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STEM as a Means for Students' Science Learning

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ABSTRACT

This paper aims to describe the outcomes of a STEM project implemented in five different school clusters. It involved the delivery of STEM curriculum projects, focusing on the contextualization of the curriculum in the students' reality. The study aims to describe students' learning during the development of the project. The research reported in this study is qualitative, adopting an interpretative orientation. Participants were 1097 students belonging to five school clusters from distinct regions of Portugal. The students came from 52 different primary classrooms (n=941), mostly from Year 3 and Year 4, and 9 lower secondary classrooms (n=156), aged between 8 and 15 years-old. Due to the diversity of school clusters and local contexts, the curriculum projects had many differences, even though they were based in the same curriculum guidelines. Data sources were focus group interviews and written documents. The results showed that all curriculum projects allowed students to have positive learning experiences and to develop a significant number of competencies. They mobilized specific scientific knowledge related to the activities, developed scientific competencies such as, to formulate questions, appreciate, justify and evaluate different perspectives, plan, deliver an investigation and communicate their findings, as well as transversal competencies related with the design.

Keywords: STEM Education; Learning Science; Science Education; Context based Learning.

STEM como um Meio para as Aprendizagens de Ciências dos Alunos

RESUMO

Este trabalho tem como objetivo descrever os resultados de um projeto STEM implementado em cinco agrupamentos de escolas. Este projeto envolveu o desenvolvimento, em cada agrupamento, de projetos curriculares STEM, tendo como foco a contextualização do currículo na realidade dos alunos. O estudo pretende descrever as aprendizagens dos alunos durante a implementação do projeto e, para tal, é utilizada uma investigação qualitativa com base numa orientação interpretativa. Neste estudo participaram 1097 alunos dos cinco agrupamentos de escolas, de diferentes regiões de Portugal. Os alunos participantes tinham idades compreendidas entre os 8 e 15 anos: a maior parte dos alunos (n=941) pertencia a 52 turmas do 1.º ciclo do ensino básico (3.º e 4.º anos) e os restantes (n=156) pertenciam a nove turmas do 3.º ciclo do ensino básico. Tendo em conta a

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diversidade dos agrupamentos de escolas e contextos locais, os projetos curriculares STEM foram distintos, mas tiveram como base a mesma matriz curricular. A recolha de dados foi realizada através de entrevistas em grupo focado e documentos escritos. Os resultados mostram que os projetos curriculares permitiram aos alunos realizar experiências de aprendizagem positivas e desenvolver um número significativo de competências. Em particular, os alunos mobilizaram conhecimentos científicos relacionados com as atividades desenvolvidas, desenvolveram competências científicas tais como formular questões, considerar, justificar e avaliar diferentes perspetivas, planificar, concretizar uma investigação e comunicar os seus resultados, bem como competências relacionadas com o *design*.

Palavras-chave: Educação STEM; Aprendizagem de Ciências; Educação em Ciências; Contextualização das Aprendizagens.

INTRODUCTION

Nowadays, it is widely recognized that the social, economic and cultural development of a country is related to the literacy of its citizens and, in particular, to scientific literacy (OECD/PISA, 2015). Nevertheless, some international documents have been highlighting that students tend to choose less scientific careers and to pursue studies related to science and technology (OECD, 2016; Potvin & Hasni, 2014; UE, 2004). The reasons are, among others, the students' lack of interest for the school science themes, the low self-efficacy regarding science learning and the perception that the science curriculum is very difficult (Osborne, Simon & Collins, 2003; Sjøberg & Schreiner, 2010). As a response to this scenario, several different proposals have been introduced in order to deliver the science curriculum. One of such proposals comprises STEM integration, involving two or more school subjects. STEM integration in the curriculum has the potential to motivate students for learning science, to enable science learning and the development of competencies, such as problem solving, critical thought and creativity (Hurley, 2001).

Several studies have pointed out additional benefits of STEM integration for students. For example, Lamb, Annetta, Meldrum and Vallett (2012) reported positive effects on students' self-efficacy regarding science learning, and on students' interest for STEM fields. Christensen and Knezek (2017) verified that there was a relation between middle school students' interest with STEM fields and their intention to pursue a STEM career. Additionally, several studies found a positive impact of STEM programs in informal contexts on middle and high school students' motivation and interest with STEM fields (e.g., Chittum, Jones, Akalin & Schram, 2017; Kitchen, Sonnert & Sadler, 2018; Shahali, Halim, Rasul, Osman & Zulkifeli, 2017).

While these results are encouraging regarding students' motivation and interest, other studies have revealed ambiguous findings regarding science learning (e.g., Means, Wang, Young, Peters & Lynch, 2016). The current study aims to make a contribution to the field, by exploring the students' learning during the development of a STEM curricular project in a formal learning context.

THEORETICAL FRAMEWORK

It is widely recognized that the social, economic and cultural development of a country is related to the literacy of their citizens. Moreover, the transition from the information age (or digital revolution), to the synthesis age, defined by a way of thinking with a goal, an end, or an objective in mind, as well as a procedure for making a thing (Hall, 1995), focuses on new domains of expertise in what concerns teaching and learning (Cai, 2011). These domains comprise the evaluation and application of miscellaneous information, the preparation of transdisciplinary careers, the adaptation to new knowledge and technologies, and the fusion of traditional disciplines in order to accomplish the needs of the 21st century citizens (Nadelson & Seifert, 2017).

STEM education has been presented as an approach aimed to meet the needs of modern societies, not only in terms of literacy of their citizens but also in enticing students to pursue STEM careers (Christensen & Knezek, 2017). Furthermore, although qualified professionals in STEM fields are needed, it has been recognized that careers that are not apparently related to a STEM field, also require knowledge of STEM concepts and competencies (Bøe, Heriksen, Lyons & Screiner, 2011). In this sense, STEM-literacy has become an educational primacy and it is defined as the knowledge of the nature of STEM disciplines and the fluency in some of their central concepts (Thibaut et al., 2018).

In the last decades, it has been debated what a STEM education means and how it can be integrated, since it cannot be perceived as a set of contents from the four STEM fields, disconnected and independent from each other. Vasquez (2014/2015) presents a comprehensive perspective on different levels of STEM integration that evolves from a disciplinary integration to multi- and interdisciplinary integrations, until it reaches a transdisciplinary integration. At this upper level, where the interconnection and interdependence among the disciplines is greater, students apply knowledge and skills from two or more disciplines to real-world problems and projects. This allows the growth of students' interest for STEM fields and helps them to develop analytical and problem resolution skills (STEM Task Force Report, 2014). According to Johnson (2013), "integrated STEM education is an instructional approach, which integrates the teaching of science and mathematics disciplines through the infusion of the practices of scientific inquiry, technological and engineering design, mathematical analysis, and 21st century interdisciplinary themes and skills" (p. 367).

Recently, Thibaut et al. (2018) have done a systematic review of literature and published a paper where it is described a well-defined framework for instructional practices in integrated STEM education. The proposed theoretical framework is based on five key principles and is widely applicable, both in teaching practice and in educational research. According to these authors, the presented framework is aligned with social constructivist learning theory, that states that knowledge is actively constructed by students, based on their previous experiences and ideas, and that is a shared, rather than an individual experience. This theoretical framework contemplates: 1) integration of STEM content, that relates to the "explicit assimilation of learning goals, content and practices from different STEM disciplines" (Thibaut et al., 2018, p. 8); 2) problem-centered learning that allows students to be involved in authentic real-world problems; 3) inquiry-based learning that allows students to be engaged in the different processes that enable them to solve the initial problem, to learn new concepts and to develop new skills through questioning, experimental learning and hands-on activities; 4) design-based learning, related to engineering design processes and practices with the implementation of hands-on design challenges, that allow students to deepen their knowledge about core ideas; and 5) cooperative learning that promotes teamwork, collaboration and communication.

In order to engage students in the learning process through an integrated STEM education, it is essential that the context of the real-world problems presented is relevant to the students (Pilot & Bulte, 2006). Thus, the contexts should be selected in order to increase students' interest, and their motivation to learn the contents (Sevian, Dori & Parchmann, 2018). As stated by Pilot and Bulte (2006), a context-based approach "bring the learning of science closer to the life and interests of students" (p. 953). In fact, it is important that a selected context allows students to realize "Why am I learning this?" (Roberts, 1982, p. 245) and according to Bennett, Lubben and Hogarth (2007), this improves students' attitudes, motivation and interest towards STEM disciplines.

METHODOLOGY

The research reported in this study is qualitative, adopting an interpretative orientation (Erickson, 1986). An interpretative research provides us with a powerful tool for examining pupils' work and thinking. A constructivist view of learning supports this investigation and considers that knowledge is constructed by individuals based on their interpretations of experiences and interactions with others (Carlson, Humphrey & Reinhardt, 2003). All research was approved by our institutional ethical review board.

Participants

The participants of this study were 1097 students belonging to five school clusters located in five different regions of Portugal: Northern Region, Central Region, Estremadura Region, Alentejo Region and Southern Region. The students were distributed by 52 primary classrooms (n=941), mostly from third and fourth grades, and nine lower secondary classrooms (n=156), mainly from eighth grade. Students have an identical gender distribution, with 52% male, and with an average age of 8,50 years old (SD=0,84) for elementary school students and 13,46 years old (SD=1,01) for middle school students.

STEM Curricular Projects

To develop the STEM curricular projects in each school cluster we adopted the principles of the STEM integration framework, proposed by Thibaut et al. (2018). Therefore, STEM curricular projects were based in the five categories of the framework: (1) *integration of STEM content*, i.e., during the development of STEM curricular projects students were led to identify problems, systematically explore explanations and answers to problems, integrating science, technology, engineering and mathematics subjects; (2) *problem-centered learning*, by taking into account the context of learning experiences, i.e., the curricular projects grounded in students' local contexts, which facilitate the construction of personal meanings and increase the meaningfulness and the interest on the content to be learned, leading to a higher involvement of students; (3) *inquiry-based learning*, i.e., the STEM curricular projects promoted not only science learning (concepts, facts and relevant theories that comprise the body of fundamental knowledge), but also the development of students' knowledge about science (i.e., how science works, how knowledge is built and what´s the nature of that knowledge); (4) *design-based learning* was also considered in the STEM curricular projects and students were involved in hands-on design challenges that allowed them to actively experience learning and to deepen their understanding of disciplinary core ideas; (5) *cooperative learning*, i.e., during the activities students communicated and collaborate with each other in order to strengthen their knowledge.

In the northern region, the STEM curricular project intended to highlight the three varieties of landscapes of the region: the green landscape associated to the mountains, the blue landscape related to the water, and the grey landscape connected to the different type of rocks. In the central region, the project sought to explore issues associated with the history of local heritage and explore topics related to the natural wealth of this region (e.g. water, mines, fauna and flora). In the Estremadura region the project explored the wine cycle. In the Alentejo region, the project emphasized the historical, cultural and natural heritage. Finally, in the southern region, the project addressed issues related to the sea.

A sequence of activities was developed for each school cluster, taking into account its STEM curricular project and education level. These activities focused on different topics, such as water, types of rocks associated with the local heritage, planting of vines and the tracking from plant growth to wine production, renewable energies, fermentation, electricity, mining, biodiversity, food conservation, fires, electricity, flotation, chemical reactions, sound, etc. Thus, each school cluster had their own activities, and these were applied in a formal context, with the support of several local partnerships like city councils, local business and local associations.

Data Collection

For data collection, two different instruments were used: students' written productions and interviews. Students' written productions, developed and concretized along the academic year, were collected in order to describe the learning outcomes provided by the students' involvement in the project. More than one thousand written productions were collected from all the classrooms. At the end of the academic year, focused group interviews were conducted to students, in order to know their perspective about their learning, as a result of their participation in the project: 12 groups of students, each one with 6 to 12 participants, performing a total of 96 students interviewed.

Data analysis

The documents and the interviews were analysed according to previous defined categories: (i) mobilize scientific knowledge (in which students mobilizes scientific knowledge for making sense of natural phenomena, raising new questions, critically evaluating some aspects of their community, like practices, customs, etc.); (ii) investigate the world (in which students formulate researchable questions from what they observe, develop a research plan, gather evidences and analyse them in order to propose a reasoned answer to the initial question); (iii) recognize perspectives (in which the student reveals the understanding that, according to his position in relation to the object of study, each person will have a different perspective and, thus, what he observes will be different; ability to evaluate and negotiate different perspectives during the cooperative learning); (iv) design (in which the students are engaged in engineering design processes, applying and developing their knowledge about science, technology and mathematics).

RESULTS

Mobilize scientific knowledge

Mobilization of scientific knowledge was a fundamental feature of the STEM curricular projects and it was perceived as the ability of students to mobilize scientific knowledge for making sense of natural phenomena and to develop the scientific knowledge (through questioning and critically evaluate some aspects of their contexts), i.e., use this knowledge, in a suitable way that gives significance to different situations.

In the Alentejo's school cluster, the focus of the STEM curricular project was the historical heritage of the region, favouring an integration of engineering- and technology-related topics. For instance, in the scope of the STEM curricular project, students developed the activity "The colour of our houses", that aimed to involve 4th grade students with experiences about the light in order to learn about optical phenomena (in particular, reflection and absorption of the electromagnetic radiation). The background for this activity was the typical white facades of the houses of this region. The activity starts with the problem: why are houses in this region predominantly white? In order to answer the question, students planned and implemented an experiment with white and black-painted soda cans. With this experiment students were able to establish a comparison between temperature variation and the colour of the object (black or white): exposing two cans (one white and the other black) to an electromagnetic radiation source (a lamp, for example), students registered the variation of temperature during a defined period of time. This allowed them to conclude that the houses in Alentejo are white because there is the need to reflect part of the solar radiation, to keep them cooler, as illustrated in the written production elaborated by a group of students (Figure 1).

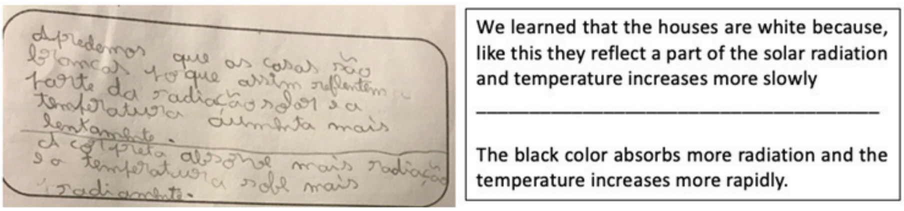


Figure 1. Students' written document about "the color of houses".

Also in the school cluster of Alentejo, other activity had a partnership with the Nature's Portuguese Union (Liga Portuguesa da Natureza- LPN) and the students were challenged with an activity in which they had to observe the shape of birds' beaks and relate them with the birds' feeding. This allowed students to learn that the shape of birds' beaks was determined by their feeding, as described in the following excerpt (Figure 2).

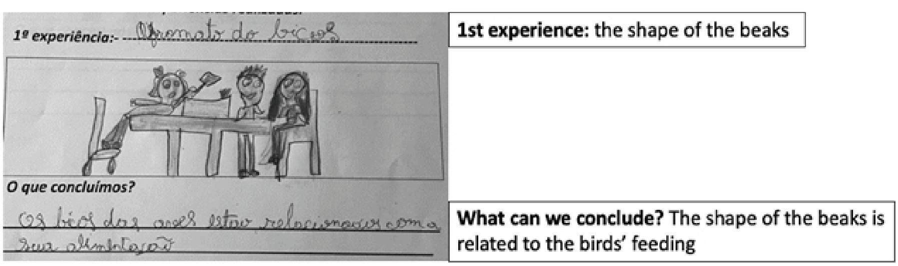
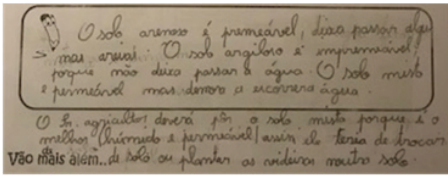


Figure 2. Students' written document about birds' beaks.

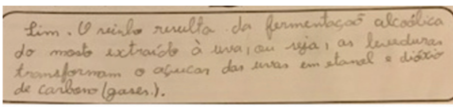
In the Estremadura region, the cultural heritage was approached during the development of the STEM curricular project and in this sense, activities concerning the characteristics of the soil in vine planting, were planned. The 3rd grade students performed experiences with different kinds of soils, determined their ability to retain water and, taking in account their previous knowledge about the factors that affect the plant germination process, determined which was the most appropriated. Based on the experiments, students identified that mixed soil, due to its permeability and ability to retain water, is the best soil for agricultural purposes Figure 3).



The sandy soil is permeable and enables the passage of water. The clayey soil is impermeable because it does not let the water pass through. The mixed soil is permeable but the water takes longer to pass. The farmer should use mixed soil (moist and permeable) because it is the best.

Figure 3. Students' written document about soils.

Besides this study of the soil, students also had the opportunity to visit the Winery Cooperative of the region, to learn about the wine production process and described it (Figure 4).

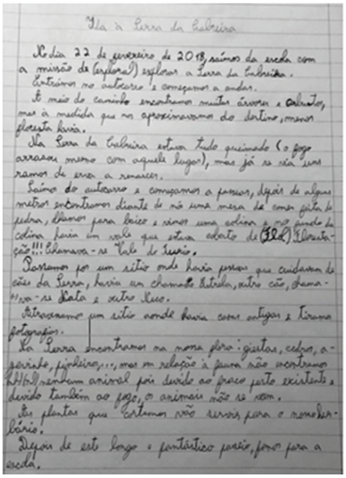


Wine is the product of the alcoholic fermentation of the must extracted from the grapes, i.e., yeasts transform the grapes' sugar, resulting ethanol and carbon dioxide (gas).

Figure 4. Students' written document about wine production.

With this field trip, students developed their knowledge about the process of alcoholic fermentation since they were able to identify the must and the yeasts that are indispensable for wine production, and referred the resulting products as being ethanol and carbon dioxide.

In the northern region, the students performed an activity in which they had to explore the nearby mountain. It was asked the students to make a report about what they had observed, regarding the mountain wildlife and vegetation. Students were able to identify some of the vegetation that they have already learned in the classroom. In what concerns the wildlife, the students justified the absence of animals, based on the fires that recently devastated that region and destroyed the meadows. The report made by a group of students (Figure 5) from the 3rd grade allowed us to live the experience.



Ida à Serra da Cabreira

No dia 22 de fevereiro de 2018, saímos da escola com a missão de (explorar) explorar a Serra da Cabreira.
Entrámos no autocarro e começamos a andar.
A meio do caminho encontramos muitas árvores e arbustos, mas à medida que nos aproximavamos do destino, menos floresta havia.
Na Serra da Cabreira estava tudo queimado (o fogo arrasou mesmo com aquele lugar), mas já se viam uns ramos de erva a renascer.
Saímos do autocarro e começamos a passear, depois de alguns metros encontramos diante de nós uma mesa de comer feita de pedra, olhamos para baixo e vimos uma colina e no fundo da colina havia um vale que estava cheio de [illegible] vegetação!!! Chamava-se Vale do Túrio.
Passamos por um sítio onde havia pessoas que cuidavam de cães da Serra, havia um chamado Estrela, outro cão, chamava-se Nata e outro Neco.
Atravessamos um sítio onde havia casas antigas e tiramos fotografias.
Na Serra encontramos na nossa flora: giestas, cedros, azevinho, pinheiros..., mas em relação à fauna não encontramos [illegible] nenhum animal pois devido ao pasto pouco existente e devido também ao fogo, os animais não se veem.
As plantas que cortamos vão servir para o nosso laboratório.
Depois de este longo e fantástico passeio, fomos para a escola.

Visit to the Cabreira Mountain

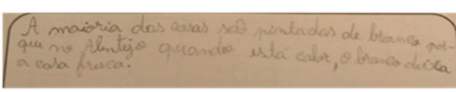
On the 22th of February of 2018 we left out of school with the mission to explore the Cabreira Mountain.
We went on the scholar bus and there we went.
On the midway we saw a lot of trees and bushes, but as we approached the destination, the forest became scarce.
At the Cabreira Mountain all was burnt (the wildfire really razed that place), but we could already see some plants beginning to grow.
We left out of the bus and started walking, and after a few meters we found a table made of stone, we looked down and we saw a hill and at its bottom there was a valley full of vegetation!!! It is called the Túrio's Valley.
We passed a local where we saw people that take care of the Mountain Dogs. One of the dogs was called Estrela, other was called Nata and another was called Neco.
We pass through a place where there were some old houses and we took photos of them.
In the mountain we found our flora: genisteaes, cedars, hollys, pine trees… but about the wildlife we didn´t found any animal because due to the lack of pasture and the fires, the animals were not visible.
The plant samples that we collected are going to be used in our laboratory.
After this long and awesome tour, we went back to school.

Figure 5. Students' written document about the visit to the mountain.

Investigate the world

The second category of analysis concerns students' ability to investigate the world. This dimension is related to the inquiry-based approach and requires students to develop several competencies related to the scientific process, such as formulate hypotheses, plan investigations, observe, register experimental data and elaborate conclusions. The STEM curricular projects, where students accomplished various activities, allowed them to develop such skills, as illustrated in the following examples.

Regarding the hypotheses' formulation, students from the Alentejo's region elaborated the following hypothesis (Figure 6) to give an answer to the initial problem: why are houses in this region predominantly white?



A maioria das casas são pintadas de branco porque no Alentejo quando está calor, o branco deixa a casa fresca.

Most of the houses are white because in Alentejo, when is too hot, the white color assures that the house stays fresh.

Figure 6. Students' written document about explanatory hypothesis.

Although the inappropriate use of scientific terminology (i.e. misunderstanding between heat and temperature), the explanatory hypothesis formulated by the students is scientific exploitable. The teacher has a main role in students' progression concerning the acquisition of scientific rather than the common sense language. Following the activity, in an inquiry-based approach, students outlined a plan that allowed them to test the initial hypothesis (Figure 7):

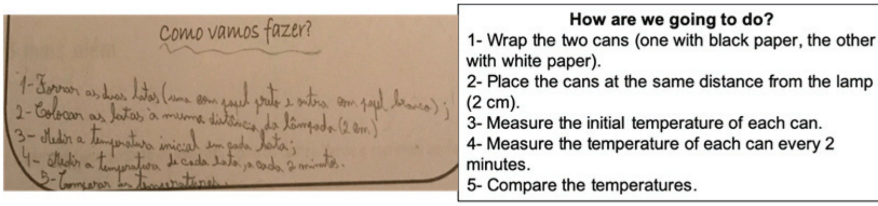


Figure 7. Students' written document about planning an experience.

From the previous example, it is possible to corroborate that students were able to describe how they should proceed and it is evident that they realize that is necessary to control variables. Moreover, another important fact is that students were encouraged to write down and organize their observations and measurements and to use them to substantiate their positions, explanations and argumentation (Figure 8):

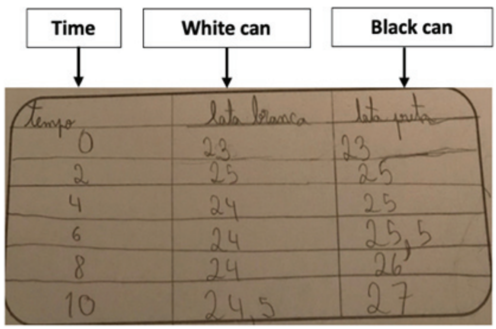


Figure 8. Students' written document about register data.

Students choose to register the data in the form of a table. However, they did not indicate the variable temperature (although they have identified the can) nor the units. As referred, this recording allowed students to formulate their conclusions, as shown in next extract (Figure 9).

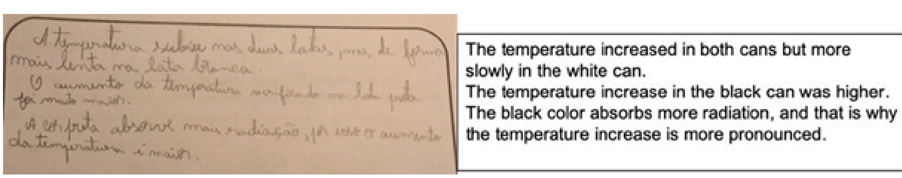
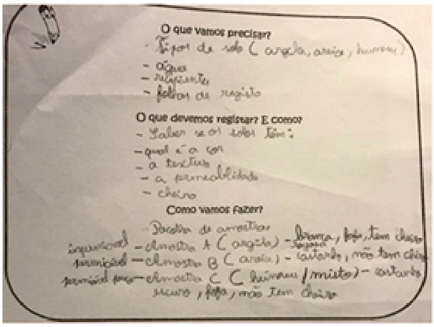


Figure 9. Students' written document about formulate conclusions.

In the school cluster of the Estremadura region, where the STEM curricular project was developed around the wine cycle theme, students had to, among other tasks, plan an experimental activity about different soils for vine planting to answer the problem that they identified: what is the importance of the soil in the vine growth? (Figure 10).


O que vamos precisar?
- Tipos de solo (argila, areia, humus)
- água
- recipiente
- folhas de registo
O que devemos registar? E como?
- Saber se os solos têm:
- qual é a cor
- a textura
- a permeabilidade
- cheiro
Como vamos fazer?
- Recolha de amostras
impermeável - Amostra A (argila) - branca, fofa, tem cheiro
permeável - Amostra B (areia) - castanho, não tem cheiro
permeável - Amostra C (húmus/misto) - castanho escuro, fofo, não tem cheiro

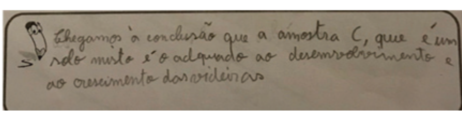
What are we going to need?
- Different soils (clay, sand, humus)
- Water
- Container
- Registration sheets

What should we register? And how?
To see what is the:
- Color
- Texture
- Permeability
- Smell

How are we going to do?
Sample Collection
Impermeable- Sample A (clay)- white, soft, with smell
Permeable- Sample B (sand)- Brown, rough, smelless
Less Permeable- Sample C (humus/mixed)- Dark brown, soft, smelless

Figure 10. Students' written document about planning an experience.

This plan, along with the execution of the experimental activity, enabled the students to analyse what is the most appropriate soil for vine growth and they reached to the following conclusion (Figure 11):


Chegamos à conclusão que a amostra C, que é um solo misto é o adequado ao desenvolvimento e ao crescimento das videiras

We have came to the conclusion that the sample C, mixed soil, is the most appropriate to the vines development and growth.

Figure 11. Students' written document about formulate conclusions.

The experimental activity led students to conclude that the mixed soil is the most appropriated to the development and growth of the vines in their region and is one of the factors that students must identify, according to their curricular matrix, as determinant for plant growth. In addition to the study of the soils, students also investigated the process of chemical transformation in wine production. Once again, students made the plan of the experience that would allow them to answer the question: besides the grapes' crush, does any transformation occurs during the wine production? In their plan, and after the visit to the Winery Cooperative of the region where they were taught about the wine production process, students identified the most important steps, namely the addition of yeast to the grape juice and the observations that they needed to do. Therefore, the students evaluated some properties of the wine over a five days' period and a table was drawn, where the variables were identified, namely the colour, the smell and the presence of gas in the flask (Figure 12).

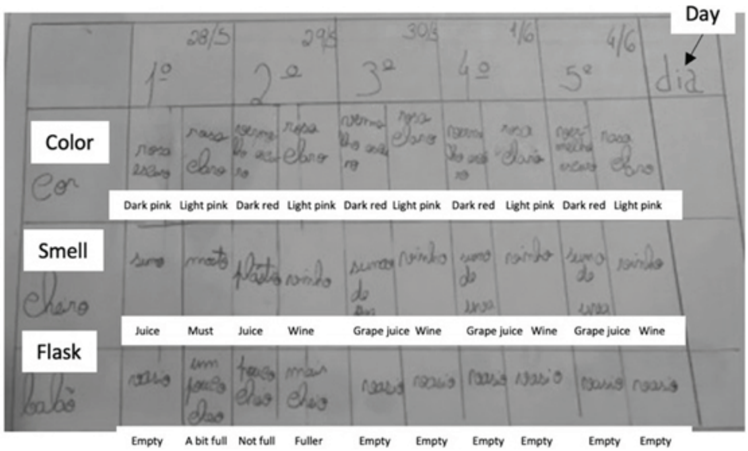


Figure 12. Students' written document about register data.

In the school cluster of the central region of the country, one activity of the STEM curricular project was related with the sound. Since this region won the prize of "least noisy region", the 8th grade students studied the noise level by means of a field trip that aimed the evaluation of noise pollution in their region. To do so, students planned and performed an experiment where they proposed to measure the noise levels in several locations that they selected as the ones that could be noisier. Since the students had previous knowledge about how to measure the noise level and about the noise effect on human health, they were able to identify not only the place with highest noise level, but also to conclude that the continued exposure to that noise levels could have an impact on human health (Figure 13).

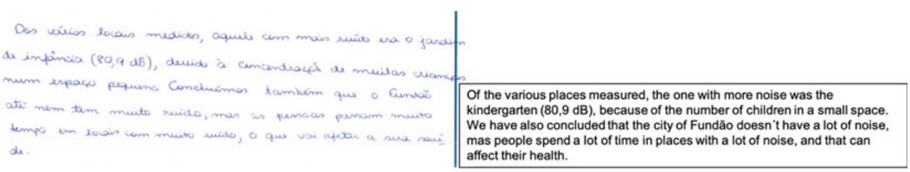


Figure 13. Students' written document about formulate conclusions.

Recognize perspectives

Another essential aspect for the successful of the STEM curricular projects was the recognition of the importance of cooperative work that allows students to express their own perspectives, analyse, appreciate and respect the perspectives of others, negotiate perspectives and reach a consensus. In their written productions (Figure 14), students revealed that they enjoyed learning when working collaboratively and enjoyed the interaction with other colleagues through the sharing of ideas.

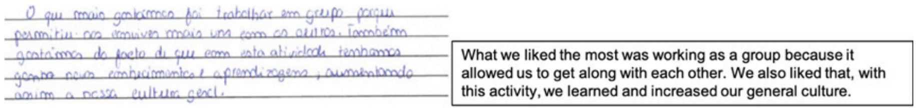


Figure 14. Students' written document about work in group.

In the interviews, the cooperative work and the developed activities are mentioned by the students:

> (…) not only because of the visit, but also, and mainly, because of the argumentation, because we were working. Each class had several groups and we were working between classes. Our group in particular was working in the miners' activity and we had a WhatsApp group where we talked about the work in order to organize the discussion and it was an interesting dynamic because it allowed us to know and talk with colleagues from other classes.
>
> We discussed in group and we had to work together, which help us learning (…) I had difficulties in planning the sound activity and with the group discussion we developed it together, following the several ideas (…) we made it together and we learned with one another.

In the first interview transcription, the student shows evidences that had appreciated and valued the cooperative work, underlining the use of technologies to discuss the theme they were working on. Moreover, the student also emphasized, as a positive aspect, the opportunity they had to work with colleagues from other classes. The second transcription illustrates that this student, through cooperative work, learned how to plan an activity about the sound, by considering the ideas from other colleagues to reach a final procedure.

Design

Another emphasized dimension that was present in the STEM curricular projects, was the design process that allowed students to apply and demonstrate what they have learned, as well as, to acquire new knowledge Therefore, students were engaged in engineering design processes, in which they could reinforce their knowledge about science, technology and mathematics.

The design component was introduced at the end of the activities proposed to the students, i.e., after performed the activities students were asked to apply their knowledge in a design artefact. Moreover, these design artefacts were used by the students to alert the local populations for local problems, allowing them to see the relevance of engineering in their live. The students exhibited the design products in a final exhibition that took place at the headquarters of the municipalities and had the participation of local authorities, local corporations and other members of the educational community.

For example, in the northern region school cluster, the students built a real-sized horse (Garrano, from the Iberian horse family) from solid waste residues (Figure 15), aiming to alert the local community to the development of attitudes that conduct to the valorisation and preservation of the natural heritage, namely the conservation of the species from the Cabreira's mountain.

Figure 15. Real-sized worse built by students from the northern region.

With this design artefacts students showed that, by doing the activity, they learned about the Garranos' horses. For instance, students used the internet to investigate some characteristics of these horses, namely their size, their look, what they eat, etc., and used that information to design the horse model. Also, students had to investigate, calculate and measure the horse size and proportions (of the head, the body, the legs, etc.) and finally they had to think of a way to make the horse structure stable.

In the school cluster from the central region, students made Oyas pots (Figure 16) to sensitize the community to reduce water consumption in irrigation systems and to promote local pottery activity. To do so, students had to investigate about this kind of pots and to apply what they learned about plant water needs, sustainable water consumption and clay permeability properties. They also developed their creativity and critical thinking, as is students by the students in the interviews: "we had to think about how we were going to make Oyas to be more efficient in reducing water consumption (…) we used the paints to paint and we could be imaginative".

Figure 16. Oyas pots made by the students from the central region school cluster.

In the southern region, one of the students' design product was a boat made with collected plastic bottles (Figure 17) as a way to alert the local society to the pollution associated to plastic residues that affects the oceans and to promote attitudes that lead to the reduction of plastic use.

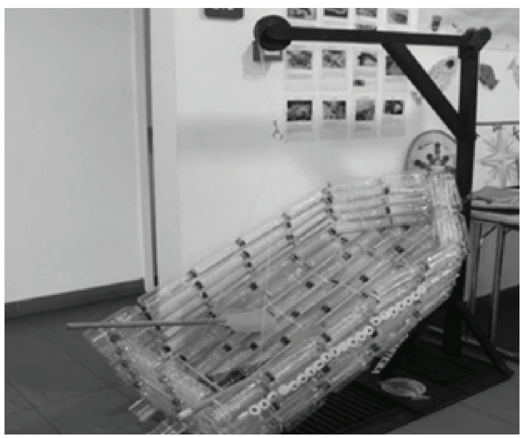


Figure 17. Boat built by the students from the southern region school cluster.

The boat was planned and constructed taking into account the knowledge of students about floatability and was projected to be functional, i.e., to be able to transport one student inside it, which required students to decide how many bottles they would need and how they should be placed together.

CONCLUSIONS

Given the diversity of school clusters and local contexts, the STEM curricular projects, although based on the same curricular matrix assumed distinct contours. Nevertheless, all curricular projects allowed students to experience activities that contributed to the development of their learning and competencies. Their involvement in the project gave them the chance to develop a set of substantive knowledge skills (mobilization of specific scientific knowledge related to the implemented activities), a set of transversal competencies related with investigate the world and cooperative work, as well as, to apply and develop their knowledge during the design process.

Actually, the results showed that each curricular project fulfil the goal of students' learning and mobilization of scientific knowledge. Foremost, the focus on inquiry-based learning allowed the students to investigate the world while developing scientific competencies, such as questioning, formulating hypotheses, planning and executing experiences, communicating conclusions, etc. The results also showed that the cooperative work was described by the students as a way of learning together, to discuss ideas and recognize different perspectives. As described in the literature, perspectives' conflict can be fundamental for cognitive development (e.g. Doise, Mugny & Perret-Clermant, 1975) and to promote a more complex understanding of questions for which there is not a single answer. Finally, the engineering design projects, allowed the students to fill the gap between scientific knowledge, abstract knowledge and application (Thibaut et al., 2018) because it allowed them to apply the scientific concepts that they have learned, as well as to develop their learning about scientific concepts and other competencies (such as, creativity and critical thinking) during the process of design artefacts (Ting, 2016).

Based on the described results, this work suggests that STEM curricular projects have a positive impact in students' learning and should be implemented in classrooms, since an early age, in order to allow students to acknowledge the importance of science and science processes, as well as develop several transversal competences and apply their knowledge in a design product.

AUTHORS' CONTRIBUTIONS STATEMENTS

M.B. coordinated the project, conceived of the presented idea, collected and analysed the data. I. M conceived of the presented idea and analysed the data. M.B and I. M. discussed the results and contributed to the final version of the manuscript.

DECLARATION

The data used and analysed during the current study are available from the corresponding author, M.B., on reasonable request.

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