Implementing STEM Projects Through the EDP to Learn Mathematics: The Importance of Teachers' Specialization

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1 Introduction

In the last two decades, the European Union (EU) has increasingly encouraged the training of competent citizens for meeting the demands of a progressively technological society (European Union Council, 2018). The idea of developing students' competences and stimulating them to study and work in STEM-related fields to form a solid society has also been supported by national governments (Niss et al., 2017). An effort to diversify STEM-related careers has also proliferated recently after detecting an under-representation in certain sectors of the population, such as women (Eurostat, 2018). It is, however, questionable whether these objectives are being accomplished. International reports, like the Programme for the International Student Assessment (PISA; OECD, 2019), point out that many 15-year-old students across countries do not achieve the minimum required level of mathematics and science competency. Although in the EU there is a growing number of STEM graduates (Eurostat, 2018), this rate is smaller than the one raised in countries like the USA, Russia, and Canada (Watson & Munkoe, 2019). Similarly, the number of graduated females in STEM-related fields still remains under-represented in the EU (Eurostat, 2018).

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As a consequence of the above priorities, researchers have approached the integration of content by combining different disciplines. Technology has been incorporated into the learning of mathematics through innovative technological devices and software (Cullen et al., 2020). The creation of tools like GeoGebra has certainly helped to acquire mathematical knowledge that was difficult to gain through the traditional approach (Prodromou, 2014). Similarly, researchers have promoted the connection between science and mathematics (Maass et al., 2019a; Potari et al., 2016; Triantafillou et al., 2021) by a number of European initiatives (e.g., Mascil, PRIMAS, and Fibonacci). The incorporation of engineering into the science, technology, and mathematics disciplines has also been considered, completing the acronym STEM (Diego-Mantecón et al., 2019; English, 2016, 2020).

STEM education usually employs engineering as a context to integrate the three remaining disciplines (Moore et al., 2014; Thibaut et al., 2018b). This has often led teachers to adopt the engineering design process (EDP) for implementing STEM projects. The EDP is thus used as a way to teach mathematics in a contextualized manner (English & King, 2019; Fidai et al., 2020; Margot & Kettler, 2019). Some authors have questioned this approach for its difficulty to raise mathematics (Lasa et al., 2020; Ubuz, 2020). The present study aims to verify teachers' capacities to explore and promote mathematical content within this approach. The EDP requires teachers to integrate content in which they are not experts. In particular, we will analyse the mathematics school content addressed by technology and mathematics Spanish teachers (out-of-field and in-field, respectively) when implementing STEM projects.

2 Teaching Mathematics Through Technology

Technology is traditionally viewed as a tool for teaching mathematics. Most official curricula and textbooks incorporate technological devices and software to work out mathematics tasks. Researchers worldwide also recommend technology to support instruction (e.g., Blanco et al., 2019a; Borba et al., 2016, 2017; Fabian et al., 2018; Kovács et al., 2020; Lavicza et al., 2020; Prodromou & Lavicza, 2017). The use of technology in mathematics education has quickly evolved; not just calculators but also computer laboratories, mobile technologies, and Massive Open Online Courses (MOOCs) are nowadays available (Borba et al., 2016, 2017). There seem to be three main ways in which technology is employed in mathematics classrooms: (1) as a tool for delivering content; (2) as a supply for facilitating analyses, proofs, and conjectures; and (3) as a tutor for receiving feedback. Although, in general, these three ways of learning seem to contribute positively to mathematics learning, research arises contradictory conclusions.

(1) The use of technology for delivering content through tablets or laptops may not have a significant impact on learning mathematics. One-child-one-device does not necessarily ensure meaningful learning (Dubé et al., 2019; Hall et al., 2021), especially when the purpose of using devices is to simply replace the traditional resources.

(2) The employment of technology to encourage cognitive aspects of learning also generates contrary outcomes. Prodromou (2014) suggests that technology facilitates the visualization processes to learn concepts. Zulnaidi and Zamri (2017) found a positive relationship between using GeoGebra and understating conceptual and procedural knowledge. In contrast, Wijers et al. (2010) conclude that digital games do not always report positive impacts on mathematics knowledge. (3) Intelligent tutoring systems have also reported different findings (El-Khoury et al., 2005; Pai et al., 2021; Richard et al., 2011). While some authors found intelligent tutoring systems suitable to apply mathematical concepts and to develop problem-solving skills (Dašić et al., 2016), others did not identify significant differences in achievement between students utilizing a tutoring system and the ones following the traditional approach (Pai et al., 2021).

Some of the discrepancies identified above may be explained by issues associated just with the integration of technology in the classroom. Implementing technology implies overcoming key challenges related to pedagogical, technical, and organizational aspects (Borba et al., 2016). Still, many teachers have not even attempted to use technology because of factors concerning resistance to change and precedents of previous failed initiatives (Diego-Mantecón, 2020; Lavicza et al., 2020; Vinnervik, 2020). Moore et al. (2014) talk of the need of setting a context where technology naturally incorporates and applies mathematics. They, for instance, highlight the importance of using engineering design for employing technology and applying mathematics and/or science in meaningful learning.

3 STEM Projects and the Engineering Design Process for Learning Mathematics

In response to the European priorities, STEM education is becoming more important in the current educational systems (Diego-Mantecón et al., 2021; Maass et al., 2019b; Thibaut et al., 2018a, b, 2019). Authors have conceptualized STEM under slightly different approaches (English, 2016; Kelley & Knowles, 2016; Martín-Páez et al., 2019; Toma & García-Carmona, 2021). These approaches are characterized by various forms of boundary-crossing among the four STEM disciplines (English, 2016, 2020; Kelley & Knowles, 2016; Maass et al., 2019b; Martín-Páez et al., 2019), and even in relation to Art in the so-called STEAM education (Diego-Mantecón et al., 2021; Herro et al., 2019; Mohd-Hawari & Mohd-Noor, 2020; Quigley & Herro, 2016). English (2016) distinguishes three ways of integrating disciplines: multidisciplinary, interdisciplinary, and transdisciplinary. The first implies teaching concepts and skills separately in each discipline but within a common theme. The second entails teaching concepts and skills from two or more disciplines aiming to narrow knowledge down. The third relates to applying knowledge and skills from various disciplines to solve real-world problems shaping the learning experience.

To implement STEM education, several authors propose contexts or processes where usually one discipline is emphasized over the others (Martín-Páez et al., 2019; Thibaut et al., 2018a, b for a review). One of these processes takes engineering like a context and promotes technology and mathematics in similar ways; this is the so-called engineering design (Diego-Mantecón et al., 2019; English & King, 2019; English et al., 2017; Li et al., 2019). The engineering design process (EDP) often comprises the following steps: 'problem scoping', 'idea creation', 'designing and constructing', 'assessing design', and 'redesigning and reconstructing' (English et al., 2017). Problem scoping seeks understanding problem boundaries by clarifying the goal and identifying constraints. Idea creation implies developing a plan to approach the problem, which includes formulating questions, sharing ideas, and developing strategies. Designing and constructing encompasses sketching designs, interpreting them, predicting possible outcomes, and transforming them into models. Assessing design involves checking constraints, testing models, and verifying the accomplishment of objectives. Finally, the redesigning and reconstructing step entails reviewing initial designs and sketching new ones for refining the model.

Several researchers view the EDP as a way to apply mathematics and technology in a creative and innovative manner (Akgun, 2013; English & King, 2019; Fidai et al., 2020; Margot & Kettler, 2019; Quigley & Herro, 2016). Others suggest, however, that this process does not necessarily require a deep mathematics focus. Lasa et al. (2020) claim, for instance, that mathematical content in engineering-orientated activities is often basic and utilitarian, and involves mainly geometry and measurement. Concerning technology, some researchers consider it as a tool to create, activate, and test engineering artefacts (Akgun, 2013), while others point out that technology is often under-represented in STEM education (English, 2016).

4 Design and Implementation of STEM Activities in Secondary Education

The design and implementation of STEM experiences seem to be affected by teachers' specialization and thus their understanding of the discipline. In many educational systems, primary school teachers are responsible for instructing most subjects, while high school teachers are characterized by being subject-specific. In Spain, the latter holds a bachelor's degree and a subject-specific master in teacher training. Toma and García-Carmona (2021) suggest that this training is contrary to STEM education and thus to the integrated approach. An integrated approach requires a solid conceptual, procedural, and epistemological knowledge on various disciplines. Many authors criticize the lack of content and pedagogical knowledge of high school teachers to integrate disciplines (Domènech-Casal et al., 2019; Frykholm & Glasson, 2005; Toma & García-Carmona, 2021), and teachers have reported to feel unconfident when designing and implementing STEM activities (Frykholm & Glasson, 2005).

According to Davis et al. (2019) and Triantafillou et al. (2021), the epistemological ground that teachers adopt when implementing an activity significantly affect the way it is elaborated and the concepts that students learn from it. During the STEM activities instruction, mathematics and science teachers put different emphasis on the concepts and properties used to explain the same topic (Potari et al., 2016). Vale et al. (2020) reveal that Australian mathematics and science teachers do not have the same beliefs about these two disciplines, and the way these should be taught. Epistemological differences are even explicit in trainers when guiding teachers into the design of integrated activities (Triantafillou et al., 2021). In this sense, Davis et al. (2019) claim the need of instructing teachers on approaching STEM concepts from various epistemological orientations (or ways of knowing).

To facilitate STEM implementation, researchers suggest setting real contexts from which to naturally integrate content (Frykholm & Glasson, 2005; Potari et al., 2016; Triantafillou et al., 2021). Nevertheless, framing experiences in real contexts does not imply promoting high content integration (Domènech-Casal et al., 2019), and authors often advocate for using design-based processes (Burghardt & Hacker, 2004; English, 2019). Design processes, commonly used in the technology subject, are often applied by a trial-and-error approach that does not always foster conceptual understanding (Burghardt & Hacker, 2004). To increase discipline integration, teacher collaboration has also been promoted (El-Deghaidy et al., 2017; Nelson & Slavit, 2007; Potari et al., 2016; Triantafillou et al., 2021). Potari et al. (2016) reveal that the collaborative work between science and mathematics teachers allowed for a deep content integration and contextualization. Similarly, teachers' interactions help to better explore the relationships across subjects, often overlooked in fragmented approaches (Nelson & Slavit, 2007). Although teachers are aware of the importance of collaborating, several studies highlight the difficulty of establishing connection between peers (Al Salami et al., 2017; Potari et al., 2016; Thibaut et al., 2018b; Triantafillou et al., 2021). In this regard, Frykholm and Glasson (2005) state that willingness to share classroom experiences facilitates collaboration. Nelson and Svait (2007) and Triantafillou et al. (2021) highlight also the necessity of establishing a sense of community between teachers. Trainers should participate in this community to support teachers in the activity design (Triantafillou et al., 2021).

5 The Study

This study seeks to assess the design and implementation of STEM projects through the EDP to learn mathematics. We analyse how technology and mathematics teachers (out-of-field and in-field, respectively) address high-school mathematics content in STEM projects elaborated through the EDP. We thus formulate the following question: Does teachers' specialization affect the way in which STEM projects are executed through the EDP to learn mathematics? For tackling this question, we call on high school teachers willing to implement STEM projects with an engineering-oriented focus.

5.1 Sample

Five Spanish teachers were selected for this study from an initiative run by the Open STEAM Group (https://www.opensteamgroup.unican.es/). The five teachers were selected, from a total of 54, because they implemented STEM projects within the engineering design process, where mathematics and technology were somehow applied. Two of the teachers were specialized in mathematics, holding a pure mathematics bachelor's degree (in-field). The other three were qualified in technology with engineering bachelor's degrees; they thus taught mathematics without having such specialization (out-of-field). The five teachers executed a total of ten STEM projects.

The teachers had more than 15 years of experience instructing technology, computer, or mathematics subjects in state and state-subsidised Spanish high schools. The teachers did not have formal training nor background experience in STEM education. About 30 students were involved in the initiative, beginning at the age of 14–15. These students followed the regular Spanish curriculum including mathematics and technology subjects. The mathematics subject embraces numbers and algebra, functions, geometry, and statistics and probability. The technology subject comprises information and communication technologies, domestic installations, electronics, control and robotics, pneumatic and hydraulic, and technology and society.

5.2 Guidelines for Project Development

The in-field and out-of-field mathematics teachers implemented the STEM projects in their classrooms with groups of 4–5 students, through the EDP and using the KIKS format (Blanco et al., 2019b; Diego-Mantecón et al., 2021; Ortiz-Laso, 2020). The KIKS (Kids Inspire Kids for STEAM) format goes beyond project-based learning, actively involving students and teachers in dissemination actions worldwide. To deliver their outcomes, students produce a video and a text report in English. The videos aim to provide quick overviews about the project, the constructed artefacts, and their functioning. The report addresses in-depth information about the analytical processes. Projects are presented in different formats (online and face-to-face) and events (e.g., conferences and outreach activities) to a variety of audiences. In this study, students developed several projects for a period of at least two years. These projects were designed by their teachers or by experts of the Open STEAM Group.

5.3 Data Analysis

To analyse the mathematical content addressed in the elaborated projects, we assessed the text documents and videos produced by the students. The mathematical content was classified according to the following blocks: 'numbers', 'algebra', 'geometry', 'functions', 'statistics', and 'probability'. The three authors of this chapter independently classified the mathematical content, to be compared later. To gain precise information about how mathematics was used in the projects, teachers' semi-structured interviews and observations were also conducted. We identified whether the teachers promoted solutions by intuition instead of a planned approach (Lin & Williams, 2017), whether they endorsed inquiry processes through questioning strategies (Bruce-Davis et al., 2014), and challenged students to think deeply about concepts and ideas to foster skills like abstracting, analysing, applying, formulating, and interpreting (Herro et al., 2019). All the interviews were audio-recorded and transcribed. The raw data was entered into a text document and analysed by identifying key statements and associating patterns.

6 Results

As shown in Table 1, most of the projects included geometry and algebra content. Only two of them included statistics, probability, and/or numbers. A preliminary analysis suggested that technology teachers tended to use algebra, while mathematics teachers usually applied geometry content.

The technology teachers introduced algebra for designing circuits, covered in the electronic block of the technology curriculum (Boolean algebra). To design the pieces composing the artefacts, measurement and geometry content from the mathematics curriculum was applied. For example, students quantified lengths and angles, employing instruments such as rule, triangle, protractor, and compass. They also required basic geometry concepts as perpendicular and parallel lines and drew the nets of different 3D shapes such as prisms and cylinders.

Table 1 STEM project categorization

Project name	Maths curricular content emphasized	Subject of implementation
Star Wars Robot	Algebra, Geometry	Technology
Simon Says	Algebra, Geometry	Technology
Lights of Buildings	Algebra, Geometry	Maths
UV Light in Rudimentary Health Care Centres	Algebra, Geometry	Maths
Rubik's Cube	Geometry, Probability	Maths
Vehicle Avoiding Obstacles	Algebra, Geometry	Technology
Solar cars	Algebra, Geometry	Technology
Astrolabe	Geometry, Statistics, Numbers	Maths
Hothousing Gardens	Algebra, Geometry	Technology
Wireless Telegraph	Algebra	Technology

The mathematics teachers involved geometry in all the projects to a larger extent than the technology ones. This geometry content was also more formal than the one applied by the engineers, being often the vertebral column of the projects. That was the case, for example, of the Lights of Buildings and Astrolabe projects. In the former, trigonometric relations were employed to determine the angle and height where to locate the lights, while in the latter students were introduced to the stereographic projection. Mathematics teachers also promoted the interaction with 3D shapes, using software to draw them during the design and construction of the artefacts. In the Lights of Buildings and UV Light projects, students drew and built truncated pyramids. Regarding algebra, the mathematics teachers used similar contents to the technology teachers. Other content employed by the mathematics teachers were probability, statistics and numbers, used in the Rubik's Cube and Astrolabe projects.

A deep analysis of the projects showed that mathematics was exploited at least in three different ways: identification, reasoning, and modelling. For exemplifying each of these ways, we describe how mathematics was addressed in the Star Wars Robot, the Rubik's Cube, and the Astrolabe projects.

6.1 Identification: Star Wars Robot

The Star Wars Robot project, supervised by a technology teacher, aimed to construct the famous R2-D2. The project idea arose from the students after being challenged to create film characters. Initially, students thought about different characters including Bender (The Simpsons and Futurama) and Lighting McQueen (Cars). However, they discarded the aforementioned characters because of constraints like the difficulty of reproducing Bender's movements of legs and arms or modelling the Lighting McQueen's hood or bumper. Students considered that it would be easier to construct characters from objects found in daily life or by assembling 3D shapes obtained from a net. As a consequence, a group of students agreed to work on the design and construction of the R2-D2. The teacher suggested drawing an initial design of the robot and constructing it according to a certain scale. Nevertheless, the students proceeded freely, not following such suggestion; they searched for objects, in their surroundings, representing different parts of the robot for joining them together. They designed the widest part of the leg, decomposing it into a semicircle and a non-regular hexagon. To sketch and construct this piece the notions of diameter, parallel and perpendicular lines were applied. Once the piece was produced, they replicated it three times more; finally, these were cut, painted, and assembled (Fig. 1a, c).

In the next step, students programmed the robot using App Inventor with an Arduino board (Fig. 1b). When programming, the measures of length and angles were used to reproduce the movements of the prototype (Fig. 1c), involving geometrical concepts like rotation and translation. This project could have offered the possibility of applying other concepts related to proportionality. However, the students did not attempt an accurate reproduction of the original R2-D2, focusing mainly on assembling objects and programming the different functions.

a. Assembling Materials | b. Programming | c. Final Design

Fig. 1 Star Wars Robot

6.2 Reasoning: Rubik's Cube

The Rubik's Cube project, led by a mathematics teacher, was intended to construct a robot for solving a Rubik's cube of $3 \times 3 \times 3$ dimensions. The project idea emerged from the teacher who is fascinated by the variety of strategies that can be used to solve it.

To set the project, the teacher provided the LEGO MindStorm robotic Kit-tool and introduced geometrical concepts such as a polyhedron, cube, faces, edges, rotation, symmetry, vertex, and so on. The students explored the structure of the cube discovering that only the central pieces of the six faces maintain a fixed position with respect to each other, being able only to rotate around the axis perpendicular to the face. Counting the number of small cubes in the bigger one, as well as the number of faces, edges, and vertices, they applied probabilistic content concerning permutations to work out the number of possible positions of each small cube in the bigger cube. At this stage, they understood the importance of following an ordered sequence for the resolution process, and they continued investigating into the combinatorial world. They found out that in the original Rubik's cube there are $8!$ ways to combine the eight vertices. Seven of these vertices can be oriented independently, and the orientation of the eighth will depend on the previous seven, resulting in 3^7 possibilities. Then, the teacher promoted reasoning by helping understand that there are $\frac{12!}{2}$ ways to arrange the 12 pieces with two colours located in the middle of the physical edges, since a parity of the corners also implies a parity of the edges. The students also learnt that 11 edges can be turned independently, and the rotation of the 12^{th} edge will depend on the previous ones, giving 2^{11} possibilities. Finally, they were able to work out the total number of permutations, and to understand where the figures were coming from. Figure 2a exemplifies the students' reasoning.

At this point, the students became aware of the amount of mathematics needed and realized that different ways of solving the cube drive to different algorithms. They searched for traditional algorithms and related them to the steps undertaken when solving the cube by hand. Recalling their own experience in solving the cube by hand, they were employing their visual-spatial ability to search for an algorithm and thus transferring each particular piece of the cube to the desired position. Similarly, talking

a. Mathematical reasoning	b. Building process	c. Final Design

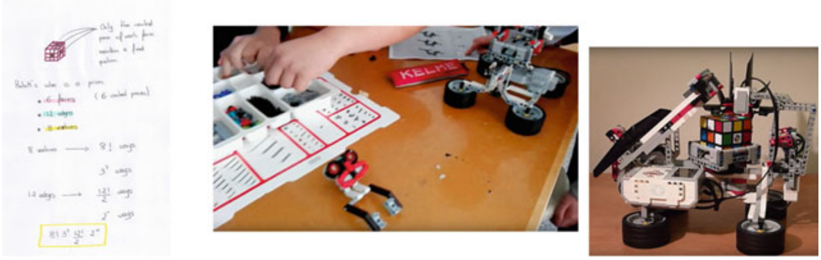

Fig. 2 Rubik's Cube project

about positions, rows, and columns, they realized the necessity of using matrices to store the colours.

6.3 Modelling: Astrolabe

The Astrolabe project, guided by a mathematics teacher, aimed to construct an astrolabe employing 3D printing. The project idea arose from the teacher, as he is an enthusiast of this instrument. In this project, the teacher initially explained the aspects and content of geometry and astronomy needed to understand the functioning of the instrument. Regarding geometry, he reminded the 3D projection of objects on the plane, emphasizing the stereographic projection as it is not feasible to represent the sphere on the plane. This required students to become familiar with elements such as parallels, meridians, great circles, angles, and spherical triangles. They also had to learn that properties of the plane are not extrapolated to the sphere; for example, the sum of the interior angles of a triangle is not fulfilled when working with spherical triangles.

In the design and construction phase (Fig. 3a), students applied the content acquired in the initial phase to design the astrolabe with software and using scales. At

a. Initial Design	b. Assessing design	c. Refined design

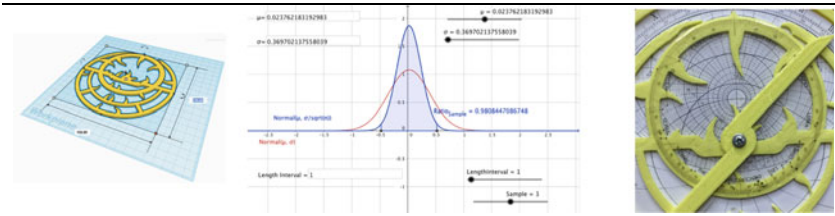

Fig. 3 Astrolabe project

that stage the main difficulty was the design of the astrolabe front piece (named rete). Then, they assembled all the 3D printed pieces. Once the artefact was constructed, the students took measures to calibrate it; they analysed a sample of 57 observations. The students observed that the distribution of errors followed a normal curve, not being accurate (Fig. 3b). During this process, they were managing statistical content such as mean, standard deviation, variance, and confidence interval. Consequently, they sketched a new design for refining the initial artefact (Fig. 3c).

7 Discussion

The project selection, the content, and the applied mathematics differed in relation to teachers' specialization. In the projects guided by out-of-field mathematics teachers, mathematics was hardly involved. Teachers and students verbalized mathematical terms related to the components of the artefacts (e.g., cylinder, sphere), but rarely they engaged in reasoning or conjecturing processes; at least it was not perceived by these researchers. Out-of-field teachers tended to overlook the mathematical content and to focus on specific aspects of their subject, not promoting content integration. Domènech-Casal et al. (2019), in an analysis of STEM projects, already noticed that, in general, high school teachers do not integrate content from different disciplines. According to our analyses, the teachers were usually embedded in their context facing difficulties to breakout from it and to integrate disciplines. This concurs with Potari et al. (2016) when reporting that teachers usually address concepts from the perspective of their specialization, struggling to exploit the same concepts from an out-of-field perspective.

During the project design and construction, our out-of-field mathematics teachers normally worked with their students under a trial-and-error strategy, restricting the application of mathematics. This outcome is in line with English (2019), as well as with Lin and Williams' (2017) observations, when suggesting that teachers with a lack of STEM training seek solutions by intuition rather than by considering mathematics and science principles. Our out-of-field mathematics teachers usually implemented projects where students simply have to identify and recall geometric components of the artefacts. We concur with Burghardt and Hacker (2004) that in design-based projects teachers are frequently focused on the product rather than on the learning process. Conjectures and data analysis were rarely attempted. They even avoided activities promoting inquiry processes, appropriate for facilitating the integration and application of content. Normally, the mathematics aroused was employed in the designing of circuits and programming, using for example Boolean algebra. This fits, to some extent, with Lasa et al. (2020) when reporting that engineering projects lack school mathematics content, mainly related to basic geometry.

Unlike the out-of-field mathematics teachers, the in-field ones took mathematical concepts and procedures as a starting point from which to elaborate the projects. They usually proposed their own ideas on topics where they felt confident. In-field teachers involved mathematics to a greater extent than technology ones. In contrast to technology teachers, the in-field ones attempted to elaborate the projects under an iterative process of design, analysis, and redesign. In-field teachers tended to make an effort for matching project content with high school mathematics curriculum. In addition to the basic and utilitarian content promoted by out-of-field teachers (e.g., the identification of mathematical terms or measures), the in-field ones incorporated concepts, properties, and ideas. In some projects, data collection, analysis, and modelling were also promoted. The projects were mainly used to reinforce and apply previous knowledge, as also reported in the study of Margot and Kettler (2019). The in-field teachers tended also to engage their students on reasoning, and conjecturing processes. For example, in the Rubik's cube project the teacher was questioning the number of possibilities for arranging the pieces of the cube, encouraging mathematical thinking. In the astrolabe, the students proved the sum of the interior angles of a triangle is 180° in a Euclidean space and observed that such property is not fulfilled in a spherical triangle. The teacher drove their students also in the process of verifying the astrolabe consistency by taking and analysing measures.

8 Conclusions and Implications for Further Research

This study examined the extent to what school mathematics is addressed in STEM projects following the EDP, and consequently the suitability of the integrated approach in the school contexts. The analyses showed that teachers' specialization is a key point in the implementation of the projects, and it determines how mathematics would be promoted and reflected in the instruction process. In the majority of the projects, mathematics was poorly promoted. Only in some of them, mathematics content and reasoning were stimulated, and in rather few projects teachers encouraged high cognitive processes by means of questioning, conjecturing, analysing, and verifying.

Out-of-field mathematics teachers selected projects designed by experts, requiring a dose of effort to personalize them, and becoming familiar with the materials. They put the focus on the assembly and construction of the artefacts, as well as in their functioning, avoiding to explore mathematics in-depth. Such focus on the construction phase seems to be due to the strong influence of teachers' specialization, which leads them into the creational part of the engineering process, and the stimulating part of the technology usage. They actually achieved rather exciting artefacts with their students, but with a substantial lack of school mathematics content.

In contrast, in-field mathematics teachers evaded selecting the proposed projects. They tried to design their own projects based on their mathematical experiences and content in which they felt confident. Unlike the out-of-field mathematics teachers, the in-field ones provided their students less freedom to conduct their projects, guiding them into the resolution process. They asked their students to deal first with the mathematics content, offering them less time for hands-on activities. The in-field teachers encouraged the application of mathematical concepts, properties, and ideas, as well as data collection and analysis.

This study presents some methodological limitations concerning the sample, but we could still claim that integrating school mathematics content through the EDP is rather challenging for high school teachers. They are subject-specific and thus rooted into a limited content and context. Within these courses, we recommend promoting collaboration among teachers from different specializations to join their best knowledge for achieving a common goal. The Open STEAM Group is already running such courses with in-service teachers to initiate them in a collaborative teaching before their incorporation in the school. Doing so, we seek to protect the idea that teachers must hold a specialized knowledge, as reported by many experts in mathematics education.

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