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Promoting STEAMH at primary school: a collaborative interdisciplinary project

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Abstract

There is a growing call on the integration of Science, Technology, Engineering and Mathematics (STEM) at the primary school level, aiming to motivate students to learn these subject matters, in order to correspond to the scientific and technological challenges of an increasingly demanding society. Recently, many studies sustain the importance of extending STEM to STEAM by adding Arts to the previous areas, to better prepare students for real life. In this article, we present a way to promote STEAMH, by integrating Heritage with STEAM. With a qualitative approach and an action research methodology, we intend to investigate how to develop a pedagogical intervention project that fosters STEAMH learning at primary school and local community. It is concluded that it is possible to implement a STEAMH pedagogical intervention project, being necessary to develop a collaborative partnership with local community and local schools.

Keywords: STEAMH, hands-on, interdisciplinarity, primary school, collaboration

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1. Introduction

There is a growing call on STEM (Science, Technology, Engineering and Mathematics) integration, at the primary school level, aiming to motivate students to learn these subject matters, in order to correspond to the scientific and technological challenges of an increasingly demanding society (Rocard et al., 2007).

Becker and Park (2011) refer lack of research about STEM integration and present a study about the benefits of this approach on student's learning, concluding that integrative approaches among STEM subjects have positive effects on student's achievement, with larger effects at the elementary school level. In this study they argue the need for more empirical research on the effects of STEM education.

To better prepare students for real life challenges there is a growing call to promote interdisciplinary, namely introducing STEAM by adding Arts to STEM (Fitzallen, 2015; Kim & Bolger, 2017). Heritage is a very important part of our real-world, namely UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage, such as the Taj Mahal (India), Pergamo (Turkey) and Belem Tower (Portugal), just to name a few.

If it is argued the importance of preparing students for real life challenges, Heritage is a very important feature of the real world since its beginning. That is the reason we argue the importance of promoting STEAMH, by integrating Heritage with STEAM. The literature is full of research diagnosing problems about implementing STEM with efficacy, especially at the primary school level. Even more difficult is to integrate Arts with STEM, because it is not easy to have enough knowledge to work all these subjects together (English, 2017; Kim & Bolger, 2017). Recommendations to overcome these difficulties have to do with teachers' Continuous Professional Development (CPD), being crucial to support them, by developing hands-on experiments, being necessary to accompany them in class, to promote Content and Pedagogical Knowledge (Shulman, 1986), that may conduct to the innovation and sustainability of their practices (Zehetmeier & Krainer, 2011).

Problems on STEAM implementation and findings about lack of research on empirical studies about these subjects predict it is a big challenge to promote STEAMH teaching and learning. But it is not enough to talk about STEAMH. It is crucial to use methodologies that promote children's interest for STEAMH and potentiates meaningful learning. Johnston (2005) sustains that students should be encouraged to interact with the environment and to explore the scientific phenomena of their world, being the surrounding environment "accommodated" to the child and not the other way round.

The above points of view are the main reasons that led us to propose a pedagogical intervention project, at the elementary school level, that focuses on establishing a constructivist approach of STEAMH knowledge with adult supervision (higher school teachers and elementary teachers).

As far as we know, the acronym STEAMH does not exist till now and there are no studies joining Heritage to STEAM and how to work these subjects together in an interdisciplinary way. Our research aims to contribute to give some answers about how to implement STEAMH at primary schools. Findings may help researchers and educators interested in developing interdisciplinary projects on these subjects.

2. Context of the study: the STEAMH project

In Portugal, there are three main curricular units from 1st to 4th grades of primary school (ages from 5–9 year old): Portuguese, Mathematics and Study of the Environment. The first two units are considered crucial for students and are the subject of national assessments to gauge students' knowledge. The Study of the Environment unity has about 3 hours a week and integrates contents such as Astronomy, Physics, Chemistry, Natural Sciences, Geography, History, Heritage and Human Body, amongst others. Study of the Environment is at the intersection of all other units of the school syllabus and can be a driving force for learning in these areas (Ministry of Education, n.d.). In the general objectives of the same school syllabus it is emphasized that the students should "Recognize and value the historical heritage" (p. 104) and:

> Use some simple processes of knowledge of the surrounding reality (observe, describe, formulate questions and problems, advance possible answers, rehearse, verify), assuming an attitude of permanent research and experimentation (p. 103).

It is expected that teachers re-design the program, to adapt it to students' and to the school surrounding reality. Recommendations are to find student-centered strategies, where real-life problem solving is promoted.

But, in Portugal, as in many other countries around the world (Abd-El-Khalick, 2013), the reality of a classroom is still the traditional teaching, using text books and giving priority to other disciplines without promoting interdisciplinarity (Carvalho, Silva, Lima, Coquet & Clement, 2004; Rocard et al., 2007).

These reasons led us to design a pedagogical intervention project that focuses on establishing a constructivist approach of knowledge of the students, with higher school teachers' supervision, in a laboratory environment (Costa & Loureiro, 2016). This project (http://www.academiacap.ipt.pt/), called Academy of Science, Arts and Heritage (AcademySAH), was created on 2013 at the Instituto Politécnico de Tomar (IPT), in Portugal. The AcademySAH promotes the design of hands-on experiments and prototypes to enhance the participants' interest in STEAMH learning. This project started with activities during primary school children's holidays at the laboratories of IPT. Activities consist of several hands-on STEAMH workshops, with a duration of about 1.30 hour. Children stay at the IPT for about a week during their Christmas, Easter or Summer holidays.

Due to the success of this initiative, at 2014 the project's team started going to local primary schools to perform hands-on workshops. To fulfill this objective, topics already worked at the school holidays were selected according to school syllabus and collaboration of the in-service teacher responsible for the students.

With the growing solicitations of visits to primary schools, at 2015 was created a Continuous Professional Development (CPD) programme with a partnership of university teachers, training centers and local schools. This course is targeted to primary school teachers, in order to help them gain motivation, subject content knowledge and autonomy to implement hands-on interdisciplinary experiments. Our research is based on findings from school holidays, visits to primary schools and teachers CPD, according to the context described above.

3. Literature review

To ensure quality scientific practices in the future it is necessary to improve students' performance, producing positive attitudes towards science in an early age, by developing programs with hands-on and minds-on activities, in real-life scenarios (Mathers, Pakakis and Christie, 2011; Osborne, 2009; Roberson, 2015; Roberts, 2014).

Technologies in primary education can promote children's attention, socialization, language development and learning (Gimbert & Cristol, 2004). Technology leads to a positive impact on student's motivation and meaningful learning, provides learning oportunities and can integrate school subjects like mathematics (Costley, 2014).

STEM education can be a form of innovation for learning and teaching mathematics (Fitzallen, 2015). Relating mathematics with science and technology has been widely advocated by several authors (Berlin & Lee, 2005), but it is not an easy goal to achieve (Baxter, Ruzicka, Beghetto & Livelybrooks, 2014).

In recent years, appeals for extending STEM to STEAM, by integrating Arts to the previous areas, have been increasing. At some countries, such as Korea, STEAM education is a major educational policy since 2011 (Kim & Bolger, 2017). Although STEAM education holds considerable promise, it presents additional challenges for teachers and curriculum designers in ensuring that the respective disciplines are given adequate coverage and are meaningfully and effectively linked (English, 2017). Teacher confidence and willingness to implement a STEM or STEAM program in which two or more of the disciplines are integrated are essential, as well as curriculum resources to facilitate such implementation. Kim and Bolger (2017) sustain the creation of a curriculum that integrates STEAM, being crucial to involve teachers into interdisciplinary lessons adequate to this approach.

Teachers are the cornerstone of any renewal of student's education and being part of a network motivates them, contributes to improve the quality of teaching and promotes the sustainability of their professional development (Hewson, 2007; Rocard et al., 2007; Zehetmeier & Krainer, 2011). To improve teaching and learning, Geiger, Goos, Dole, Forgasz and Bennison (2014) suggest a partnership between researchers and designers that promotes appropriate pedagogical approaches in the integration of learning tasks at the classroom.

The team of researchers that integrate the STEAMH project already developed some preliminary studies. Costa and Domingos (2017) present a study about how to potentiate the teaching of mathematics through hands-on STEM experiments. They conclude that it is crucial to develop teachers' content knowledge through a collaborative teachers' CPD where they feel supported, motivated and secure to innovate their practices.

Ferreira, Neves, Costa and Teramo (2017) sustain a constructivist paradigm that integrates science and technology. In this study, they conclude that this approach promotes young people's interest in STEM and propose the implementation of this approach in a teachers' professional development context.

Pinto and Costa (2016) presented a study describing how the history of the book and the reproduction of decorative marbled paper was disseminated with children and their families. At this study they conclude that this approach has a positive impact on children's learning and promotes good relations among the participants.

In our research we did not find significant studies about the integration of Heritage with STEAM, which we believe it is important to better prepare students for real life challenges. This will be the main focus of our investigation in order to contribute to fill this lack in the literature.

With this research, we want to contribute to the development of more strategies that really promote the efficacy of integrating STEAMH at the primary school level, through an interdisciplinary collaborative pedagogical intervention project.

4. Methodology

Action research (Cohen, Lawrence & Keith, 2007; Stringer, 2007) combines diagnosis, action and reflection with the researcher and the participants to identify any issues and make new proposals to improve, and so on until achieving the desired results. With a qualitative approach we intend to investigate how to develop a pedagogical intervention project that fosters STEAMH learning at the primary school level. To implement the project, a collaborative work was carried out between higher education teachers, training centers and school leaders, to design and develop a training context that corresponds to the needs of students and teachers and is appropriate to promote STEAMH subject matters. With an action research methodology, we intend to adapt and improve several cycles of implementation of this project in order to make it sustainable. The 1st cycle at the 2013/2014 school year included children's school holidays: a total of 6 weeks distributed by Christmas, Easter an Summer holidays. In the 2nd cycle, at the 2014/2015 school year, it was included visits to primary school classrooms. The 3rd and 4th cycles included teachers' CPD and occurred at the 2015/2016 and

2016/2017 school years. Our research is based on the four cycles: 1st cycle started at September 2013 and last cycle ended at June 2017.

The participants are children who attended school holidays at the AcademySAH or at visits to their school and teachers who participated in the CPD course. More than 100 children participated at school holidays activities at the IPT and more than 600 had the team project teachers implementing hands-on experiments at their classroom. Also, about 90 teachers participated on the CPD course till now.

Data collection consisted in semi-structured interviews (including focus group), observations; written, audio and video records of activities performed by children and teachers (Cohen et al., 2007). Concerning the teachers' CPD there are also data from their written reports, which includes critical accounts on the impact of the training course in their practices, including the description of their own experimental activities in the classroom context. First author of this paper takes the role of observer and is also a facilitator, since it is responsible for the coordination of the project. She takes field notes and makes transcriptions of all the audio records. All the records and transcriptions are reviewed by the second author to triangulate and validate the collected data and supervise all the research.

5. Data analysis and discussion

In this section, we will analyse data from the STEAMH project, in the field since 2013. The context of this study includes school holidays with the children at the AcademySAH, visits from 1st to 4th grade primary school classrooms to perform hands-on experiments and teachers' CPD (on the field since 2015).

5.1. Design of interdisciplinary experiments at the AcademySAH

One of the main goals of the AcademySAH is to design hands-on prototypes and experiments that promote interdisciplinary among several subject matters, according to school syllabus. Implementation methods follow some known authors' recommendations. Harlen and Qualter (2014) advocate to use children's draws to analyze their previous conceptions and discuss them. Also, Jerome Bruner (1990) highlights a model in which the student discovers, step by step, facts, phenomena and relationships, under the guidance and questioning of a well-prepared adult such as a teacher. Ausubel (2012) argues that the main function of pedagogy is to know how to present ideas in a meaningful way and it is up to the teacher to adapt the teaching to facilitate the interaction with the previous knowledge of the student, to facilitate his learning.

Next, we present some examples of how experiments are designed and implemented, by the coordinator and the team of collaborators of the AcademySAH.

5.1.1. Working the clay and simulating volcanic eruptions

The following example refers to an interdisciplinary activity developed by teachers from the Archeology, Conservation and Restoration and Heritage Department and Chemistry teachers. After several meetings, it was decided to build clay volcanoes, in order to perform the simulation of volcanic eruptions at the Chemistry lab. Here is an excerpt of how the activity was conducted at the Conservation, Restoration and Heritage laboratory:

Coordinator: What is a volcano?

Children 1: It is something that explodes and expels lava.

Coordinator: How does it look like?

Children 2: Like a mountain. Sometimes they are very big!

Coordinator: Do you want to build a clay volcano?

All the children: Yes!!!

Coordinator: Start by drawing what you think is a volcano.

For about 10 minutes, all children draw what they thought it was a volcano. At this workshop the focus was on the creativity and on what volcanoes look like. After this task, they were encouraged to show the draws to their peers. This was a very interesting moment: the sharing and discussion of their creativity and perceptions. Some laughed and others were surprised about authentic works of art of some participants. After choosing the draw that they thought better represented a volcano, children were invited to finally start working the clay.

This part of the workshop was conducted by the teacher responsible for the Conservation and Restoration laboratory. He started by explaining what clay is, its properties, where it comes from and how to work it. After this brief explanation, he gives a piece of clay to each one of the children and at the same time he builds his own volcano to exemplify how to work the clay. This task took about 30 minutes. Everyone wanted to make the most “perfect” volcano. When this task ended, they wanted right way to take their “masterpiece” home, but it was explained that the clay volcanoes needed to go to the oven to get hardened. On another day they decorated the volcanos with the glaze technic and had to wait for another day, because it needed again to bake in the oven to become more robust.

Finally, the volcanos were ready to be used to simulate the volcanic eruptions at the chemistry lab. At this lab, the chemistry teacher started the activities by questioning the participants if they knew what is a volcano. Now the focus is on the volcano characteristics and properties. An important question is: why does it expels lava? What is lava? After this inquiry, children performed the volcanic eruptions with very excitement. In the end more inquiry was applied to gauge what they have learned. Surprisingly or not, every answers were correct.

5.1.2. Technology to promote STEAMH

Technology is always being used in our lives and is crucial for our project. Internet resources and several software are very frequently used to promote STEAMH learning and teaching. Also, QR Codes and gamification are very popular between the youngest who use tablets or mobile phones.

The AcademySAH welcomes projects of undergraduate higher school students under the supervision of the team’s project higher school teachers. In the scope of these projects, several games were designed to be performed with mobile devices. Examples are “Sonicpaper” (Ferreira, Neves, Costa & Teramo, 2017), “SolarSystemGO” (Patricio & Costa, 2016) and “Heritage hunting”. These games have in common the challenge and competition to promote learning of interdisciplinary subjects, highlighting school syllabus topics such as the sound, astronomy and heritage. Unfortunately, there is no space to discuss all topics in this paper, so we will choose “Heritage hunting” to show an example of implementation of this kind of game by integrating Heritage with STEAM.

5.1.3. Promoting interdisciplinarity with Heritage

Heritage is part of past generations, our lives and of the AcademySAH since its beginning. Examples of topics, already worked with the children, are “Hispano-Moorish Art” (build a mosaic panel as it was made in the 12th to 14th centuries, during the Islamic occupation of the Iberian Peninsula), “Heritage Detectives” (based on a series of tile fragments, collected from the demolition of an 18th-century palace, built a contemporary panel using conservation and restoration techniques), “Little Archaeologists”, amongst others (Costa & Loureiro, 2016).

At school, heritage is mainly taught by showing images from books or making visits to heritage monuments. Also, students are asked to make research works about one or another local heritage monument.

Nowadays, children use technologies such as mobile phones or tablets to socialize, play games and search for information, amongst others. Being unquestionable children and adults' interest for mobile devices, the AcademySAH promoted an activity titled “Heritage hunting” in the context of the final project of an undergraduate higher school student from the course of “Tourist and Cultural Management”, under the supervision of the head of the AcademySAH and a teacher from the Social Sciences Department of IPT. This activity was performed at Summer 2017 children’s school holidays at the AcademySAH.

The Tourism student made a research about local heritage monuments and organized the “Heritage hunting game”, by developing a questionnaire with questions about the monuments. Also, she compiled information about the selected monuments and created QR codes with that information. Clues to find the monuments were also given in the form of QR codes. The panels with the information and the clues were distributed by the IPT campus in a total of eight stations. To play the “Tomar heritage hunt” children were organized in groups with a tablet or mobile phone per group. First, they installed on their tablets/smartphones the QR code reading application. After a brief explanation they started the game with the questionnaire and the first clue to find the first monument. At each key point with a heritage monument they read the QR codes and discuss the information with the other members of the group, in order to correctly answer the questions. After answering the question they read the second QR code with the clue to the next key point.

For the whole afternoon, children were very engaged on the game following the rules and looking for information to answer questions related to the monuments that they found at each station/key point.

At the end, they returned to the classroom to confirm if the answers were correct. The team with all the right answer and with the best time wined the game, receiving a little gift for their effort.

This experience, as previous one concerning the sound and astronomy, leads us to conclude that this kind of activities engages children to learn these subject matters, in a ludic way.

5.2. Teachers’ professional development

In Portugal, as in many other countries, CPD is mandatory for in-service teachers (OECD, 2014). In our country, teachers need to have about 25 hours of training every year, but they can choose between the several CPD courses available. Our CPD course consists of several workshops, with a duration of 2–4 hours with topics such as astronomy, electricity, sound, technology, mathematics, water and air, arts and heritage. Workshops are conducted with inquiry and it is provided an informal environment where the trainees feel confident to ask questions and collaborate, in order to improve the laboratorial experimental activities and teaching pedagogy. The CPD context is in line with Kuzle and Biehler (2015) who sustain that it is crucial to promote cooperation among the participants and the professional developer. Teachers are asked to implement hands-on experiments with their students and to promote their autonomy by proposing their own STEAMH tasks.

5.2.1. Teachers' perceptions about the training context

In this section we will present some teachers' perceptions and reflections about the training context. All names are fictitious. Most of the teachers found this CPD programme very useful and adequate. The support of the trainers was very highlighted such as the hands-on activities performed at the workshops. Also visits to the teachers’ classroom to perform experiments were very appreciated. Next, we present some teachers’ reflections.

> This course allowed not the repetition of ideas and made formulas, being them of content order, methodologies or materials, but rather a development of consistent knowledge, built from the reflection on the materials and the tasks presented by the trainers (Aurea’s final report, June 2017).

> Undoubtedly, this action allowed other types of experiments to be carried out, in addition to those in the manuals, enabling students to be active agents in the learning process (...) encouraged the application of new methodologies in the classroom and allowed the sharing of activities among all the trainees. The application of new ideas to address specific contents experimental sciences and mathematics has provided interdisciplinary practice in different areas (Mathematics, Portuguese, Plastic Arts, Study of the Environment) (Maria's final report, June 2017).
>
> I emphasize that the training action has contributed to the acquisition of new knowledge that will allow me to improve the professional performance and to have a positive impact in the classroom, providing to the students diversified experiences of learning and the development of scientific competences (Micaela's final report, June 2017).
>
> I believe that this training will bring to my learner practice a wider range of possibilities for new activities, to be carried out in the context of the classroom. The most interesting thing is that these new approaches, which we had in training, are mostly practical approaches, which is very good (Anacleto's final report, June 2017).
>
> One of the highest points, I think it really is the visit of trainers/teachers, because it is a unique moment in the classroom. Students will be able to learn/experiment with the help of accredited technicians equipped with all the necessary materials (Anacleto's final report, June 2017).

These perceptions of the teachers reflect the CPD context and show that it was a very positive experience, with impact on their practices and their students. Most of the teachers gained motivation and skills to innovate their practices, designing and implementing hands-on interdisciplinary tasks.

5.2.2. STEAMH tasks created and implemented by the teachers

We will start by making a summary of some tasks proposed by the teachers (all names are ficticious) and how they worked at the classroom. An example is Teacher Manuela (50 year old, titular of a 3rd grade class with 20 students) who choose to work the astronomy by making the model of the solar system. She started by asking children to draw about what they thought it was the solar system. Based on the perceptions of the children she conducted an inquiry and showed a little movie explaining this subject. Finally, in another class she conducted the modeling by giving children tables with the planets and sun diameters. The sun (0.5 meters of diameter) was drawn with a compass on a yellow card and then cut with scissors. The bigger planets were drawn on a paper and painted with a color pencil. The smaller planets with plasticine. The planets were placed according to their distance to the sun. In the end, the teacher performed an inquiry with her students to find out what they learned about this topic. This is an excellent example of an interdisciplinarity activity proposed by a primary school teacher.

Another example is teacher Anacleto (45 year old, no class attributed) and Micaela, who implemented the sound topic on the 2nd grade class of teacher Micaela (48 year old, class with 20 students). They started by introducing the topic with inquiry: "What is the sound?", "Where does it comes from?", "How is it produced?" and "What is the sound for?". After a discussion with the students about their opinions, they searched for information in the Internet. Among other activities they measured the sound frequency and intensity, using free software such as the "Sound Meter". With these measurements, they worked mathematics by constructing tables and exercises related to the organization and processing of data.

In her final report, teacher Micaela highlights that: "these practices allowed to verify that it is possible to make a transversal approach of contents, relating the mathematics, the study of the environment, the musical and dramatic expression" and "revealed that students are more motivated and engaged in this kind of task". Teacher Anacleto sustains: "students become more interested and engaged on the tasks, collaborating in a more active and committed way, which is then evident in learning".

These examples reflect many other teachers who innovated their practices in an interdisciplinary way. Some of these teachers presented their work to their peers and this was a very high moment of this CPD context.

6. Final considerations

With a qualitative approach and an action research methodology, we investigated how to develop a pedagogical intervention project that fosters STEAMH learning at primary schools and local community. With our research we propose four stages of implementation of the project:

1st stage: the project coordinator and the team of higher school teachers design STEAMH hands-on experiments adequate to primary school syllabus.

2nd stage: test the experiment with children during their school holidays at the IPT laboratories. From observations, video and audio record inquiries, the experiments are analyzed and, if necessary, improved to better adequate to children's needs and school syllabus.

3rd stage: when the tasks are approved, we take them to a primary school to be implemented with students at the classroom (with the agreement of the veteran teacher and the school leader).

4th stage: when previous stages succeed, finally the tasks are worked with primary teachers in the context of their Continuous Professional Development. The final goal is that teachers can do more than they can reproduce the proposed tasks; it is expected that they develop and create new tasks adapting the learned subject and content knowledge to their students.

This is the model we already used to work topics such as astronomy, sound, electricity, water and air, arts and heritage. When topics are worked with the teachers we already know they promote the attention of the children, they are adequate to school syllabus and can engage children to learn STEAMH subject maters. Till date, when supported by the trainers, teacher's gain motivation and appreciate the CPD context. Also, most of the participants are able to innovate by designing and implementing their own tasks, which gives us confidence to keep developing this project by designing new tasks in order to maintain innovation and meet the society challenges.

In our study all the teachers who innovate their practices highlighted the importance of realizing this kind of work with the students, sustaining that it potentiates meaningful learning, increases their interest in STEM and promotes collaborative work amongst the students. Also, they referred the clairvoyance and the support that trainers gave during the CPD programme. Specially, visits to their classroom were referred to as unprecedented and a very good surprise because it really helped them to motivate students for these subject matters.

Nowadays there exist a trust relationship amongst teachers, trainers, school leaders and formation center leaders, which constitutes a network that contributes to the efficacy of the pedagogical intervention project, as recommended by several authors (Rocard et al., 2007). Also, participation on conferences to disseminate the project is important to increase this network to involve more participants contributing to the project' sustainability.

7. Conclusion

It takes time to implement a pedagogical intervention project (Murphy, Smith, Varley & Razı, 2015). Even more difficult is to promote an interdisciplinary project involving different subject matters such as is the case of STEAMH (Baxter et al., 2014; English, 2017; Kim & Bolger, 2017). To promote the efficacy of this implementation, the literature is full of studies sustaining that it is crucial to promote teachers' professional development (Hewson, 2007). Also, research refers the importance of supporting teachers during this process, in order to have impact on their classroom practices. In fact, innovations should be appropriated by teachers and transformed into their own practice, in order to have real effects, developing their skills to teach and updating their content knowledge of subject matter and pedagogical knowledge (Zehetmeier, Andreitz, Erlacher & Rauch, 2015).

Our experience in the field shows that the proposed approach is very efficient to catch children's attention and promote learning of interdisciplinary subject matters such as heritage, history, technology and science, amongst others. Also, the teachers CPD context has impact on their practices promoting their motivation and autonomy to design and implement hands-on STEAMH tasks. With our research, we propose to keep supporting teachers in order to help them innovate their practices by designing and implementing STEAMH tasks and promote their CPD.

It is concluded that it is possible to implement a STEAMH pedagogical intervention project, being necessary to develop a collaborative partnership with local community and local schools.

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