reas & Fry, 2015). These codes could be written in their own software or even in the MS Windows notepad, however, we chose to use the p5 website (https://p5js.org/) for simplicity, since the use of notepad software would bring the need to teach additional steps to students, namely, basic HTML, which were neither relevant nor the focus at the time.

The students had access to a video lesson produced by the teacher that explained how to access the website and basic commands such as drawing circles, rectangles and lines, colors of light (red, green and blue) and to use and interpret the RGB color code. The video-lesson brought additional in-depth material for students who wished to become more involved with the programming and indication of references that students could consult if they so wished.

ACTIVITY 5A - LET'S CODE: DYNAMIC CIRCLE

The “let's code: dynamic circle” activity, also lasting one week, was performed only by the 7th grade B and 8th grade A classes. The 7th grade A and 8th grade B classes performed another activity called stop motion which will be described below.

For this dynamic circle activity, students accessed again the video lessons provided by the teacher to learn new commands, such as condition commands (if something happens do this; if not, do that) and logical operators “and” and “or” which together with the condition commands allow a certain action to occur under situations specified by the user.

They had three challenges to be solved:

> challenge 1: Circle that increases in size as time goes by;
>
> challenge 2: Circle that increases in size when the mouse left button is pressed;
>
> challenge 3: Circle that changes color according to the position of the mouse in the screen.

ACTIVITY 5B - STOP MOTION

This activity was performed only by the 7th grade A and 8th grade B classes. This activity was done by the students over a week and aimed to create a film from photographs. To do so, students should take several photographs of a scene and change the scene little by little. Next, they used the video editing program contained in Microsoft Windows to join the photographs and assemble the video. Students could use any material available, including drawings.

Although the literature (FARROKHNIA; MEULENBROEKS & Van JOOLINGEn, 2020; HOBAN & NIELSEn, 2014) reports that this type of activity is often centered on the presentation of some science topic, it was decided to give students freedom to decide what to do.

ACTIVITY 6 - SOLAR OVEN

This activity was carried out by the students over two weeks and aimed to build a solar oven. The choice of this activity was related to the fact that in physics classes, 7th grade students were studying energy sources, both renewable and non-renewable, and 8th grade students were studying optical phenomena, in particular, reflection and absorption of light.

Students should plan what they intended to construct and then build the solar oven. Students were also encouraged to make a test, which required the presence of the guardian, in which they placed some type of food to cook.

RESULTS AND DISCUSSION

Table 2 shows the descriptive statistics for the questionnaires answered by the students. The table provides the number of respondent students (N), the minimum and maximum value attributed to each activity by them and the mean and standard deviation.

Table 2 - descriptive statistics

Descriptive Statistics					
Activity	N	Minimum	Maximum	Mean	Std.
Free activity	82	1	6	4,90	1,14
Stone, boat and water	82	2	6	4,60	1,12
Chain reaction	82	1	6	4,80	1,35
Let's code: snowman	82	1	6	3,55	1,87
Let's code: dynamic circle	39	1	6	4,23	1,60

Stop motion	43	1	6	3,67	1,81
Solar Oven	82	1	6	4,16	1,63

Font: The authors

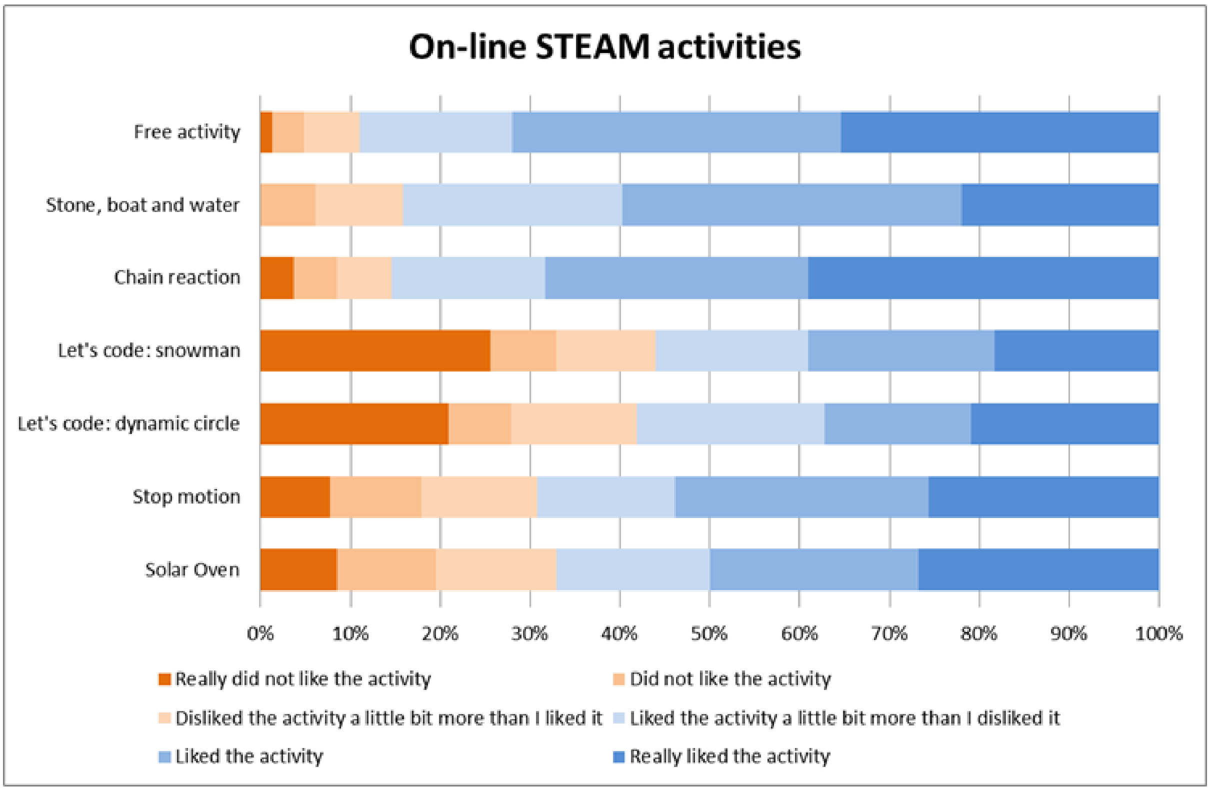
Even though the results shown in table 2 could bring some enlightenment about the activities, knowing only the mean, minimum and maximum of each activity is not enough for a broader understanding about the students' answers. Therefore, we present in table 3 a more detailed result obtained after analyzing the questionnaires answered by the students, in which is shown how many percent of students responded to each level from 1 to 6 in each activity. These values are represented in figure 2 in the form of a stacked bar graph.

Table 3 - Detailed descriptive statistics of table 2

Detailed descriptive statistics						
Activity	Really did not like	Did not like the activity	Disliked the activity a little bit more than I	Liked the activity a little bit more than I	Liked the activity	Really liked the activity
Free activity	1,22%	3,66%	6,10%	17,07%	36,59%	35,37%
Stone, boat and water	0,00%	6,10%	9,76%	24,39%	37,80%	21,95%
Chain	3,66%	4,88%	6,10%	17,07%	29,27%	39,02%
Let's code: snowman	25,61 %	7,32%	10,98%	17,07%	20,73%	18,29%
Let's code: dynamic circle	20,93 %	6,98%	13,95%	20,93%	16,28%	20,93%
top motion	7,69%	10,26%	12,82%	15,38%	28,21%	25,64%
Solar Oven	8,54%	10,98%	13,41%	17,07%	23,17%	26,83%

Font: The authors

Figure 2 - Stacked bar chart representation of results from table 3



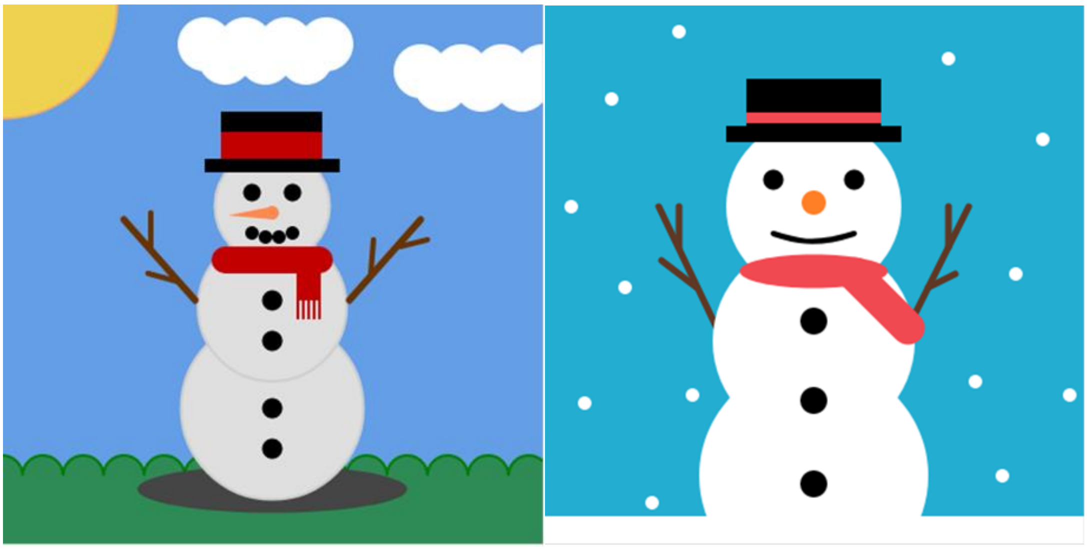
Font: The Authors

Figure 2 clearly shows that two activities stand out more negatively when compared to the others: "let's code - snowman" and "let's code – dynamic circle" (although for this one the mean was 4.23, as seen from table 2). Both were virtual activities performed through online programming to create images or animations, which was a first for everyone.

Despite the virtual activities were not the best evaluated, it was possible to identify from the interviews that some students really enjoyed these activities and were receptive to new activities involving line programming. Some extracts of the interviews are provided below:

> It was my favorite activity (…) after making the snowman I spent an entire afternoon programming a lot of drawings. I saw a random figure and did it (...) I think it was the one I most enjoyed working on (...) the programming [activity] [helped] in Arts because of the colors and also in Math, because of the coordinates. I loved the programming part. It's a topic I really liked to work on (…)

Figure 3 - Let's code: snowman activity - draws from programming of two different students



Despite the images of figure 3 look like some drawing made in some paint editor, they result from code lines used to develop programming skills. We present in figure 4 some random lines from the code just to give the reader an idea about those lines**.**

Figure 4 - Some code lines as an example to create objects in p5.js

```
//--Solo
//-Início Círculos
fill(46, 139, 85);
stroke(0, 125, 0);
circle(0, 350, 30);

fill(223, 223, 223);
stroke(207, 207, 207);
circle(200, 300, 135);
circle(200, 225, 110);
circle(200, 150, 85);

//-Nariz
fill(255, 137, 81);
triangle(202, 160, 202, 150, 167, 157);
circle(200, 155, 10);
```

The solar oven activity (figure 5) was the building activity with the worst evaluation among all, but with an intermediate evaluation when considering all activities. This result can be explained due to the complexity of this building activity when compared to the others and for bringing in its scope some contents that students were still studying in the Physical-Chemistry discipline.

Another factor to be considered would be a possible fatigue of the students, as this activity was proposed at the end of the school year and with the tests of other curricular contents taking place while they were carrying out the activity.

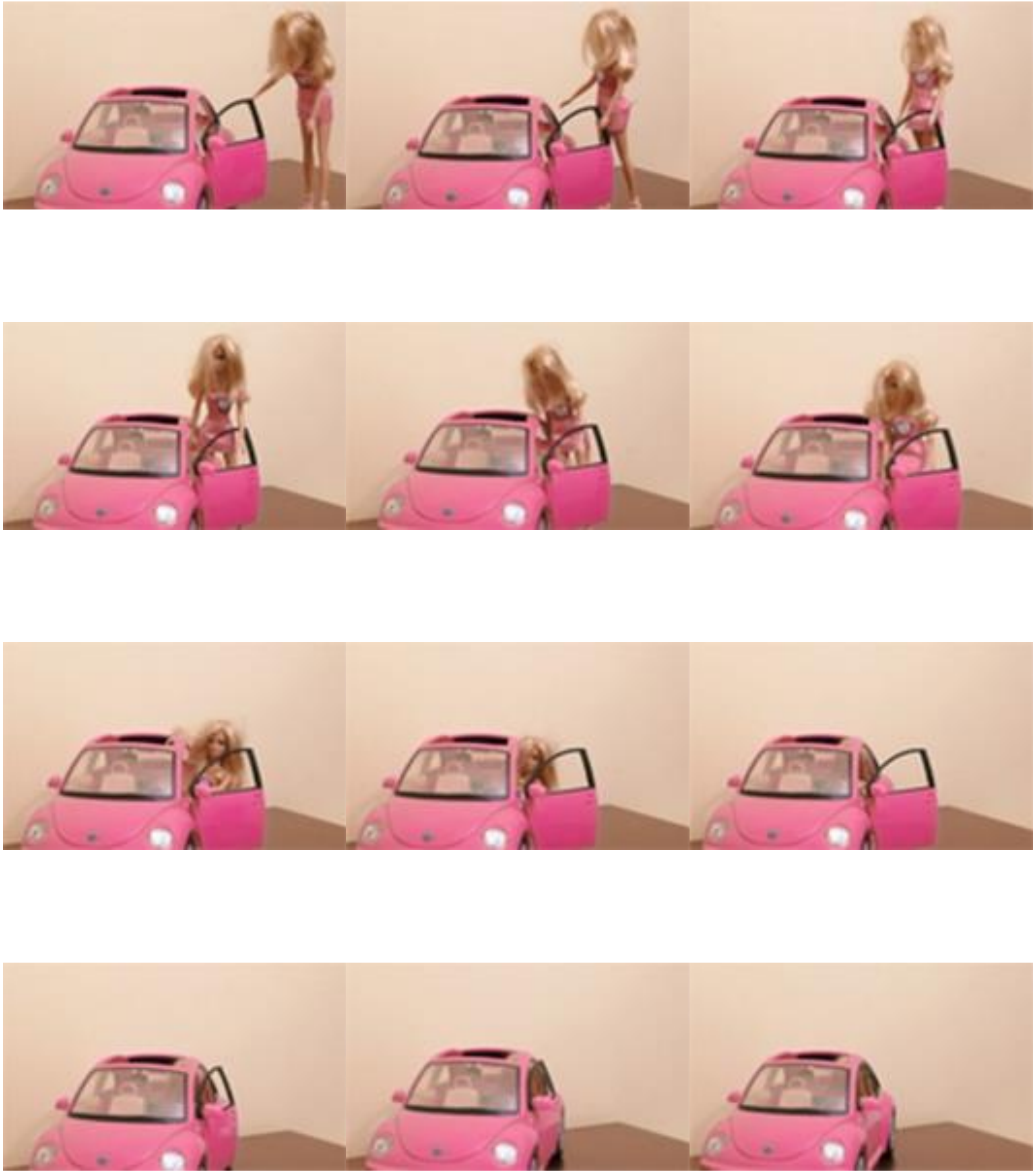
Even so, some students said in the interviews they enjoyed this activity very much and that they were able to verify, experimentally, some of the contents that were being addressed in Physical-Chemistry discipline.

> In the solar oven (...) I remember for example, perceiving many of the Physical-Chemistry contents were present (…) for example, light, the interaction of light, light reflection, refraction and I think it also brings more interest because you have scientific concepts behind it. (…) for example, the solar oven worked not by chance.

Figure 5 - Solar oven - images of ovens built by different students

The stop motion activity achieved a good acceptance from the students. This activity, although inserted for accidental reasons, was apparently enjoyed by the students and, certainly, with a minimum of additional preparation and planning could obtain better results. In the future this activity can be even more focused on the teaching of science and arts, thus making it an activity more directed towards STEAM teaching. Figure 6 presents a sequence of images to show a Barbie stepping in the car.

Figure 6 - Stop motion - Barbie's travel (name given by the student)



The three best rated activities were the “free activity", “rock, boat and water” and “chain reaction”, all of them building activities, which embraced the student’s creativity.

The activity “chain reaction” had a lot of acceptance by the students. Through conversations with students during classes and from the reports of interviews, and even through the videos that students sent to the teacher to present the work, it was noticed the participation of family members, which made this activity almost like a family project. Also, when the goal of the activity was achieved, it was visible from the videos the family cheering together and the sense of accomplishment filling the room. Overall, the students and family members embraced this activity and were very happy with the results.

One of the students said during the interview:

> I liked [the chain reaction activity] because I had to think about how to arrange books, the ball, the dominoes and then I had to use my knowledge from other disciplines, such as Mathematics and Physical-Chemistry to carry out this activity.

This activity required the students to have a lot of commitment, patience and perseverance, because until they managed to obtain the desired result, several attempts were necessary. It can be speculated that the feeling of reward for achieving the goals in an activity that required a lot of work and effort was great, hence the expression of enthusiasm on the part of the students.

Another student detailed the experience during this activity in the interview as follows:

> [I liked the] chain reaction … there were times when I was a little irritated because… the bouncing-ball in this case, which I used, went down and then hit something… I had to go there again and reassemble it… but I ended up doing something that I thought was fun, watching it go down and go through all the little things and then reach a bottle. I thought it was funny.

Figure 7 - Chain reaction - details of two student assemblies

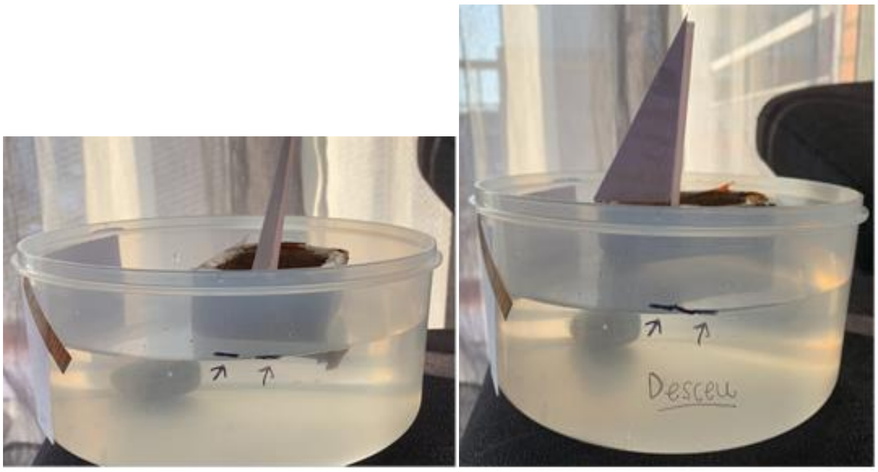
For the rock, boat and water activity, the strong point was, undoubtedly the unexpected result found by the students. The reversal of expectations regarding the prediction made by most of them made them curious to know the scientific reason and the explanation for the observed phenomenon (figures 8 and 9). Activities of this type should be seen as a way to stimulate the students' critical reasoning and investigative spirit.

Some students demanded an explanation for the phenomenon observed and some of them even went to search on the internet for a possible explanation, discussing this activity furthermore with the teacher. Some reports of the interviews clarified some of the reasons for the great acceptance of this activity:

> [in the stone, boat and water activity] we were able to stimulate our reasoning (...) I could also put into practice some knowledge of Physical-Chemistry [contents] such as density and so I liked this activity a lot.
>
> (…) I felt the curiosity to search why that happened and I was also amazed because we waited for something, but then it didn't happen, so we were like: but why didn't it happen? So, it made me more willing to investigate the topic.
>
> (…) it was quite curious mainly because I thought, as I believe everyone else, that the water level was going to rise [laughs]. Then when it lowered, I even did the activity three more times to see if I was doing well or not [laughs]. Because I didn't believe it.

Figure 8 - Rock, boat and water - photos provided by two students with the rock inside the boat

Figure 9 - Rock, boat and water - photos provided by one student with the rock outside the boat and the markers of the water level



The excellent acceptance of the first project "free activity" can be easily understood by considering that the students felt a sense of freedom that they were not used to and could choose to do what they wanted, as long as it was still related to the STEAM areas. They chose to carry out practical activities concerning topics they like the most.

Different projects were made by the students in this activity, including little games, such as table football (foosball), mini-golf, marble maze and others. Some students made race-cars, water dispensers, mechanical claws, watermills, etc. The results were very interesting and also with very different themes, but always based on scientific content that the students had to write down in their activity plan (figures 10 and 11).

Some comments given by the students in the interviews were:

> (…) the part I liked the most was in the first project where we did a free activity (…) the scientific concepts had to do with energy transfer, for example, kinetic energy and I thought that this was very motivating for us (...)
>
> I liked the free activity (…) I had made that liquid dispenser. I really liked it. I also found it very motivating, also for us to be able to choose once in a while what we are going to do, because it turns out to be something that maybe we liked or saw on the internet and we are very interested in.
>
> For me the most motivating ones were (…) for example that of the free activity where I did a game of snooker (…) the game I named "fournooker" because I only managed to make four holes for the balls to fall (…) So I think this one was the most motivating because it was something that was really interesting (...) [the free activity] is more motivating. We put more effort into something we can choose by ourselves.

Figure 10 - Free activity: marble maze (left) and watermill (right)

Figure 11 - Free activity: liquid dispenser (left) and mechanical claw (right)

STATISTICAL ANALYSIS OF RESULTS

Results from the inquiry concerning the enjoyment of students during the online activities were analyzed with IBM SPSS STATISTICS software. For each of the research questions identified for this study, we used the Mann-Whitney U Test, a nonparametric statistical test that enables us to compare results between two groups, even when our distribution is non normal and our sample is not random. We state as our null hypothesis H_0 that there is no difference between the studied groups and as an alternative hypothesis H_1 that there is a statistical significance difference between those medians with a confidence level of 95%.

Comparing the responses from students of the 7th and 8th grades, we get the following results shown in table 4.

Table 4 - Results of comparing the responses of 7th and 8th grade students regarding the enjoyment of activities

Null Hypothesis	Sig.	Decision
The distribution of free activity is the same across categories of grades.	0,012	**Rejec**t the null hypothesis.

The distribution of rock, boat and water is the same across categories of grades.	0,638	**Retain** the null hypothesis.
The distribution of chain reaction is the same across categories of grades.	0,341	**Retain** the null hypothesis.
The distribution of let's code: snowman is the same across categories of grades.	0,719	**Retain** the null hypothesis.
The distribution of stop motion is the same across categories of grades.	0,832	**Retain** the null hypothesis.
The distribution of let's code: dynamic circle is the same across categories of grades.	0,460	**Retain** the null hypothesis.
The distribution of solar oven is the same across categories of grades.	0,722	**Retain** the null hypothesis.

The only activity where we have to reject the null hypothesis is the "free activity", the first one the students made during the pandemic. That means that one of the grades, in this case the 7th grade, liked the free activity more than the students from the 8th grade. This conclusion is taken from another analysis of the questionnaire results of table 2 by separating the answers by grades, where we find the 7th grade has a higher mean value to this activity than the 8th grade. Other than that, all activities were rated at almost the same level in both grades, which means they were at the same level of satisfaction for both grades.

Concerning the results by gender, there seems to be no difference between the results found for males and females. The Mann-Whitney U test analysis in table 5 suggests that the STEAM activities proposed were equally enjoyed by students of both sexes. It does not mean that all activities have always been tailored to their preferences, only that they were rated as about the same from males and females.

STATISTICAL ANALYSIS OF RESULTS

Table 5 - Results of Mann-Whitney U test when comparing the results among students' sex

Null Hypothesis	Sig.	Decision
The distribution of free activity is the same across categories of sex.	0,140	**Retain** the null hypothesis.
The distribution of rock, boat and water is the same across categories of sex.	0,811	**Retain** the null hypothesis.
The distribution of chain reaction is the same across categories of sex.	0,807	**Retain** the null hypothesis.
The distribution of let's code: snowman is the same across categories of sex.	0,086	**Retain** the null hypothesis.
The distribution of stop motion is the same across categories of sex.	0,471	**Retain** the null hypothesis.
The distribution of let's code: dynamic circle is the same across categories of sex.	0,560	**Retain** the null hypothesis.
The distribution of solar oven is the same across categories of sex.	0,830	**Retain** the null hypothesis.

CONCLUSION

Even in a time of pandemic and with a distance learning model, it is possible to maintain activities related to STEAM areas suited for 7th and 8th grades, well accepted and stimulating for male and female students.

The results of this study show a positive rating of all STEAM activities, because as the interviews confirm, they provide stimulating moments and opportunities for understanding contents already taught in the classroom. Field observation also provided evidence of artistic creativity in students' work, confirming the assumption of Kobayashi (2019) and Yakman (2006) that STEAM activities allow for greater acceptance of other types of learning / perspectives, narrowing the differences between the STEM areas while Art can promote truly transdisciplinary learning.

It was also clear from our research a large preference of students for practical activities that engage them in critical and creative thinking. This result is quite interesting as we expected that virtual activities would have more acceptance by this new generation of students. Maybe the pandemic was responsible for saturating the mental health of students by looking too many hours at the computer. Or simply this is a wider symptom that computers and practical work are complementary educational tools, working together for a new interdisciplinary panorama of science, society, technology, and environment.

The possibility of family members to engage in the learning process is considered a plus and encouraged, since the feedback received by the students pointed out that they were very happy to develop the activities alongside the family. Therefore, group work and the contribution of the family must be seriously considered by teachers to the teaching and learning process as real advantages to motivate students towards STEM areas.

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