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MATHEMATICAL CONTENT ON STEM ACTIVITIES

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Abstract

In this paper, a number of STEM educational proposals are systematically analyzed from the lens of mathematics education. An extensive innovation project was implemented during the 2019/2020 academic year in a pilot study carried out in Schools and Teacher Training Programs in Navarre (Spain), comprising a bibliographical and source analysis as a previous step to characterize the existing material, and ultimately to design and test STEM projects at different educational levels from the point of view of mathematical education. All activities belong to international publications and widely used and contrasted web repositories, and seize the usual interval of compulsory education, i.e., from the beginning of Primary School (age 6/7) to the end of Secondary School (age 15/16). The findings draw a panorama of STEM activities where mathematics is mostly utilitarian, numbers and units are functionally used to measure quantities of magnitudes, and geometric contents serve the purpose of modeling a technological prototype. As it turns out, some STEM-labelled activities do not fulfill their principles and fundamental purposes. In lower levels, there is a common confusion between STEM activities and science laboratory projects; in higher levels, complex mathematical content could appear. Even though some activities are guided science laboratory projects, it is concluded that most STEM activities have the potential of a-didactical situations, i.e., contexts where students put into practice their personal problem-solving techniques before teachers formalize the mathematical content.

Keywords: STEM, Spanish and Portuguese mathematics curriculum, Primary education, Secondary education, Didactical situations in mathematics

Abstrak

Pada makalah ini, sejumlah proposal pendidikan STEM dianalisis secara sistematis dari kacamata pendidikan matematika. Proyek inovasi ekstensif dilaksanakan selama tahun akademik 2019/2020 dalam studi percontohan yang dilakukan di Program Pelatihan Guru dan Sekolah di Navarre (Spanyol), yang terdiri dari analisis bibliografi dan sumber sebagai langkah sebelumnya untuk mengkarakterisasi materi yang ada, dan akhirnya merancang dan menguji proyek STEM di tingkat pendidikan yang berbeda dari sudut pandang pendidikan matematika. Semua aktivitas didasari oleh publikasi internasional dan repositori web yang digunakan secara luas dan kontras, dan memanfaatkan pendidikan yang wajib pada umumnya, yaitu, mulai dari awal Sekolah Dasar (usia 6/7) hingga akhir Sekolah Menengah (usia 15/16). Penemuan ini menggambarkan aktivitas STEM yang mana matematika sebagian besar bersifat *utilitarian*, bilangan dan unit secara fungsional digunakan untuk mengukur besaran, dan konten geometri berfungsi untuk memodelkan prototipe teknologi. Hasilnya, sejumlah kegiatan berlabel STEM tidak memenuhi prinsip dan tujuan yang mendasar dari konten STEM itu sendiri. Di tingkat yang lebih rendah, terdapat kesalahan umum antara aktivitas STEM dan proyek laboratorium sains; sedangkan, di tingkat yang lebih tinggi, konten matematika yang kompleks dapat muncul. Meskipun beberapa kegiatan merupakan proyek laboratorium sains terbimbing, dapat disimpulkan bahwa sebagian besar kegiatan STEM memiliki potensi situasi didaktis, sebagai contoh konteks yang mana siswa mempraktikkan teknik pemecahan masalah pribadi mereka sebelum guru memformalkan konten matematikanya.

Kata kunci: STEM, Kurikulum matematika di Spanyol dan Portugis, Pendidikan dasar, Pendidikan menengah, Situasi didaktis dalam matematika

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The sudden emergence of STEM-labelled activities in the Spanish and Portuguese educational systems around 2018 compelled *Federación Española de Sociedades de Profesores de Matemáticas* (FESPM) or Spanish Federation of Mathematic Teachers Association and *Associação de Professores de*

Matemática (APM) or Mathematics Teachers (Portuguese) Association to rethink what interdisciplinary projects mean in terms of mathematical education (Lasa, 2019). On the one hand, different mathematical content blocks in Spanish and Portuguese educational programs and curricula generally lack inner articulation and generate a growing bias towards decontextualized algebra; thus, a STEM project is an opportunity to contextualize mathematical content. On the other hand, there seems to be a lack of STEM projects where complex mathematical contents arise, making it hard to fulfil all the formal requirements of mathematics in such a project.

Lasa et al. (2020) conceived a theoretical frame to develop mathematical contents in STEM-based projects using theoretical, methodological and technological tools from the Theory of Didactical Situations in Mathematics (TDSM), the Onto-Semiotic Approach (OSA), and Instrumental Genesis (IG). In order to develop the curriculum principle (NCTM), STEM projects could be considered as didactical situations (TSDM) which contextualize algebraic contents; the formalization of the algebraic content will come later. Researchers and teachers implemented this frame within a pilot study carried out in Schools and Teacher Training Programs during the 2019/2020 academic year.

Hence, one can regard a STEM project as a scenario where students may use a number of basic strategies and apply their personal knowledge to solve a particular task. The STEM environment plays the role of the antagonistic milieu which students confront and from which they get mathematical feedback. Students take decisions, discuss different options and verify their suitability, and teachers may exploit the context to develop and shape the mathematical knowledge arising from the final project into their institutional form (Lasa, 2019).

According to the curriculum principle (NCTM, 2000), notions of proportionality (or Thales theorem in geometric context), ratio and linearity are some of the key notions that back up the mathematics curriculum in secondary school, and allow the articulation of algebra, geometry and functions. Thus, social science studies, environmental studies or STEM projects offer a setting for students to solve simple tasks using their own basic strategies (manipulation of large numbers, measurement and statistics), giving coherence to the curriculum and interlinking different mathematical ideas.

Before attempting any design on our own, it was essential to get the wider picture, i.e., the state and conditions of STEM activities in books and websites from the point of view of mathematical education. When analyzing the material, some previous hypotheses were checked, which arise from previous discussions of teachers and researchers on FESPM and APM:

a. Mathematical content in STEM activities is basic and utilitarian, mostly related to measuring magnitudes and using fundamental geometrical language.
b. STEM projects are seen as the final step of a learning process, where students apply new concepts they have recently learned to address a practical problem of some sort. However, this approach usually leads to a closely guided application with a lack of student initiative.

In this work, researchers intend to verify these suspicions, by systematically analyzing a number of STEM activities, on international publications and websites. For each activity, its mathematical content was examined, and whether it satisfied STEM-based suitability criteria. The results and their discussion should provide both a general view and a starting point.

Mathematics and Technology: STEM Skills and Aptitudes

The STEM approach to scientific education emphasizes an interdisciplinary educational strategy where academically rigorous concepts are coupled with real situations (Sanders, 2009), i.e., science, technology, engineering and mathematics are put into practice in contexts related to school, society, sport, or work (Tsupros et al., 2009; Berube, 2014), increasing the complexity to integrate them correctly and with coherence (Lagrange & Monaghan, 2009). STEM educational base attempts to remove barriers separating the four above-mentioned disciplines and integrate them with rigorous and meaningful learning experiences for students. Thus, researchers seek for contextualized teaching situations, where the student's environment takes on greater relevance (Laboy-Rush, 2011; Rico & Lupiañez, 2008), and such educational model should offer students tools to understand and interpret the world around them (Valencia, Méndez, & Jiménez, 2008; Hegedus et al., 2017). Briefly, science provides a context for reflection, organization and action, where technology and engineering offer technical tools enable the construction of models, and mathematics provides a set of notions and skills that allow solving problems (Lupiañez & Cruz, 2019; Lupiañez & Ruiz, 2017; Capraro, Capraro & Morgan, 2013). Therefore, students facing a STEM problem must be able to draw up an action plan for a problem, to propose solutions to the needs of today's world, and they should be creative when applying science processes, and capable of understanding their nature, using their own rational and logical initiative (Morrison, 2006; Benjumeda & Romero, 2017; Taub et al., 2018).

Source and Sample

There can be found any number of STEM activities, both in books and websites. Therefore, the focus is placed on a sample of activities meeting the following selection criteria. In the case of printed book activities (e.g., Heinecke, 2019; Hutchinson, 2019), they must be taken from largely distributed editions, with some commercial impact, translated into many languages, and widely used in different countries; in the case of websites, activities from supervised scientific repositories are considered, publicly funded and linked to verified educational projects (e.g., SCIENTIX, EU-HOU; etc.). All STEM activities are designed for Primary School students (age 7/11) and for Compulsory Secondary School students (age 12/15), and approved by FESPM and APM as high-quality educational sources.

METHOD

The research implements a multimethod methodology. Quantitative and qualitative paradigms are applied on a sequential explanatory design. The research is based on a descriptive analysis, complemented by a documentary analysis of bibliographic review. The choice of a mixed method is justified by the statistical tools used in the analysis, since joins together statistical descriptive analysis and implicative analysis techniques (Gras, Suzuki, Guillet, & Spagnolo, 2008).

Mathematics Education in Spain and Portugal share common backgrounds (Lasa, 2019). Spanish Primary Education and Portuguese Basic Education Cycles 1 and 2 comprehend ages 7 to 11. Spanish Secondary Compulsory Education comprehends ages 12 to 15, while Portuguese Basic Education Cycle 3 comprehends ages 12 to 14. In spite of these differences, it is therefore consistent to break both levels at the common ground of age 11.

A non-intentional set of 164 STEM activities from the literature referred to in section B (source and sample), labelled with explicit mathematical content was systematically analyzed. Table 1 displays the distribution of activities according to educational levels, student ages and source supports. Half of the activities were for Primary School / Basic Cycles 1 and 2 students (7-11 years), of which 58 were taken from printed books (35.4%) and 24 from websites (14.6%). The other half were for Compulsory Secondary School / Basic Cycle 3 (12-14/15), of which 46 were taken from printed books (28.0%) and 36 were taken from websites (22.0%).

Table 1. Distribution of activities in accordance with age

Age	Source	Frequency	Percentage (%)
7-11	Books	58	35.4%
12-14/15	Books	46	28.0%
7-11	Websites	24	14.6%
12-14/15	Websites	36	22.0%
Total		164	100.0%

Characteristics and features for each activity were measured. The principal aim was to identify the mathematical content stated in the activity. Therefore, five categories were defined for mathematical content, which arise a priori from the organization of mathematical topics in school curriculum: arithmetic, measurement, statistics, geometry and functions; and researchers checked which activities stated these mathematical contents. Each activity could state one, more than one, or none. For practical reasons, arithmetic was considered a single category, as it contains algebraic content as well, secondary school being a transitional stage from one content to the other. Proportionality was also tagged as a functional content related to linearity, rather than as an independent content, due to its backbone character, i.e., a longitudinal content that backs up mathematics across the curriculum in secondary school.

Additionally, suitability factors were analyzed for each activity, i.e., researchers checked whether the activity follows objective rules in order to qualify as a STEM activity. According to Morrison (2006), students should express six abilities when facing a STEM activity, namely they should be: (1)

problem solvers, (2) innovators, (3) inventors, (4) self-sufficient, (5) logical thinkers, and (6) technologically literate. Those six abilities were gathered together into four suitability factors. Thus, it could be decided to what extent the design of a particular activity enables the emergence of these abilities, i.e., whether the activity: (a) is a challenge for the student and requires solving a problem; (b) requires innovation and inventiveness; (c) students face it with autonomy; and, (d) requires technological literacy (both digital technology and technology related to science).

For each activity, the explicit presence of a particular mathematical content was tagged by means of Boolean values: true (1) or false (0). Researchers only focused on mathematical content, even though additional scientific content should arise from the activity. They also kept qualitative track of all mathematical contents in each activity. Sometimes, a particular activity is labelled as containing mathematical content, but there are no mathematical contents at all to work with; in these cases, all values were set to zero. For each activity, they also tagged the appearance of a particular suitability factor by means of Boolean values: true (1) or false (0).

Researchers compiled data from the sample activities, and analyzed these data using two techniques. First, they made a statistical descriptive analysis: they measured frequencies and percentages to make a quantitative description of the activities. Then, they analyzed the sample using implicative analysis techniques (Gras, Suzuki, Guillet, & Spagnolo, 2008). This second approach could ensure the conclusions from the descriptive analysis, and could lead to hidden relations between variables, which are hard to see at the descriptive level.

RESULTS AND DISCUSSION

The 34 activities in this sample (20.7%) do not envisage any mathematical content at all. 28 of these 34 activities are taken from books and addressed to primary school students, i.e., half of the activities in primary school books do not envisage any formal use of mathematical contents. The lack of mathematical contents appears, mostly, in artistic activities (handmade production processes, e.g., paper, sculptures; activities with natural object, e.g., fruits and vegetables), and science activities (experimental introduction to notions of physics and natural sciences, e.g., pressure, light, solar energy, ecological wrappers). Engineering and technological projects do envisage a more mathematical activity. However, sometimes the aim of the activity is to illustrate the functioning of technological prototypes, so mathematical content also disappears (e.g., airplanes, parachutes, drones, bridges, internet, telephone, satellites, spin-dryers, zippers).

There are 130 activities (79.3%) using contents from at least one mathematical category. Table 2 displays mathematical content frequencies for all activities; percentages do not add up to 100%, since more than one mathematical content could appear in a particular task. Note that measurement and geometrical contents appear most frequently, followed by arithmetic, statistics and functions.

Table 2. Mathematical categories

Category	Frequency	Percentage (%)
Measurement	80	48.8
Geometry	49	29.8
Arithmetic	33	20.1
Statistics	25	15.2
Functions	20	12.2

On the one hand, activities tagged as engineering or technology mostly deal with measurement and geometry contents. On the other hand, activities tagged as science or art do not have much mathematical content. Finally, there are specific activities tagged as mathematics, where complex geometric and numerical notions arise.

When facing tasks tagged as engineering or technology (46 activities have this label), students are required to measure lengths, mostly in centimeters. Engineering tasks have a number of geometrical contents for: modelling (e.g., square, line, parallel, horizontal, vertical, diagonal, middle point; circumference, circle, arc, angle; lens, projection; direction, orientation, axis of rotation, mirror, reflection; symmetry, rotation); using geometrical drawing instruments (rule and compass); fundamental function contents (e.g., vibration, wave); basic probability and random notions; and search for patterns. In technology activities, students mostly measure the intensity of electric currents (A), and they use positive and negative numbers to do so. The measurement of lengths (m, cm) and capacities (ml) is required when dealing with mechanical prototypes, and geometric language (e.g., circumference, center, diameter, line, perpendicular, middle point, cut point; axis of rotation, angle, direction, orientation) and drawing instruments (rule and compass) arise in this context, as well as random trajectories and algorithms.

Engineering and technology STEM projects deal with workshop construction of many instruments, such as: telescopes (Thales Theorem and the measurement of distances); flashlights (electrical magnitudes); turbines and pendulums (rotation, oscillation); and kaleidoscopes (symmetry, reflexion-angle). Sometimes, students must build and program a robot in order to accomplish a particular task, using software and sensors: trajectory modelling, speed, etc.

In mathematic-tagged activities (24 labelled activities), measurement does appear too. Students are required to deal with a variety of magnitudes, and they deepen in the measurement process itself. They estimate results before making any calculation, compare approximate and precise measures using symbolic representations (≈, =), convert measures from non-standard to standard units and from one unit to another, and measure accurate units other than centimeters (mm), as well as many other magnitudes (e.g., capacity, ml, l; mass, g, kg; temperature, C; time, h, min). Geometric contents in mathematic-tagged activities deal with elementary plane geometry (e.g., square, triangle, similarity; circumference, arc, line, curve; edge, middle point, median), and geometrical drawing instruments (rule and compass), but they also release complex mathematical contents (e.g., fractal geometry, snowflake geometry, mosaic and tessellation; spiral, Fibonacci spiral, loops, Moebius band, projective geometry and shadows). GeoGebra usually supports geometrical activities, and modelling usually requires 3D printers (Nisiyatussani et al., 2018).

In activities tagged as science (23), students mostly measure capacity (ml) and time (day, min), as well as mass (g) and temperature (C). These activities deal with notions from natural sciences and physics, and basic mathematical contents arise, such as the use of positive and negative numbers, statistical variables, and basic geometric notions. For example, students may collect data from the Solar System, in order to define its rotational model; deal with force and mass to balance weights; etc.

Only 2 artistic activities in this sample contain measurement notions that have to do with mass (g), capacity (ml, l), and time (s). Table 3 summarizes the use of magnitudes and their measurements in sample activities.

Table 3. Magnitudes in measurement activities

Magnitude	Units	Frequency	%
Length	m, cm, mm	41	51.3
Volume, capacity	ml, l	21	26.3
Time	Day, h, min, s	15	18.8
Mass	Kg, g	10	12.5
Area	cm^2	7	8.8
Temperature	°C, °F	7	8.8
Money	€, $	7	8.8
Amplitude	$°, ', ''$	7	8.8
Electric intensity	A	5	6.3
Light intensity	$Candle$	3	3.8
Energy	J	2	2.5
Density	$Kg \times m^{-3}$	2	2.5
Power	N	1	1.3
Wavelength	$Hertz$	1	1.3
Speed	$m/s, Km/h$	1	1.3

11 activities from the sample (out of 25; Table 2) are based on statistical content. Students are taught about data collection, data analysis and data representation techniques (e.g., double input table, tree-diagram, bar-diagram), using spreadsheets. Then, students use data with a specific purpose (e.g., geometrical design of an interior space, or a school; geometrical modelling and 3D printing of a beehive, or a bird-nest; measurement, quantification, and classification of waste in a recycling factory; pulse steadiness graphs; time-laps and speed measurement of vehicles in various routes). 6 statistical activities

for young primary school pupils deal with the identification of sensorial qualitative variables (stiff/flexible; robust/weak; rough/smooth; seriation of sensorial characters).

7 activities from the sample (out 33; Table 2) are based on arithmetical content. The purpose of these activities is to show young pupils fundamental arithmetical notions: counting and cardinals; the difference between recursive and Cartesian multiplication; division; use of positive and negative numbers; rational numbers; rounding up and down; etc. Arithmetic notions arise in mathematic-tagged activities, dealing with: fractions and powers: Fibonacci sequence: Eratosthenes method: second grade equations: etc. An extract from the history of mathematics provides the background to introduce complex arithmetic and geometry contents.

Activities in other groups or classifications can be found. For instance, 10 activities in the sample deal with optimization problems. In such activities, students design geometrical or functional models according to statistical data (e.g., spaces and volumes, construction or insulating material costs, cloth measures depending on growth rates, insurance products), and build physical prototypes (e.g., scale models).

In 107 activities (65.2%), none of the four suitability factors are identified. All book activities are included in this category. In 57 activities (34.8%), at least one suitability factor can be identified. Most website activities fulfil one or more than one suitability factors (Table 4). 54 activities are considered to be (a) a challenge for students and require to solve a problem; 32 activities (b) require innovation and inventiveness; 57 activities (c) are faced by students with autonomy; and 38 activities (d) require technological literacy. There is no significant difference between requirements on the use of digital technology (55.3%) and science-related technology (44.7%). 18 activities fulfil all four suitability factors, and 32 fulfil three of them. All 3-SF activities are (a) a challenge for students and require to solve a problem, and (c) students face them with autonomy.

Table 4. Suitability factors

SF	Fr.	%
(a)	54	32.9
(b)	32	19.5
(c)	57	34.8
(d)	38	22.6
All 4	18	11.0
3 out of 4	32	19.5
2 out of 4	5	3.0
1 out of 4	2	1.2

On the one hand, only one single activity (no. 123) in the sample could be identified where all mathematical contents are considered, and which fulfil all four suitability factors. In this activity, students design and build a water rocket, and they must launch it as high as possible (https://www.stem4math.eu/mission-mars). Instructions deal with real world motivation: “In the 21st century, many countries and space agencies are attempting to send probes and landers to Mars. Mars is an interesting planet because conditions on its surface may have been very similar to conditions on Earth. The ESA (European Space Agency) sent a lander called Schiaparelli to Mars at the beginning of 2016. In October 2016, Schiaparelli reached Mars, but something went wrong with its landing. Unfortunately, the lander was completely destroyed”.

In activity no. 123, students must investigate the influence of different variables on the flight of the rocket (*science*), designing and constructing the best possible water rocket (*technology* and *engineering*). *Mathematical* skills take into account scaling, calculating averages, calculating big numbers (to stick to a budget), measuring volumes of water, and working on proportions. Suitability factors include: asking questions and problem-solving (e.g., controlling variables in order to find the best possible rocket design); planning and budgeting; collecting, analyzing and interpreting data (e.g., why is it important to measure something several times?); reporting data (e.g., explaining what influence different variables had on rocket flight); and reflecting (e.g., what process did we go through in finding and producing the best possible rocket?).

On the other hand, 30 activities in the sample were identified where no mathematical contents are considered, and which fulfil none of the suitability factors (out of 34 activities, where no mathematical contents are considered), e.g., (no. 131) students design a healthy, multicultural meal for their school by investigating and collaborating (http://www.scientix.eu/resources/details?resourceId=23080). Activity no. 131 is useful and educational, but cannot be included in a STEM catalogue:

> “In this open activity students design a healthy, multicultural meal for their school by investigating and collaborating. How healthy a meal is, is described in relation to the five food groups and a calculation of the nutritional value. Multiculturalism is explored by investigating the students' eating habits and linking them to their cultural backgrounds. Collaborating on an open and rich task allows for diversity in the ways of working as well as in the level of achievement. Students can discuss and support one another and/or divide tasks according to their preference, ability, etc.”

Sometimes, the main purpose of a STEM activity is to illustrate a natural principle or give an example of a technological prototype. These activities rarely show any mathematical activity. Electronics based projects or user-level software-based projects are clear examples. This also happens when an activity uses a scientific principle for artistic purposes (e.g., music or sculpture). Even in contexts where the use of numerical models could be justified and would be interesting (e.g., estimate how much food can the Earth produce; design of nesting nets), this opportunity is sometimes not fully exploited in the activities.

A glance at Table 2 reveals the utilitarian use of mathematics in STEM activities. In most tasks, numbers and units are helpful to measure lengths for technological prototypes, and they are useful to measure volumes in laboratory experiments, i.e., mathematics is functional to measure magnitude quantities. Geometric contents are utilitarian too, since they serve the purpose of modelling a technological prototype, and they target the design of parts, pieces and elements of a mechanism (Apsari et al., 2020). Sometimes, a STEM project is tagged as *mathematical*, and the educational objectives build on those same notions relating to magnitudes and geometric language; yet, they rarely introduce any other complex mathematical content.

Mostly at lower education levels, STEM projects and science laboratory projects are jumbled together, and both terms are indistinguishable in the same contexts. Anyhow, STEM activities demonstrate that, even at lower levels, pupils can face STEM projects, using numbers and statistical notions to tackle actual problems, e.g., young pupils can analyze physical phenomena and sensorial variables by using qualitative perception and numbers.

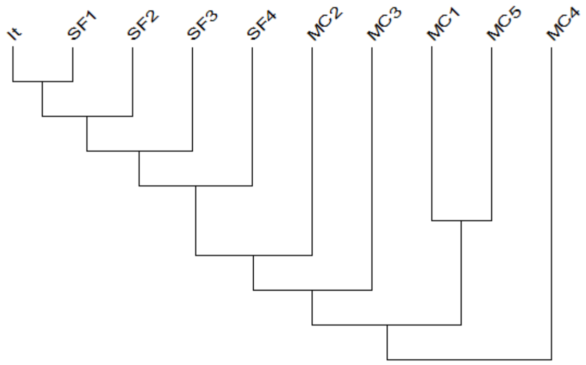
It is hard to find reliable STEM activities requiring to solve an interesting problem with inventiveness, autonomy, and technological literacy. Findings shows that books are not a good source of STEM activities anymore: numerical data, dynamic models, additional information, etc., are more easily found in websites and links; and objective analysis shows that website proposals are more satisfactory from the point of view of task-design.

Statistical implicative analysis confirms previous assertions. Table 5 summarizes meanings and values for one external variable (source support), five internal variables with mathematical content information, and four internal variables with suitability factors information.

Table 5. Variables and implicative analysis

Variable	Meaning and value
IT	Source: Website (1), Book (0)
MC1	Arithmetical content: Yes (1), No (0)
MC2	Measurement content: Yes (1), No (0)
MC3	Statistical content: Yes (1), No (0)
MC4	Geometrical content: Yes (1), No (0)
MC5	Functional content: Yes (1), No (0)
SF1	Challenge problem: Yes (1), No (0)
SF2	Innovation inventiveness: Yes (1), No (0)
SF3	Students autonomy: Yes (1), No (0)
SF4	Technological literacy: Yes (1), No (0)

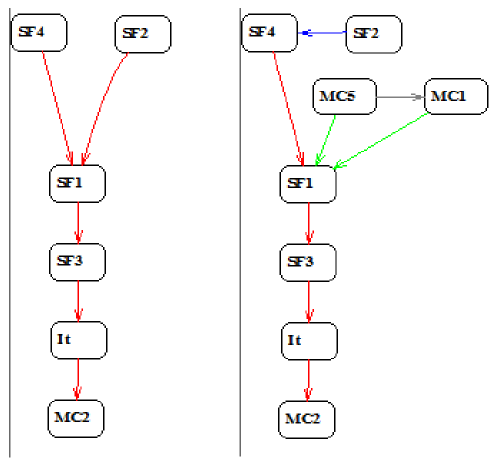
Implicative analysis confirms the strong relationship between activity support and suitability factors. The implicative tree (Figure 1) gathers IT and SF variables together in the main branch, i.e., these variables contribute most to the main branch, in terms of frequency. Measurement and statistical mathematical contents make an important contribution to the main branch too. Some other relationships arise which were hard to see with descriptive statistical procedures. For instance, arithmetical and functional contents share a strong similitude index, i.e., STEM activities envisage the use of numbers and operations, along with functions and proportionality, and vice versa. Geometrical contents constitute a diversity of backgrounds for many activities, with weak relationship to just one other variable.



	It	MC1	MC2	MC3	MC4	MC5	SF1	SF2	SF3	SF4
It	1.00	0.98	0.99	0.97	0.69	0.98	1.00	1.00	1.00	1.00
MC1	0.98	1.00	0.96	0.67	0.18	0.99	0.98	0.84	0.99	0.72
MC2	0.99	0.96	1.00	0.48	0.51	0.53	0.99	0.87	0.99	1.00
MC3	0.97	0.67	0.48	1.00	0.10	0.87	0.98	0.83	0.98	0.92
MC4	0.69	0.18	0.51	0.10	1.00	0.66	0.76	0.68	0.76	0.88
MC5	0.98	0.99	0.53	0.87	0.66	1.00	0.98	0.71	0.99	0.95
SF1	1.00	0.98	0.99	0.98	0.76	0.98	1.00	1.00	1.00	1.00
SF2	1.00	0.84	0.87	0.83	0.68	0.71	1.00	1.00	1.00	1.00
SF3	1.00	0.99	0.99	0.98	0.76	0.99	1.00	1.00	1.00	1.00
SF4	1.00	0.72	1.00	0.92	0.88	0.95	1.00	1.00	1.00	1.00

Figure 1. Implicative tree and similitude index

The implicative graph (Figure 2) shows the actual direction of the implications. Red arrows show a 99% implicative relationship between variables. There is a 99% implicative relationship from variables SF4 / SF2 to SF1, meaning that activities requiring technological literacy, as well as activities requiring innovation and inventiveness, are a challenge for students when they require problem-solving skills. There is a 99% implicative relationship from SF1 to SF3 (challenge activities imply student face it with autonomy) and from SF3 to IT (autonomous activities found in websites): this section of the implicative chain shows strong correlation between variables (Figure 2). Finally, there is a 99% implicative relationship from IT to MC2 (website activities dealing with magnitudes and measurements).



	It	MC1	MC2	MC3	MC4	MC5	SF1	SF2	SF3	SF4
It		0.22	0.32	0.21	0.06	0.22	0.92	0.65	0.96	0.71
MC1			0.21	0.04	-0.10	0.23	0.23	0.10	0.24	0.06
MC2				-0.01	0.00	0.01	0.33	0.14	0.34	0.35
MC3					-0.13	0.10	0.21	0.09	0.22	0.14
MC4						0.04	0.08	0.05	0.08	0.13
MC5							0.21	0.05	0.24	0.16
SF1								0.70	0.96	0.74
SF2									0.67	0.40
SF3										0.74
SF4										

Figure 2. Implicative graphs and correlations

At a lower level, the blue arrow shows a 95% implicative relationship between variables: activities requiring innovation and inventiveness also require technological literacy. Green (90%) and grey (85%) arrows show week implicative relationships between variables. The use of functional and arithmetical contents implies a challenge or a problem-solving context, and functional mathematical contents imply the use of arithmetical (algebraic) language.

Teachers and researches must be aware on the inner articulation of mathematical content in STEM proposals, in order to design faithful learning situations from the mathematical point of view. Sharing this knowledge within the community will lessen fear and afford teachers confidence (Chahine, Robinson, & Mansion, 2020). On the other hand, the findings assert the point of view that STEM projects hold the potential to be used as a-didactical situations.

CONCLUSION

Asserting hypothesis (A), mathematical content in STEM activities is basic and utilitarian, being mostly related to the measurement of magnitudes, statistical interpretation of numbers and the use of fundamental geometric language. Since students do not require complex knowledge of mathematics to address a STEM activity, the activity itself is a potential a-didactical situation. Suitable activities reinforce challenge, inventiveness, autonomy and technological literacy, all elements related to a didactical situation. This approach would be used in the future to integrate the different areas of knowledge in interdisciplinary processes, avoiding asymmetry of roles, and testing constraints and obstacles when implementing interdisciplinary and STEM activities.

Thus, instead of considering the STEM project as the final step of a learning process, where students apply new concepts they have recently learned to address a practical problem of some sort, it could be considered as a context where students put into practice their personal problem-solving skills. Afterwards, the teacher could make use of this resort to formalize the arithmetical (algebraic) and functional contents arising from the activity into their institutional meaning. The first approach usually leads to a closely guided application, with a lack of students' initiative, and could cause Topaz effects (Brousseau, 1997).

STEM is the acronym for four disciplines, aiming to bring Science, Technology, Engineering AND Mathematics together. All four disciplines should arise at the same time. A fashionable use of STEM shows that in many activities just one of the four disciplines is considered, thus replacing the conjunction AND with OR. However, this should not be our style.

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