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Article

A Novel Methodology to Develop STEAM Projects According to National Curricula

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Abstract: The objective of this work is the elaboration of a methodology to develop STEAM projects (Science (S), Technology (T), Engineering (E), Art (A) and Mathematics (M)). The methodology proposed in this article is part of the results of the project ERASMUS+DART4City (2020-1-ES01-KA227-SCH-095545) "Empowering Arts and creativity for the cities of tomorrow", whose objective is to design a methodology in order to develop STEAM projects from European curricula. The proposed methodology emerges after analysing, among others, the curricula from Spain, Italy, Cyprus, France, Finland and Germany , taking into account the international perspective of STEAM education, their priorities and problems. The proposal has two variants: "forward" and "backward". Both variants begin with the analysis of the curriculum in which the contents are grouped by similarity, classified according to STEAM disciplines so that the thematic areas can be obtained. Subsequently, in the "forward" variant, the thematic areas with most connections are selected as areas of opportunity; for the development of the STEAM project, so from the "forward" methodology, the teacher will be able to select an area of opportunity and develop the project around it, so, the concept or project idea comes from an area of oportunity. The "backward" variant starts from a concept considered interesting for society or just for the teacher and which will become the main theme of the STEAM project and, from that concept, we will select the thematic areas of the curriculum that can be included in the project. The main difference bewteen both methodologies is that in the "forward" variant, the STEAM project concept comes from an area of oportunity detected in the curriculum meanwhile in the "backward" variant the concept of the STEAM project comes from the teacher, without taking into acount, initially, the curriculum. This article shows an example of application of each variant. From the "forward" variant, the STEAM project "Sustainable City" is shown for years 4, 5 and 6 of Primary Education, which has been carried out from the opportunity area "Sustainability". From the "backward" variant, we develop the STEAM project, whose main theme is cooking, in which, based on this theme, 10 tests are developed, each of them related to different thematic areas of the Spanish curriculum.

Keywords: curriculum; project-based learning; STEM; STEAM; opportunity area

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1. Introduction

The social and technological changes of the 21st century pose the need to redefine the teaching model so that the development of skills related to creativity and innovation is linked to the acquisition of scientific-technical skills and therefore today's students will be able to solve the uncertain challenges of the future. STEAM learning is one of the models seeking to respond to this challenge by integrating art (A) with the other scientific-technical disciplines: Science (S), Technology (T), Engineering (E) and Mathematics (M).

Within the unpredictability of the future, what labour market trends do specify is that technological knowledge will be essential for 80% of workers and the qualifications necessary to enter the labour market will be measured by technological competences (European Centre for the Development of Vocational Training [1]. According to this forecast there is an emerging need to train new generations whose STEAM skills are sufficiently developed to know how to adapt and develop technologies yet to be discovered. The STEAM learning is an educational model that pursues the integration and development of scientific-technical and artistic subjects in a single interdisciplinary framework [2]. The acronym arises in 2008 when Yakman, trying to foster interdisciplinarity, introduces the A from "Arts" into another existing acronym that collected the English initials of the disciplines of Science (S), Technology (T), Engineering (E) and Mathematics (M).

In 2008, Yakman's essay states that, assuming the need to opt for an integrating concept of STEM learning, it is essential to introduce in the model what in English is called "the arts" in order to generate a truly integrated and creative learning [2]. The idea of "the arts" introduced by [2] is a very broad concept that covers fields such as language arts, social sciences and physical arts in addition to those traditionally considered to be fine arts. Thus, with their integration into STEM learning, "the arts" become a multidisciplinary agent that connects the sciences with artistic fields which facilitate communication, the understanding of reality and bring out creative strategies and solutions [3].

When the Pisa report [4] revealed the low level of knowledge, interest and motivation of South Korean students, the Korean government, looking at the educational trends of the moment, but especially taking into account the US contributions, devised an education plan based on STEAM learning. Yakman became their adviser and taking into account her theoretical framework [2], a national proposal based on STEAM learning has been developed. This national plan is one of the most used references in the scientific literature to support the viability of STEAM learning, although it is not necessary to overlook that a key point of the plan is the promotion of language arts and social sciences.

One of the institutions that has disseminated and enhanced STEAM learning most is the Rode Island School of Design (RISD) and its informative initiative, "https://www.risd.edu/steam" (last accessed date (3 February 2022)), which is one of the best-known initiatives regarding this field. The STEAM framework defined by the RISD changes substantially from Yakman's model by the way in which art is incorporated to the rest of the disciplines, by equating it to the design and giving it a strong innovative character. The RISD defines the goal of STEAM learning as a transformation of research policy in order to place art understood as design at the centre of STEM learning. From this point of view, the artist-designer has much to say in the processes of scientific-technological development and must be present in every innovation team. The RISD poses the challenge of placing arts education as a discipline fully integrated in the scientific learning of primary and secondary education. By combining art and creativity with other disciplines, aspects such as innovation and design, the development of curiosity and imagination or the search for diverse solutions to a single problem are valued.

Within the STEM field, ref. [2] showed that the need for a certain degree of curricular integration and interdisciplinary learning had already been raised individually within each of the disciplines. This review also allowed her to classify what is specific to each discipline, what makes it unique and the difference from the rest of STEM fields and discover that art (A) provided an extra component of interdisciplinarity and creativity. These definitions are included below starting with the STEM areas and leaving art (A) for the end.

1.1. Sciences (S)

Scientific education deals with everything that exists naturally and how it is studied. In this way, physics, biology, chemistry, biochemistry, Earth and space sciences and others close to technology, such as biotechnology or biomedicine, are considered areas of scientific education [2]. The interdisciplinary contribution of scientific learning lies in the methodology itself, in the so-called scientific method, whose thinking is transferable to other content and with which students learn (1) to think in a disciplined and rational way by strengthening their mind and (2) to think like scientists and imitate them formally [5]. Although one of the principles for applying STEM education is that students learn science creatively [6], art is linked to creativity and innovation. In this way, STEAM education is closely linked to ideas and research on arts integration and its implementation often uses the design thinking [7] method.

1.2. Technology (T)

Technological education is responsible for studying everything that has been created and manufactured by the human being [2]. As a school discipline, technology was the last to reach educational plans and since this happened its connections with mathematics and science became evident as they were existing disciplines that supported its emergence [8]. The main objective of technology as a subject is to alphabetize people technologically, both functionally and technically, so that they are able to adapt to rapid technological advances and therefore its approach, in relation to concepts, has been to downplay specific content and focus on the understanding of technological systems and their connections [9]. Although technology as an educational discipline has its own objectives, methodologies and contents that are independent of the rest, it is the most transversal subject of all established disciplines [8].

1.3. Engineering (E)

As science and technology progress, new fields are emerging, such as engineering, understood as the "use of creativity and logic, based on mathematics and science and using technology as an agent to make contributions to the world" ([2], p. 10), that is, engineering is the use of science and mathematics to design new technology [9]. Engineering is a field that has not been implemented as an educational discipline in basic education, although it has been related to technological education, which is the educational discipline that connects it with mathematics and science. In fact, when students study design and technology, they are studying engineering after all. Students need to assimilate engineering-related capabilities at an early age, in case they later need to design and conduct experiments, analyse and interpret data, design systems, components or processes, work in a multidisciplinary way, identify contemporary problems or solve impact problems for society [10].

1.4. Mathematics (M)

Mathematics is the discipline that was previously consolidated as an individual subject in modern education, focusing its study on numbers and its operations, the management of algebraic expressions, analytical geometry, measurement management, data analysis, probability, problem solving, logical reasoning and its communication [2]. The US NCTM makes it clear that the results should begin to be less relevant to the projects and work processes (NCTM, 1989). For his part, ref. [11] states that the objectives of the teaching and learning of mathematics always have to do with society and that this relationship must be made evident and therefore the mathematical objectives are socio-cultural and historical objectives that reflect the way of understanding reality. The essence of mathematics is problem solving and this subject is necessary to define, analyse and solve all kinds of real-life problems. From an interdisciplinary perspective, mathematics in the STEM field is revealed as the common language to the rest of the fields, the language through which all communications are regulated, defined and understood [2,12].

1.5. Art (A)

Although art education has traditionally been related to plastic arts, the concept of "art" has many other internal divisions whose incorporation makes it difficult to establish a global definition [2]. The discipline of art is divided into several types: language arts, fine arts or plastic arts, physical arts, manual arts and liberal arts that encompass social sciences [2].

Several of these arts have been considered independent disciplines in educational systems, these are language arts, social sciences, plastic or physical arts through physical education [2]. From this point of view, the presence of "art" in the educational world is wide and would not be limited to plastic and manual arts. In addition, art, understood in this way, has never been included in STEM areas, leaving it out of the educational structure considered vital to train qualified citizens.

In the development of the STEAM theory, the role of each of the disciplines in learning is established in a very specific way, defining STEAM learning as the learning of "Science and Technology interpreted through Engineering and Art based on the language of Mathematics" [2,3].

In [2] is defined which the STEAM learning concept is placed halfway between the multidisciplinary learning of STEM learning and the holistic learning. In [2] is defined a pyramid where are stratified the different conceptions that can be obtained from STEM and STEAM learning based on their degree of interdisciplinarity, placing at the base the traditional conception in which the contents were isolated within their respective subjects without any degree of integration; in the second layer are placed the moderate modern approaches of STEM learning that are committed to an interaction, cooperation or collaboration between the disciplines [13,14]; in the third layer we are shown the most radical conceptions that promote a completely integrated and multidisciplinary learning among the STEM disciplines [13,15]; in the fourth layer [13]; places his theory of STEAM learning that uses art as a transversal element and integrator of the other disciplines, placing at the top the holistic theories of some methods that defend a learning for life in which the contents remain in the background [16,17].

Ref. [2] approaches the ideas of [18] by placing mathematics as the primary language that goes through the boundaries of all other areas; mathematics is the underlying language in all communication and in the STEAM field it becomes also the liaison agent that allows concepts to be understood.

In the STEAM structure proposed by [2], engineering and art are the areas that provide a context to learning: engineering provides a research and development context, necessary to create new technology, while art, understood in its broadest form, provides a social and creative context; these two disciplines, engineering and art are the ones that focus and guide learning [3].

In this way science and technology remain as the objects of study in themselves: scientific and technological concepts will be interpreted under engineering and artistic contexts by using a mathematical language for their understanding [3].

1.6. Design and Content Integration in STEAM Projects

The creation of STEAM projects and the integration of their contents is a very complex task and is currently being investigated. Regarding the integration of STEAM content, it implies combining knowledge and skills from the STEAM disciplines where one of the disciplines usually has a dominant role [19]. In general, the literature differentiates three approaches [12]:

- The multidisciplinary approach, refs. [20,21]: It implies learning contents separately in each discipline but within a common theme [22,23].
- The interdisciplinary approach, ref. [24]: combines content from at least two disciplines, making explicit connections [25].
- In a transdisciplinary approach, refs. [26,27]: "the curriculum transcends the individual disciplines" [23] and knowledge and skills are applied in real world situations [22,23].

Regarding problem-based learning, research has shown that STEAM projects are barely contextualized in real life [12,28,29]. Most of the proposals do not make sense outside the school, due to the difficulty of setting them in real world contexts [30]. Ref. [28] suggested that the ability to establish a context is related to the specialization of educators, being more challenging for mathematics than for science [12].

The specialization or profile of teachers not only influences the design of STEAM projects, but also how they are explained. In [28] they indicated that the way in which teachers explain a concept is influenced by their academic degree and teaching experience; for example functions are taught differently in science and math lessons. In projects with an emphasis on design, technology teachers tend to exploit engineering aspects, avoiding justifications for science and mathematics [22,31].

1.7. Teacher Training for the Design of STEAM Projects

In the academic community there is a consensus on the importance of teachers as a key element in the incorporation of STEM education in the school system [32], therefore specific initial training and updating and Teacher development constitutes a main line of didactic research. In addition, as scientific subjects have traditionally dealt only with knowledge and interaction with the physical world [33], it is essential to teach teachers to use technology as a fundamental tool in their teaching activity and to develop didactic proposals that combine STEM content, so that only through changes in teacher training will positive results be obtained in STEM learning) [34].

Despite the importance of teachers receiving training in STEM [35] learning, many teachers report that they are not sufficiently trained to adequately teach STEM disciplines [36]. A survey carried out by [37] confirms that 85% of teachers consider that they do not have technological skills and that the STEM field is an interesting field in which to train. However, most STEM research has focused on students, with little research on how it prepares teachers [38,39].

STEM learning is a constructivist learning in which the student actively participates promoting their ability to apply, transfer and create knowledge, which implies a methodological change. This methodological change determines the use of active methodologies, since it is not just about knowing science, mathematics or technology, but "knowing how to solve problems in real contexts thinking like scientists, mathematicians and engineers" [30]. And, since the teacher is the one who determines the type of methodology to be used in each case, be it project-based learning, problem-based learning, collaborative learning..., they must have sufficient training in active methodologies. The combination between STEM/STEAM and active methodologies dependes mainly to the creativity of the teachers, see for instance in [40] that use the creation of animated graphs to develop Computational Thinking and support STEM Education and also can be blended, why not, with traditional lessons, see [41].

STEM learning requires a more contextualized and competency-based teaching, so the training programs must train the teacher to, based on the contents of the curriculum, propose to the students, areas of opportunity, understood as areas of knowledge that meet the characteristics of the challenging challenge of project-based learning and the characteristics of the generative topic of teaching by understanding, capable of motivating the student to build their own knowledge. Thus, both initial teacher training and professional development programs should be based, among other premises, on promoting the implementation of active methodologies and adopting an approach adapted to the student's environment. Both premises can be achieved through the method proposed in this article to help teachers design STEM projects.

2. Research Objective

Social and technological changes require that students, in order to face the challenges of today's society, acquire scientific-technological competencies and develop capacities such as creativity and innovation. These needs are not specifically addressed by the vast majority of educational models, so they must be redefined by incorporating programs and methodologies consistent with current curricula.

The objective of this work is to develop a methodology so that we can implement STEAM projects, connected with curricula, which can replace conventional teaching and solving the problems detected in current STEAM project designs, low connectivity with the real world [12,28,29], different approaches depending on the profile of the teaching staff [22,28,31] and guaranteeing transdisciplinary approach between disciplines. The methodology proposed in this article is part of the results of the project ERASMUS+ Project DART4City (2020-1-ES01-KA227-SCH-095545) "Empowering Arts and creativity for the cities of tomorrow", whose objective is to design a methodology in order to develop STEAM projects from European curricula. The proposed methodology emerges after analysing, among others, the curricula from Spain, Italy, Cyprus, France, Finland and Germany, taking into account the international perspective of STEAM education [42], their priorities and problems [43].

The proposed methodology allows selecting the area of opportunity, or thematic area belonging to a STEAM discipline that meets the necessary conditions to be the main theme of a STEAM learning project and it can be easily connected with the real world, in two ways: "forward" and "backward". In the first variant, "forward", an analysis of the curriculum is carried out for a given course or level and the areas of opportunity are selected among the thematic areas which have more connections with the rest of the thematic areas; in this way, STEAM projects developed from these areas of opportunity will contain a large number of thematic areas and will cover an important part of the curriculum guaranteeing transdisciplinary approach and defining the particular concepts that each discipline must be cover, avoiding interpretations. The second variant, "backward", is carried out from a specific theme that is considered interesting for developing a STEAM project; subsequently, the connections of the selected theme with the thematic areas obtained from the analysis of the curriculum will be sought. That is, both methodologies have a common stage in which the curriculum is classified into STEAM thematic areas and, from there, in the "forward" methodology the connections between the thematic areas are sought to find the areas of opportunity with more connections, while in the "backward" methodology the project theme is selected first and then the thematic areas related to the theme are searched.

3. Methodology for Transforming Curricula into STEAM Projects

The methodology proposed in this article is part of the DART4City project (ERASMUS+ 2020-1-ES01-KA227-SCH-095545) and one of the objectives is to develop a methodology that allows to connect STEAM projects with the curricula of European countries; for this purpose, we analysed the national curricula of the partner countries such as Cyprus, Italy and Spain, as well as the vast majority of curricula of other European countries such as Finland, France, Germany, Portugal...

The methodology has a first stage in which the curriculum is analysed to extract the thematic areas of the curriculum and subsequently two variants will emerge: "forward" and "backward".

- Regarding the "forward" variant, the main theme of the STEAM project is based on one of the areas of opportunity obtained from the thematic areas with the highest number of connections with the other thematic areas; in this way, the areas of opportunity are the areas that will cover a greater amount of content.
- Concerning the "backward" variant, we start from an idea or concept that will be the main theme of the STEAM project and then we go back to look for the thematic areas of the curriculum that are related to the selected theme.

Figure 1 shows the general outline of the methodology, with a common stage, consisting of four phases, and another specific stage to each of the variants, consisting of three phases in each variant.

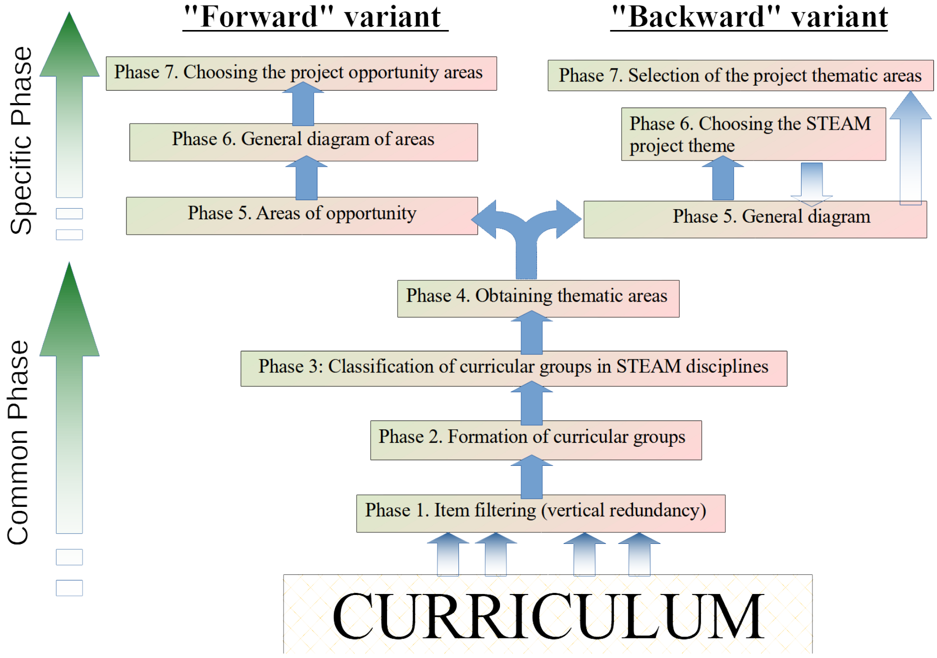

Figure 1. Diagram of the methodology for developing STEAM projects from the curricula).

3.1. Common Stage to the Two Variants of the Methodology

The first step for the application of both variants is to choose the course, the courses or the stage, in which the STEAM project will be developed. Once the recipients have been selected, the initial analysis of the curriculum begins in order to obtain the thematic areas that will consist of four phases:

- Phase 1. Item filtering (vertical redundancy): In this phase the redundant items, (An item is defined as a portion of content sumarized in a sentence), are searched in the curricula of the analysed courses, understanding that two items are redundant if they appear written exactly the same in two courses at least. In this phase, the redundancy index is also defined as the relationship between the number of vertically redundant items and the amount of initial items in the EU education law.
- Phase 2. Formation of curricular groups: In this phase, items with similar content are gathered in curricular groups, understanding that two items have similar contents if, within the same subject, they refer to the same concept, but focused from different learning perspectives.
- Phase 3. Classification of curricular groups in STEAM disciplines: The objective of this phase is unlinking the curricular groups from their subject of origin in order to classify them within one of the STEAM fields or disciplines. The classification of each curricular group within one area or another was carried out according to the definitions made by [2] for Science, Technology, Engineering and Mathematics and the Art definition made by the Rhode Island School of Design.
- Phase 4. Obtaining thematic areas: In this phase, the curricular groups of each STEAM discipline are reorganized, forming the thematic areas of each discipline. In this way, the thematic areas of each discipline bring together the curricular groups with content related to each other.

The implementation of the first two phases depends on the drafting of the curriculum of each country and the level of concreteness of the contents of each subject. For example, while the Spanish curriculum [44], is written with a very high level of detail and exactly the same items appear in different courses, in the Cypriot curriculum [45] the items are not repeated and are presented in curricular groups in each subject.

Once the curricular groups have been obtained, the STEAM classification is carried out in phase 3, in which two types of curricular groups are differentiated: conceptual and non-conceptual or procedural.

- The conceptual curricular groups are the ones directly related to the contents, they answer the question: what are we going to learn?
- Non-conceptual, or procedural, curriculum groups are those groups related to the learning process that are not specific to any STEAM discipline. They usually answer the question: how are we going to learn? In this type, curricular groups are classified as "autonomous and cooperative learning", "recognition of the work of others".

In phase 4, the thematic areas are also classified as conceptual and non-conceptual, or procedural, depending on whether they consist exclusively of conceptual or non-conceptual curricular groups.

3.2. Stage Specific to Each Variant

This stage is different in each of the variants: in the "forward" variant, the areas of opportunity that will be the main theme of the project are selected from the thematic areas with the highest number of connections, while in the "backward" variant, the main theme of the project is selected first and then we go back to look for its connections with the thematic areas obtained in the first stage.

Methodology of "Forward" Variant

The objective of this stage of the "forward" variant is to obtain the opportunity areas of STEAM projects, which can also be conceptual and non-conceptual, or procedural. An area of conceptual opportunity is defined as a thematic area belonging to a STEAM discipline that meets the necessary conditions to be the main theme of a STEAM learning project, so an area of opportunity must meet the characteristics of the challenge or challenging question of the project-based learning [30,46] and the characteristics of the generative topic of teaching for understanding [47]. From this perspective, an area of opportunity:

- Stands out for its centrality and breadth within the discipline
- Must be close to the students, connected to their reality, accessible to them and open and motivating enough to promote the whole project.
- Its study should allow to establish intra and interdisciplinary connections, that is, to relate with other areas within the discipline itself and with areas of other STEAM disciplines.

Non-conceptual areas of opportunity are made up of attitudinal and/or procedural contents. The contents of these areas of opportunity do not represent contents close to the students and are far from their daily reality, so it is considered that they cannot motivate and trigger a STEAM project, although their inclusion in STEAM projects is important.

This stage consists of three phases:

- Phase 5. Map of intra-disciplinary relationships and selection of areas of opportunity: In this phase, relationship maps are created between the thematic areas of each discipline. Two thematic areas are considered to be connected if an evident guiding principle can be found that allows them to be included within the same learning project. From the relationship maps, the thematic areas with the highest number of connections with the other areas are selected as areas of opportunity.
- Phase 6. Preparation of the general diagram: A general diagram is generated taking into account all the thematic areas: both areas of opportunity, conceptual and non-conceptual, and non-opportunity areas that will allow to relate all the areas to each other, see Figure 2.

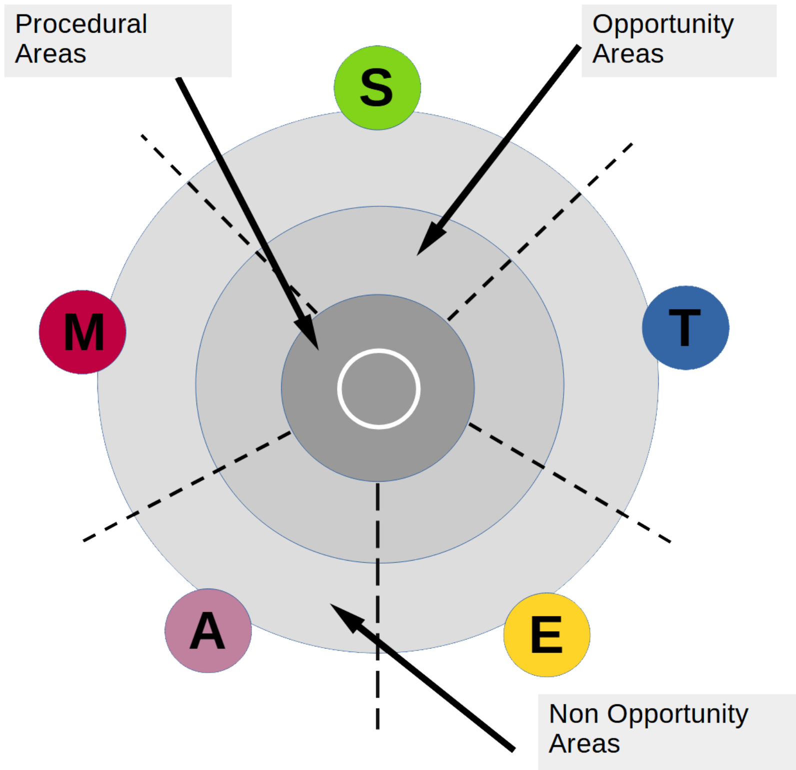

Figure 2. General diagram of "forward" methodology areas.

The diagram is divided into 5 sectors and three concentric circles. The sectors correspond to each of the STEAM disciplines and the areas of each discipline are placed in the concentric circles of each sector and therefore:

- The non-opportunity thematic areas are placed in the outer circle, that is, they do not have enough connections to trigger the STEAM project.
- Conceptual opportunity areas that do have a high number of connections are placed in the intermediate circle and they can therefore become the main theme of the STEAM project.
- The non-conceptual or procedural areas are placed in the inner circle.

- Phase 7. Choice of the area of opportunity and development of the STEAM project: In this phase, the area of opportunity is chosen, which will be the main topic on which the STEAM project will be developed, which, in order to be complete, must contain areas of each of the STEAM disciplines and, if possible, all the procedural areas of the inner diagram. This is a creative process in which countless STEAM projects can be developed for the same area of opportunity, being the teacher responsible for defining the theme of the project, its planning, its development, the use of active methodologies...

3.3. Methodology of "Backward" Variant

The objective of this stage of the "backward" variant is to define the main theme of the STEAM project and to seek its possible connections with the thematic areas of the curriculum obtained in the common stage to the two variants. This stage consists of three phases:

- Phase 5. General diagram: In this phase, a general diagram of areas similar to the "forward" variant is generated, with five sectors, one for each discipline, but with only two concentric circles, showing the conceptual thematic areas on the outside and the non-conceptual, or procedural, on the inside, see Figure 3.

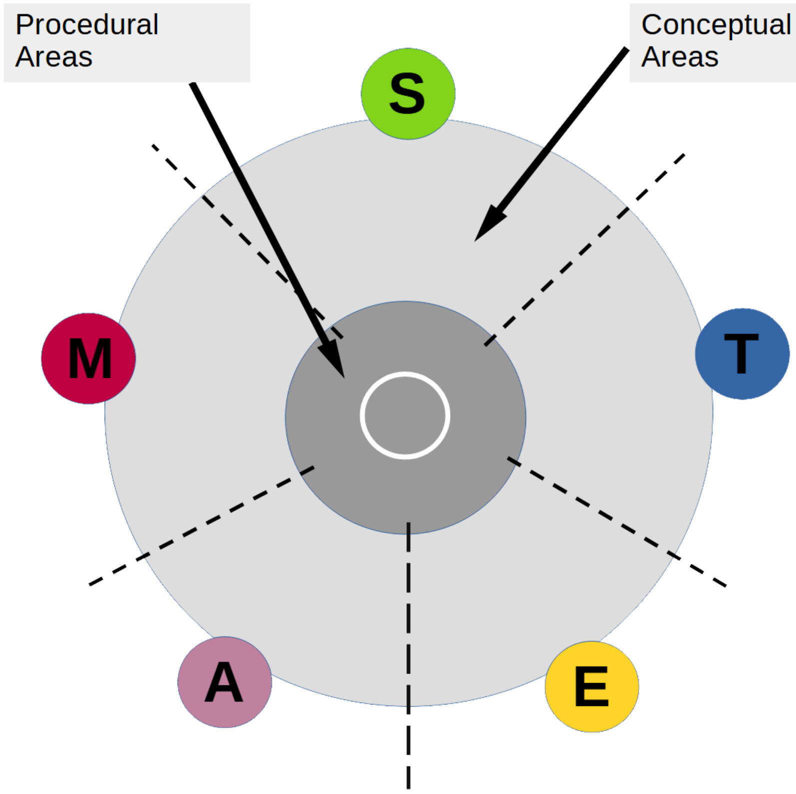

Figure 3. General diagram of "backward" methodology areas.

- Phase 6. Choosing the STEAM project theme: In this case, and unlike the "forward" variant, the theme does not come from an area of opportunity, but it can be taken from any theme generated by the teacher's or student's creativity. For the STEAM project to be considered as a quality project, the main theme must meet the same characteristics as the opportunity area of the "forward" variant: it must stand out for its centrality and breadth, be close to the student and sufficiently connected with the thematic areas of the curriculum obtained in the first stage of the methodology.
- Phase 7. Selection of the thematic areas of the project: At this time, once the main theme of the project has been chosen, we go back to phase 5 and from the diagram we select the thematic areas that have, explicitly or implicitly, connections with the main theme and that will be part of the STEAM project. In the same way as in the "forward" variant, for a STEAM project to be considered complete, it must contain thematic areas of each of the STEAM disciplines and, if possible, of all the procedural areas within the diagram.

3.4. Example of Application of the "Forward" Variant of the Methodology

3.4.1. Methodology Implementation

Regarding the example of the "forward" variant, in [48] the subjects of Mathematics, Natural Sciences, Social Sciences and Plastic Arts Education are analysed, given their direct relationship with STEAM subjects in the Primary Education curriculum.

Phase 1. Item filtering (vertical redundancy)

In the analysis of the curriculum, 269 vertical redundancies were detected out of a total of 1221 items that make up the curriculum of the four subjects of the stage with STEAM contents. Table 1 shows the quantitative data resulting from the search for these vertical redundancies of every subject.

Table 1. Summary of item filtering (vertical redundancy.)

	Mathematics	Natural Sciences	Social Sciences	Plastic Arts Education	Total
Initial curricular studies	466	296	169	290	1221
Redundant elements	131	68	6	64	269
Resulting curricular elements	335	223	163	226	952
Vertical redundancy index	0.28	0.23	0.04	0.22	0.22

The global index of redundancy is 0.22, which means that 22% of the contents are repeated in several courses. The most redundant subject is Mathematics with 0.28 and the least redundant is that of Social Sciences, with only 0.04 of redundant contents.

Phase 2. Formation of curricular groups

Once the vertical redundancies had been detected and the number of curricular items had been reduced to 922 items, the items of each subject with similar contents were gathered in "curricular groups". The results of phase 2 are shown in Table 2.

Table 2. Analysis of curricular variety.

	Mathematics	Natural Sciences	Social Sciences	Plastic Arts Education	Total
Non-redundant elements	335	228	163	226	952
Curricular groups	117	77	65	73	332
Curricular variety index	0.35	0.34	0.40	0.32	0.35

The overall curricular variety rate is 35%; moreover, this rate is quite similar in the four subjects, since it ranges from 32% in Plastic Arts to 40% in Social Sciences.

Phase 3: Classification of curricular groups in STEAM disciplines

Once the different curricular groups were established, the STEAM classification phase began, whose objective is to unlink the curricular groups from their initial subject in order to classify them within the STEAM disciplines. Table 3 summarizes quantitatively the STEAM classification assigned to each of the curricular groups.

Table 3. Analysis of curricular variety.

						STEAM		NO STEAM	
	S	T	E	A	M	Total	%	Total	%
Mathematics	0	5	28	0	75	108	92%	9	8%
Natural Sciences	36	16	18	0	0	70	91%	7	9%
Social Sciences	32	0	6	1	0	39	60%	26	40%
Plastic Arts Education	0	5	11	51	0	67	92%	6	8%
Total	68	26	63	52	75	284	86%	48	14%
%	24%	9%	22%	18%	26%				

Of the 332 curricular groups previously identified, 284 groups were classified within a STEAM discipline, that is 86%, which confirms the hypothesis that the subjects studied have a high degree of STEAM content. More than 90% of the curricular groups from the subjects of Mathematics, Plastic Arts and Natural Sciences are STEAM groups, while only 60% of the groups of Social Sciences are STEAM groups. The STEAM discipline of Technology is the one that provides the least number of curricular groups.

Phase 4. Obtaining thematic areas

In this phase, the curriculum analysis focused on bringing together the curricular groups related to each other and obtaining the thematic areas of each STEAM discipline. Table 4 shows the number of thematic areas found: 11 in Science, 4 in Technology, 9 in

Engineering, 5 in Art and 10 in Mathematics. In addition, the areas were classified into conceptual and non-conceptual or procedural.

Table 4. Summary of the collection and classification of thematic areas.

	S	T	E	A	M	Total
Conceptual thematic areas	10	2	9	4	8	33
Procedural thematic areas	1	2	0	1	2	6
Total	11	4	9	5	10	39

Phase 5. Areas of opportunity

To obtain the areas of opportunity, the five maps of intradisciplinary relationships were designed, one for each discipline, so that two areas were related if they could be included within the same learning project.

Table 5 shows the relationship maps and the connections between the thematic areas of the Science discipline; of the four areas with the highest number of connections, S1 is procedural, so only S4, S5 and S6 are considered areas of opportunity, that is, "The cell and living beings", "Ecosystems" and "Sustainability".

Table 5. Map of relationships and opportunity areas for Science. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic Area	Type	Connections
S1	Introduction to the scientific method	P	10
S2	The human body: structure and functions	C	5
S3	Health and Illness	C	4
S4	The cell and living beings	C	8
S5	Ecosystems	C	7
S6	Sustainability	C	9
S7	Weather and Climate	C	6
S8	Hydrosphere: water	C	6
S9	Lithosphere: reliefs	C	6
S10	The Solar System	C	1
S11	Economic and human activity	C	4

Table 6 shows the connections between the thematic areas of Technology, in which, following the same process, only the area T3, "Electrical machines and equipment", is considered as area of opportunity.

Table 6. Thematic areas for Technology. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic Area	Type	Connections
T1	Use of ICTs	P	2
T2	Property and security licenses in ICTs	P	3
T3	Electrical machines and equipment	C	3
T4	The adding machine	C	2

In the Engineering discipline (Table 7), the two conceptual areas with the highest number of connections are E1, E4 and E7; that is, the areas of opportunity are "Matter and materials", "Measurement: units, measurements and devices" and "Geometric drawings".

Areas A1 and A5, "The image: elements, value and functions" and "Plastic and audio-visual composition" are the conceptual areas with the highest number of connections of the Art discipline, so they are the areas of opportunity of the discipline (Table 8).

Table 7. Thematic areas for Engineering. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic Area	Type	Connections
E1	Matter and materials	C	5
E2	Electricity and magnetism	C	1
E3	Scales, maps and representations	C	2
E4	Measurement: units, measurements and appliances	C	5
E5	The measure of time	C	1
E6	The monetary system	C	1
E7	Geometric drawing	C	4
E8	Forces: gravity, friction and speed	C	3
E9	Waves: light and sound	C	2

Table 8. Thematic areas for Art. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic Area	Type	Connections
A1	The image: elements, value and functions	C	5
A2	Advertising: social function and elaboration	C	3
A3	The cinema and animated movies	C	3
A4	Interest in artistic events	P	4
A5	Plastic and audio-visual composition	C	4

Following the same process, two areas of opportunity have been obtained in the Mathematics discipline: M7, "Direct proportionality" and M10, "Statistics" (Table 9).

Table 9. Thematic areas for Maths. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic Area	Type	Connections
M1	Math problem solving	P	9
M2	Natural numbers	C	3
M3	Operations with natural numbers and mental calculation	P	9
M4	Fractions and decimals	C	4
M5	Proportionality and percentages	C	6
M6	Angles and sexagesimal system	C	4
M7	Flat figures: elements, perimeters and areas	C	6
M8	Geometric bodies	C	4
M9	Statistics	C	5
M10	Probability	C	4

Table 10 shows the 12 conceptual opportunity areas that have been obtained in the process, that is, the 12 areas that due to their characteristics can become the main topic of a STEAM project.

Phase 6. General diagram of areas

Figure 4 shows the diagram of areas in which all the thematic areas appear in their corresponding circular spaces: in the inner circle we have the 6 procedural areas, in the intermediate one we have the 12 areas of opportunity and in the outer one the 27 conceptual areas that are not considered as opportunity areas since they do not meet the necessary characteristics to become the main theme of the STEAM project.

Phase 7. Choosing the project opportunity areas

The area of opportunity chosen to develop the STEAM project has been the area of "Sustainability" that covers eight curricular groups, which cover items of Natural Sciences and Social Sciences from the six courses of Primary Education:

- Sustainable development
- Environmental balance
- Reducing, reusing and recycling
- Climate change

- Renewable and non-renewable sources
- Responsible use of energy
- Energy and sustainable development
- Shortage and depletion of resources

Table 10. Summary of the collection and classification of thematic areas.

STEAM Discipline	Opportunity Area
Sciences	S4 The cell and living beings S5 Ecosystems S6 Sustainability
Technology	T3 Electrical machines and appliances
Engineering	E1 Matter and Materials E4 Measurement: units, measurements and appliances E7 Geometric drawings
Art	A1 The image: elements, value and functions A5 Plastic and audio-visual composition
Maths	M5 Proportionality and percentages M7 Flat figures: perimeters and areas M9 Statistics

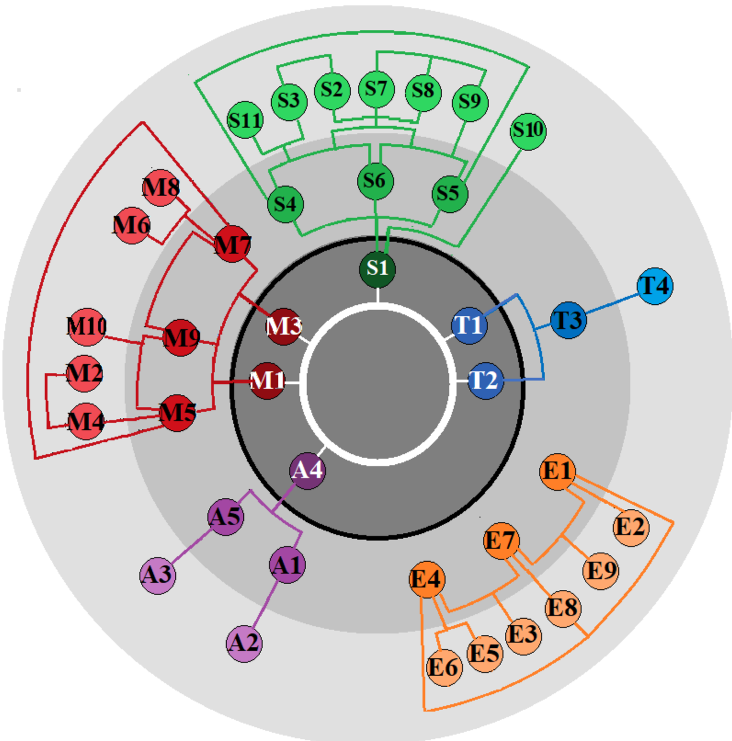

Figure 4. General diagram of areas.

The area of opportunity "Sustainability" is related, explicitly or implicitly, to all the thematic areas of its discipline, except the area "Solar System". It is also related to 15 thematic areas of the other disciplines: 4 procedural areas, 8 opportunity areas and 3 non-opportunity conceptual areas (Figure 5), which covers a large part of the entire Primary Education curriculum.

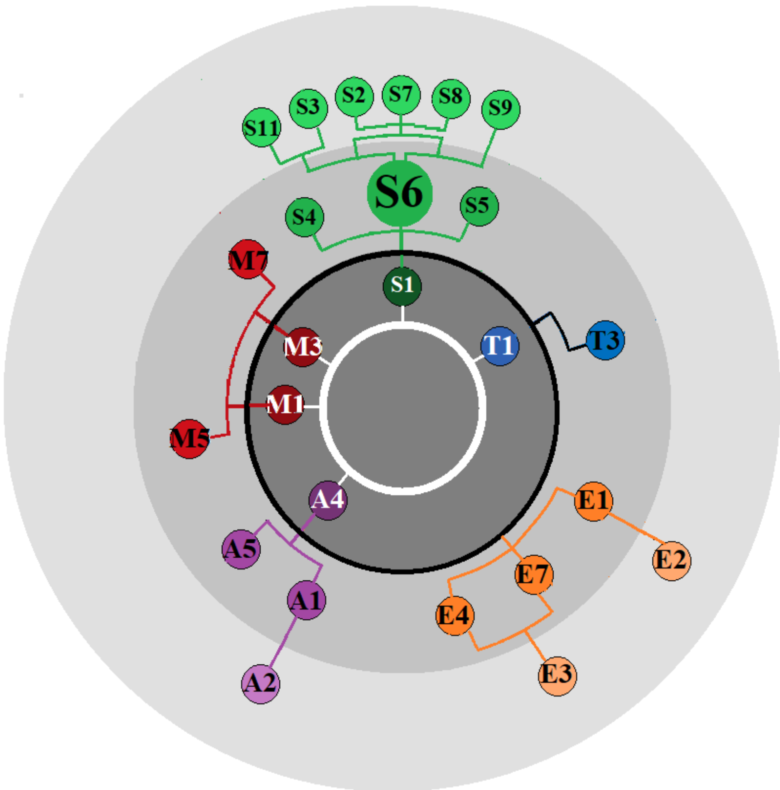

Figure 5. Summary of the collection and classification of thematic areas.

3.4.2. STEAM Project, "Sustainable City"

The project "Sustainable City", refs. [49,50] is an example of a STEAM project designed for primary school students, which uses educational robotics as a mean of learning and the opportunity area "Sustainability" as the main theme. In the project, the participants must build a board with different elements that will make up a sustainable city and program a robot to follow a line marked on the board and activate the different elements of the sustainable city. The city presented in the project is an inclusive, resilient and sustainable city, capable of adapting to social and environmental changes, which uses resources efficiently and with a reduced environmental impact.

3.5. Example of Application of the "Backward" Variant of the Methodology

In the example of the "backward" variant, in [51] all the subjects of the Secondary Education curriculum were analysed, both core and specific compulsory and optional, related in some way to the STEAM disciplines: Biology and Geology, Physics and Chemistry, Mathematics, Technology, Plastic Arts Education, Computer Science and Information and Communication Technologies, Sciences applied to professional activity and Scientific Culture.

Phase 1. Item filtering (vertical redundancy)

In the analysis of the curriculum, 846 vertical redundancies were detected out of a total of 2291 items that make up the curriculum of the stage with STEAM contents. Table 11 shows the quantitative data resulting from the search for these vertical redundancies of every subject.

The global index of redundancy is 0.37, which means that 37% of the contents are repeated in several courses. The most redundant subject is that of Mathematics with 0.62 and on the contrary, the subjects Applied Sciences and Scientific Culture do not have redundant items when taught in a single course.

Phase 2. Formation of curricular groups

Once the vertical redundancies had been detected and the number of curricular items had been reduced to 1445, the items of each subject with similar contents were gathered in "curricular groups". The results of phase 2 are shown in Table 12.

Table 11. Summary of item filtering (vertical redundancy).

	B and G	Phy and Ch	M	T	PE	CS and ICT	AS	SC	Total
Curricular items	84	91	717	158	919	267	34	21	2291
Redundant items	18	16	448	53	194	127	0	0	846
Non-redundant items	66	75	269	105	725	140	34	21	1445
Curricular variety index	0.21	0.18	0.62	0.34	0.21	0.48	0.00	0.00	0.37

Table 12. Summary of item filtering (vertical redundancy).

	B and G	Phy and Ch	M	T	PE	CS and ICT	AS	CS	Total
Non-redundant items	66	75	269	105	725	140	34	21	1445
Curricular items	30	43	91	33	126	37	16	12	388
Curricular variety index	0.46	0.57	0.34	0.31	0.17	0.26	0.47	0.57	0.27

The overall curricular variety index is 27%, ranging from 17% for Plastic Arts Education to 57% for Scientific Culture.

Phase 3: Classification of curricular groups in STEAM disciplines

Once the different curricular groups were established, the STEAM classification phase began, whose objective is unlinking the curricular groups from their initial subject in order to classify them within the STEAM disciplines. Table 13 summarizes quantitatively the STEAM classification assigned to each of the curricular groups.

Table 13. Summary of curricular group classification in STEAM disciplines.

ID	S	T	E	A	M	Total STEAM	Total No STEAM
Biology and Geology	29	0	0	0	0	29	1
Physics and Chemistry	5	4	34	0	0	43	0
Mathematics	1	5	0	0	75	81	10
Technology	1	17	9	1	0	28	5
Plastic Arts Education	0	8	14	89	2	113	13
Computer Science and ICT	1	23	0	0	0	24	13
Applied Sciences	13	2	1	0	0	16	0
Scientific Culture	7	1	2	0	0	10	2
Scientific Culture	7	1	2	0	0	10	2
Total	57	60	60	90	77	344	44

Of the 388 curricular groups previously identified, 344 groups were classified within a STEAM discipline, that is 86%, which confirms the hypothesis that the subjects studied have a high degree of STEAM contents.

Phase 4. Obtaining thematic areas

In this phase, the curriculum analysis focused on bringing together the curricular groups related to each other and obtaining the thematic areas of each STEAM discipline. Tables 14–18 show the number of thematic areas found: 7 in Science, 9 in Technology, 8 in Engineering, 8 in Art and 80 in Mathematics. In addition, the areas were classified into conceptual and non-conceptual or procedural.

Table 14. List of thematic areas obtained for the Science discipline. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic Area	Type
S1	The scientific methodology	P
S2	The Universe	C
S3	Earth history and evolution	C
S4	The cell	C
S5	The human body	C
S6	Living beings	C
S7	Sustainability and Pollution	C

Table 15. List of thematic areas obtained for the Technology discipline. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic Area	Type
T1	Hardware and software	P
T2	Security in ICTs	P
T3	ICTs in research and projects	C
T4	Office automation	C
T5	Multimedia productions	C
T6	Networks	P
T7	Programming	P
T8	Electronics and robotics	C
T9	Electrical machines and circuits	C

Table 16. List of thematic areas obtained for the Engineering discipline. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic area	Type
E1	Materials	C
E2	Atomic structures	C
E3	Matter	C
E4	Chemistry	C
E5	Chemical reactions	C
E6	Forces, work and machines	C
E7	Energy	C
E8	Layouts and representation	P

Table 17. List of thematic areas obtained for the Art discipline. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic Area	Type
A1	Language and audio-visual communication	P
A2	Elements of graphic design	P
A3	Graphic techniques and strategies	P
A4	The comic	C
A5	Photography	C
A6	Advertising	C
A7	The moving image	C
A8	Graphic design	C

Phase 5. General diagram

In the diagram of thematic areas in Figure 6, the non-conceptual, or procedural, thematic areas are placed in the inner circle and the conceptual thematic areas in the inner one.

Table 18. List of thematic areas obtained for the Maths discipline. (Note: C: conceptual, P: non-conceptual or procedural).

ID	Thematic Area	Type
M1	Numbers and operations	P
M2	Problem solving	P
M3	Algebraic expressions	P
M4	Proportionality and percentages	C
M5	Plane geometry	C
M6	Solid geometry	C
M7	Statistics	C
M8	Probability	C

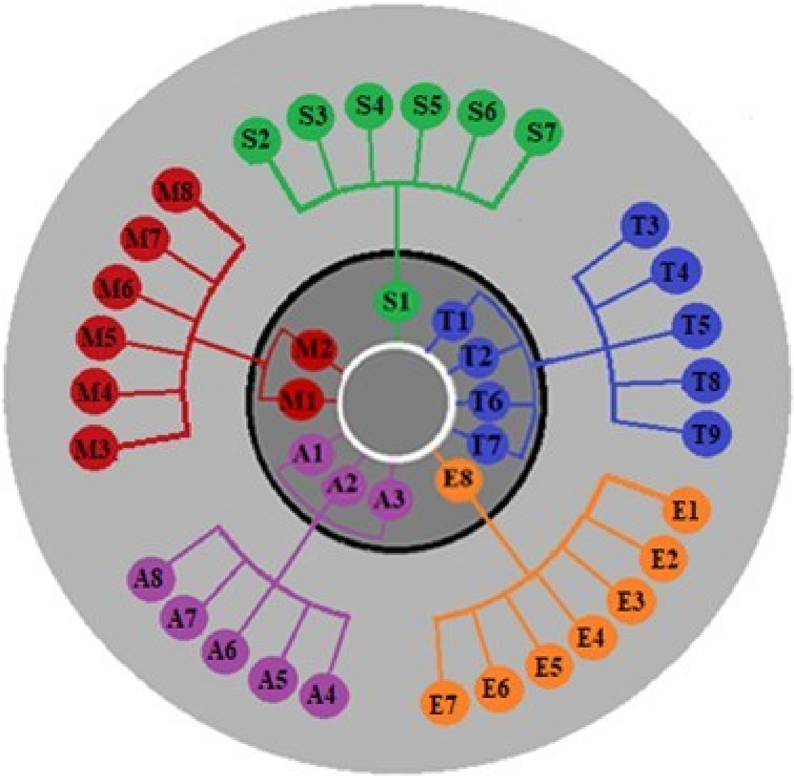

Figure 6. Diagram of Secondary Education.

Phase 6. Choosing the STEAM project theme

In the proposed example, cooking was chosen as the main theme of the project to be developed because it is an everyday activity and can generate many synergies with a multitude of thematic areas.

3.6. Phase 7. Selection of the Project Thematic Areas

Once the main theme was chosen, we went back to phase 5 and selected the thematic areas related to the theme of cooking. Table 19 shows the thematic areas related to the topic in each of the 10 sessions of the STEM-Cooking project.

In the STEM-Cooking project, 35 of the 40 thematic areas have been explicitly or implicitly addressed: 11 procedural areas and 24 conceptual areas; that is, 87.5% of the thematic areas included in the entire curriculum. Only two areas of the discipline of Science ("History and evolution of the Earth" and "The universe"), an area of Engineering ("Forces and work") and two areas of Mathematics ("Statistics" and "Probability") have been addressed. Figure 7 shows the design of the thematic areas covered in the development of the STEAM-Cooking project.

Table 19. Themes in STEAM-Cooking and its relationship with the thematic areas.

ID	Topic	STEAM thematic areas
1	Art	S(1,5,7), T(1,3,4,5,9), E(3,5,7,8), A(1,2,3,4,5,6,7,8), M(5,6)
2	Advertising	S(5,7), T(1,2,3,4,5,6,7,8,9), E(3,5,7), A(1,2,3,4,5,6,7,8), M(5,6)
3	Biology	S(1,4,5,7), T(1,3,4,5,6,9), E(1,3,5,7), A(5,7), M(1,2)
4	Maths	S(1,5,6,7), T(1,3,4,5,9), E(3,5,7), A(5,7), M(1,2,4)
5	Economy	S(5,7), T(1,3,4,5,9), E(3,5,7), A(5,7), M(1,2,3,4,6)
6	Sustainability	S(5,7), T(1,3,4,5,9), E(3,5,7), A(5,7), M(1,2,3,4,6)
7	Chemistry	S(1,5,7), T(1,3,4,5,9), E(2,3,4,5,7), A(5,7), M(1,2,3,4)
8	Physics	S(1,5,7), T(1,3,4,5,9), E(1,3,4,5,7), A(5,7), M(1,2,3,4)
9	Technology	S(1,5,7), T(1,3,4,5,8,9), E(1,3,5,7), A(5,7), M(1,2,4,5,6)
10	Product design	S(1,5,7), T(1,3,4,5,8,9), E(1,3,5,7,8), A(5,6,7,8), M(1,2,5,6)

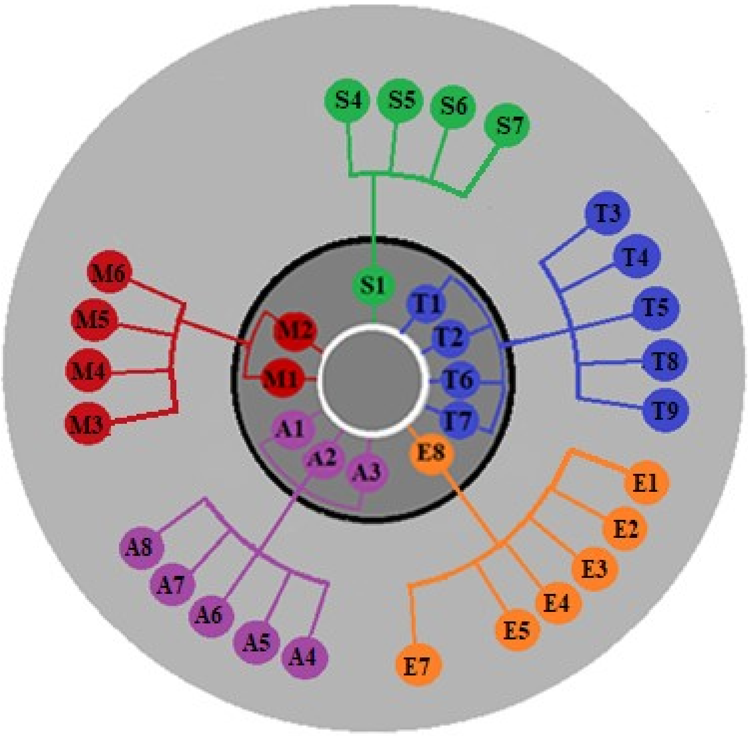

Figure 7. Diagram of STEAM-Cooking project.

Implementation of the STEAM-Cooking Project

The STEAM Cooking project is defined as a competition in which students must overcome different challenges related to different topics. The phases of the competition will be as follows:

- Registration Teams will register for the competition via the website (https://steamcocina.dart4city.eu/, (accessed on 3 February 2022)). In the registration they must provide a name of the team, which must be appropriate and pertinent to the theme of the Contest, and a video presentation of 1 to 3 min, arguing and defending their skills and motivation to participate in it.
- Phase 0 The organization selects 20 teams. The selected teams are invited to an online meeting where the competition rules and the use of the training platform are explained. The teams can present themselves and perform a dynamic work with the rest of the teams.
- Phase 1 In this phase, participants will have access to different training materials, whether texts, videos, websites or applications, to learn about the 10 topics proposed. On each of these contents, a theoretical-practical activity will be proposed, which must be delivered in the format and place indicated for each of them (presentation,

video, Padlet, mind map, infographic, etc.). Each topic and its corresponding activity are scheduled to take place in one week, although the final delivery deadline will be closed at the end of phase 1, for final evaluation and score distribution. At the end of this phase, a classification or ranking is generated with the awarded score in each topic. At this stage, a new theme will be proposed each week. This topic is published on the content website with information, links to other websites, documents, videos... to enhance self-learning. For every topic/week, a master class is also scheduled on the topic. The speakers of each master class are specialists in the topic, offering additional information to the material provided on the web. Masterclasses are saved and uploaded to the content account on Youtube channel (https://www.youtube.com/channel/UCG3LvyUZebB2mownnzRD4jQ (accessed on 3 February 2022)).
Phase 2. The teams will have 3 weeks to formalize their proposal in which they must define and argue a one-day menu, putting into practice the contents learned and complying with the instructions indicated on the website for this phase. The Jury will evaluate and score the proposals of phase 2, adding the points to those obtained in phase 1. The top 5 teams will move on to the final phase. Phase 3. The finalists classified for this phase will be summoned to a face-to-face session where they will present the project developed in phase 2 and will cook 3 dishes from their menu (main course, second course and dessert). The Jury will evaluate and taste the dishes presented and will award the corresponding points that will decide on the final classification. This score will be independent of that obtained in phases 1 and 2.

4. Conclusions

This article presents a new methodology for developing STEAM projects through the national curricula of each country. The methodology proposed in this article is part of the results of the project ERASMUS+ Project DART4City (2020-1-ES01-KA227-SCH-095545) Empowering Arts and creativity for the cities of tomorrow, whose objective is designing a methodology in order to develop STEAM projects from European curricula. The methodology obtained is the result of the curricular analysis of the vast majority of European countries including, among others, Spain, Italy, Cyprus, France, Finland and Germany. The main difference detected among them is the granularity or level of detail in the contents: while the Spanish curriculum has an excessive level of detail that makes its analysis difficult, a curriculum such as that of Cyprus provides the grouped contents almost directly. In terms of contents, level of applicability... all curricula are very similar, which makes all STEAM projects developed in one country easily transferable to another one. The proposed methodology has two variants: the "forward" methodology and the "backward" methodology. The "forward" methodology begins with the analysis of the curriculum, grouping the contents of the subjects into STEAM disciplines and looking for connections between them until finding the areas of opportunity, thematic areas with the greatest number of connections.. STEAM projects are designed from an area of opportunity, which guarantees a large number of connections with thematic areas and maximizes the project results. This type of methodology would be more aimed at member states and administrations that want to promote STEAM projects in schools. The "backward" methodology starts from an idea, or concept, and, from the idea, the connection with the curriculum, thematic areas, is sought. This other variant would be more focused on teachers interested in developing STEAM projects. As future work, we intend to use the Dart4city project to develop, implement and test different STEAM projects in Spain, Italy and Cyprus. These projects will be deposited on the project website https://dart4city.eu/, (accessed on 3 February 2022).

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