STEM School Label

STEM School Label Project Output 1

European STEM Schools Report

KEY ELEMENTS AND CRITERIA

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EXECUTIVE SUMMARY

RATIONALE

This publication presents the results of an analysis developed to establish and validate the definition of a STEM (Science, Technology, Engineering and Mathematics) school. It describes (1) which are the key elements and criteria that should be taken into account when defining a STEM strategy at school level, which would ultimately characterise a STEM School, and (2) how the different phases in the information-gathering process to select these key elements and criteria were developed.

It responds to the fact that STEM education has become a priority in European countries and strategies are being developed to improve teaching and learning and the uptake of studies and careers in STEM. The information provided in this report is based on a literature review and on consultations with four groups of key stakeholders in STEM education: schools, STEM teachers, Ministries of Education and STEM industries.

The report is written within the framework of the STEM School Label project, co-funded by the Erasmus+ Programme of the European Union (Grant Agreement N. 2017-1-BE02-KA201-034748. The STEM School Label project will develop a framework where school representatives will be able to evaluate their school's performance in STEM via an online self-assessment tool, according to the set of criteria defining a STEM School from this report. This self-assessment tool will help schools identify required areas of development and will provide suggestions of resources for applicant schools to improve their STEM activities at school level.

DEVELOPMENT OF KEY ELEMENTS AND CRITERIA TO DEFINE A STEM SCHOOL

The first step, in order to identify an initial set of key elements and criteria that describe a STEM School, consisted of a literature review, analysing the existing definitions, frameworks and classifications of the concept of a STEM School. Creating a common or even clear definition of a school of this kind is still a complicated task, as the existing research efforts on the issue often appear isolated. Furthermore, STEM-focused schools are normally established in East-Asian countries or in the United States and do not appear to be common in European countries. However, some American frameworks were considered, including the Wisconsin *STEM Education Program Self-Evaluation Rubric*, the University of Chicago *STEM School Study: The Eight Essential Elements of Inclusive STEM Schools*, the *Carnegie STEM Excellence Pathway*, the *Arizona STEM immersion Guide*, and the *Indiana STEM Strategy*, from the Indiana Department of Education. Only one European framework was found, in the Flemish Community of Belgium, entitled *STEM Framework for Flemish Schools: Principles and Objectives*.

The second step was the development of consultations addressed to four groups of stakeholders (schools, STEM teachers, Ministries of Education and STEM industries) identified as key actors in STEM education and in possession of relevant understandings to challenge, confirm and expand the initial set of key elements and criteria. An initial survey was developed targeting a number of European schools (see Section 1. Survey of schools). Further consultations were addressed to STEM teachers, Ministries of Education and STEM industries (see: 2. Survey of STEM teachers, 3. Consultation of Ministries of Education, and 4. Consultation of STEM industries).

1. Survey of schools

The respondents to the survey of schools included the organisations of the four STEM School Label project partner countries (Serbia, Portugal, Lithuania and France), as well as schools from five additional countries (Romania, Iceland, Finland, Norway and Belgium (Flanders)). At the end of the survey process, 31 responses were collected from nine different countries, which helped clarify the different elements and criteria.

2. Survey of STEM teachers

195 STEM teachers from 31 different countries completed an online survey (192 respondents from 29 European countries and three from three non-European countries, namely Zambia, the United States and India). Of the European teachers, 185 concurred with the STEM School Label criteria, representing 96% of the total and leaving only seven of them (4%) in disagreement.

Out of the 185 affirmative answers, 151 agreed that the list of key elements and criteria was exhaustive enough and that no additional criteria should be added. Nevertheless, 30 teachers mentioned that extra criteria could be integrated and 21 of them made specific comments about this.

3. Consultation of Ministries of Education

19 Ministries of Education, belonging to European Schoolnet's Ministry of Education STEM representatives Working Group (MoE STEM WG), were contacted to provide feedback on the key elements and criteria defining a STEM-oriented school. The responses ranged from appreciation of the development of this STEM School criteria, to specific comments clarifying the key elements, adding missing stakeholders to some criteria, or expanding some criteria.

4. Consultation of STEM industries

A number of companies were also approached, taking into consideration their interest and involvement in STEM education and in projects promoting its improvement. For this reason, the companies contacted were selected among active members of two European Schoolnet-led projects: the privately funded STEM Alliance initiative and the Erasmus KA2 project SYSTEMIC. While the exhaustiveness of the key elements defining the strategy of a STEM School was confirmed, the need to include more detailed information within the definition of some criteria was highlighted.

Advisory Board

Finally, the members of the STEM School Label Pedagogical Advisory Board (PAB) were consulted, to ensure the validity of the results.

IMPROVEMENT OF THE KEY ELEMENTS AND CRITERIA TO DEFINE A STEM SCHOOL

Overall, these various consultations revealed extensive satisfaction with and approval of the initial set of key elements and criteria defining a STEM School. These results are highly relevant, given that these impressions were collected from key stakeholders in the provision and development of STEM education. Nevertheless, the consultations also revealed that a number of key elements and/or criteria could be refined.

The remarks from schools and teacher respondents and the consultations with Ministry of Education and industry representatives led to some adjustments of the initial key elements and criteria that should be included in the definition of a STEM School. Examples of elements and criteria that had to be refined included:

- It was made especially clear that teachers interpreted differently what each of the criteria within *Assessment* (that is, continuous and personalised) meant and that this needed to be clarified.
- Concerning School *infrastructure*, the boundaries between *Access to technology and equipment* and *High-quality instruction materials* were not clear enough and/or the criteria were too general.
- The industry representatives approached also noted the need for a better definition of some of these criteria. This was especially relevant regarding *Assessment*, *Connections* (specifically, connections with other schools and/or educational platforms) and *School infrastructure* (particularly regarding High-quality classroom instruction materials).
- The term "interdisciplinary" was repeated throughout the consultation results, stressing the importance of criteria not operating alone but being connected to one another.
- Ministry of Education representatives suggested some additional criteria to better define STEM Schools, which confirmed the results from the previous consultations with STEM teachers and industry representatives. The key elements *School infrastructure*, *Professionalisation of staff*, *School leadership and culture*, and

Assessment were deemed to need a more in-depth and clarifying definition; and in regard to the criterion *Connections*, linkages with universities were once more mentioned as relevant.

- In addition, the key element *Instruction* was repeated a number of times as being of great importance but in need of further clarifications (it should be noted that this was also acknowledged in the survey of teachers, in relation to the importance of better characterising the pedagogical approaches stated and better contextualising the STEM disciplines). Lastly, Ministries of Education also stressed the relevance of stating the interdisciplinary character of STEM education in all the criteria that were set out.
- *Project-Based Learning* was included under *Instruction*, alongside *Problem-Based Learning*.
- *Connections with universities and research centres* and *Connections with local communities* were both criteria added under the key element *Connections*.
- The wording of the *School infrastructure* key element was improved. Particularly, it was specified how *Equipment* was inherent to the criterion *Access to technology*;
- Contextualisation of STEM teaching, referred to as *Connection of the lessons in the classroom to real-world experiences*, was added under the key element *Curricula*.
- The key element *Curricula* was changed to *Curriculum implementation*.
- The criterion *Specialised STEM curriculum* was changed to *Emphasis on STEM topics and competences (school developing a curriculum emphasising STEM subjects or topics and STEM key competences)*.

FINAL KEY ELEMENTS AND CRITERIA TO DEFINE A STEM SCHOOL

Following the different interventions, discussions and amendments, the final elements and criteria that a school's STEM strategy needs to fulfil in order to be considered a STEM School are:

- **Instruction**
  - Personalisation of learning. Instructional approaches intended to address the different learning needs, interests or cultural backgrounds of students.
  - Problem- and Project-Based learning (PBL). Student-centred pedagogy in which students learn about subjects by solving open-ended problems and/or projects, either individually or collaboratively.
  - Inquiry-Based Science Education (IBSE). Learning process in which questions, problems and scenarios are presented to students, including case studies, fieldwork, investigations or research projects, etc.).
- **Curriculum implementation**
  - Emphasis on STEM topics and competences. School developing a curriculum emphasising STEM subjects or topics and STEM key competences.
  - Interdisciplinary instruction: Teaching methodology aimed at giving instruction across different extracurricular disciplines, STEM subjects, including preparation within interdisciplinary teacher groups.
  - Contextualisation of STEM teaching. Connection of the lessons in the classroom to real-world experiences.
- **Assessment**
  - Continuous assessment. Assessment typology where students are examined continuously.
  - Personalised assessment. Assessment typology framed to demonstrate whether pupils have met specific educational goals, according to their personal development.
- **Professionalisation of staff**
  - Highly qualified professionals. Specialisation in STEM.
  - Support for (pedagogical) staff.
  - Professional development. Initial and continuous professional development for teachers, Heads of School, and career counsellors.

- **School leadership and culture**
  - School leadership. Existence of governing boards, management teams, etc.
  - High level of cooperation among staff.
  - Inclusive culture. Sharing of success, respect for colleagues' ideas, etc.
- **Connections**
  - With industry
  - With parents and guardians
  - With other schools and/or educational platform
  - With universities and/or research centres
  - With local communities
- **School infrastructure**
  - Access to technology and equipment
  - High-quality classroom instruction materials.

Of course, all the criteria do not operate alone but are connected to one another, and STEM Schools should have it in their plan to re-evaluate their STEM strategy on a regular basis. Moreover, when referring to a "STEM School", the criteria should always be considered in regard to STEM education. When the criteria are fulfilled for all subjects and at whole-school level, it was decided that we would be referring to a "Leading School".

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1.1 RATIONALE

In a number of countries in Europe, Science, Technology, Engineering and Mathematics (STEM) education has become a current priority and strategies are developing in order to improve STEM literacy, STEM teaching and learning, as well as the uptake of studies and careers in this area. This is partly due to the following reasons:

Students' low results in science, paired with a growing demand for STEM professionals

According to OECD's PISA 2015 results, only 12 of the 72 countries and economies assessed have seen their science performance improve since 2006. Moreover, in the EU, the average proportion of low achievers in science is 20.6%, more than 5% above the benchmark set for 2020. At the same time, there is a growing demand for professionals in STEM, which is met with a significant labour shortage in these fields. "Concerns (...) rely on two basic facts: the proportion of students going into STEM is not increasing at the European level and the underrepresentation of women persists."[1] For this reason, further initiatives need to examine what motivates young people and especially girls to learn and how to improve their attitudes to and their engagement with school.

Provision of pre-service training and in-service training for STEM teachers and guidance and evaluation tools for school leaders

In addition, there is a need to provide STEM teachers with pre-service, in-service and continuous professional development training, and to provide school leaders with guidance to develop STEM strategies at school level, capitalising on various existing isolated initiatives at European level. Recruiting and effectively training teachers is essential for successfully equipping pupils with the skills they will need, not only for a possible future career but also for their everyday life. Besides, it is also important for school leaders to possess self-evaluation tools to understand their schools' strengths, shortcomings and, therefore, possible needs.

1.2 AIM OF THE EUROPEAN STEM SCHOOLS REPORT

The present report describes the key elements and criteria that should be taken into account when defining a STEM strategy at school level, which would ultimately characterise a STEM School. For this reason, it has been structured in three main sections. **The first one, serving as a preface,** contains an initial literature review setting out existing definitions, frameworks and classifications of the concept of STEM School. This aims at identifying characteristics that should be included in the definition of a STEM School (and that could ultimately be used to develop a STEM School Label).

The second section aims at further developing and validating the definition of a STEM School, composed of a number of key elements and criteria, initially identified through the literature review. This process has been done through consultations with four groups of stakeholders, identified as key actors in STEM education and in possession of relevant understandings to set up the criteria mentioned. They are as follows: schools, STEM teachers, Ministries of Education and STEM industries.

However, the initial idea was to develop the consultation focused on just one of the stakeholders mentioned: the schools. For this reason, and in order to validate the key elements and criteria of a STEM School, a survey was developed and distributed among partner organisations, to be completed in relation to a selection of schools advanced in STEM. This survey contained a number of key elements and criteria that were to be reviewed as relevant or non-relevant, giving reasons for the choice. However, this initial analysis had a number of limitations. The most conspicuous of these were the very different number of respondents per country, compromising the results and making any quantitative analysis unattainable; and the lack of enough information for each of the criteria on why it was chosen as relevant or not and the lack of a variety of stakeholders and, therefore, points of view.

1 - Caprile, M. et al. (2015) Encouraging STEM studies for the labour market. European Parliament: Policy Department A: Economic and Scientific Policy. Accessible: http://www.europarl.europa.eu/RegData/etudes/STUD/2015/542199/IPOL_STU(2015)542199_EN.pdf

In consequence, these first results were complemented and further validated by developing extra consultations (closely linked to the survey of schools) with additional groups of stakeholders. Those were: industry representatives, Ministries of Education, and STEM teachers. By validating the initial key elements and criteria identified on a larger scale and with a more varied range of respondents, the report would give a representative definition of a STEM School. The procedures and results of all of these consultations are included in this section.

The third part provides the concluding remarks, derived from a summary of the key elements and criteria defining a STEM School (delineated through the literature review and complemented/validated through analysis of the different stakeholders' responses).

Finally, it should be mentioned that all the information provided in this report (Intellectual Output 1 of the Erasmus+ KA2 project STEM School Label) will serve as a first step for providing the definition of the reference framework for schools to be labelled a STEM School (Intellectual Output 12 of the STEM School Label Erasmus + KA2 project). This reference framework will be used to develop a self-assessment tool for schools that can serve as a basis to create the parameters to obtain a STEM School Label (main output of the Erasmus+ STEM School Label project).

LITERATURE REVIEW

2.1 SCHOOLS ADVANCED IN STEM

The aim of creating a common or even clear definition of a STEM School remains a complicated task, as often, the existing research efforts on the issue appear isolated. As Slavit (2016) points out, "there has been a recent worldwide movement to develop STEM-focused schools" and "many countries have developed specialised programmes and schools that focus on STEM". Most of these are established in East-Asian countries or in the United States and they do not appear to be common among European countries.

However, there are a few examples of STEM-oriented schools in Europe. This is the case with the *Collèges Lamap* in France, lower secondary schools established through the Foundation *La main à la pâte*. These are actively promoting and fostering creative, formative science and technology classroom practices and collaborate intensively with French universities, research laboratories and various companies.[2] In addition, other European experiences support STEM-oriented schools – for instance, the STEM Schools in Flanders or the Science Learning Partnerships[3] in England. These are led by local teaching school alliances, schools and colleges with excellence in science, higher education institutions, and other local partners with advanced expertise in science, and combine expertise in science teaching and learning, facilitating Continuous Professional Development and providing school-to-school support.

2.2 REFERENCE FRAMEWORKS AND KEY ELEMENTS IN SCHOOLS ADVANCED IN STEM

A number of common elements concerning STEM Schools were identified following an initial analysis of the existing literature on the topic. The first one refers to school types, as pointed out by Erdogan and Stuessy (2015), the National Research Council (2011), and Slavit (2016). STEM Schools appear to be primarily classified as selective STEM Schools, inclusive STEM Schools, or schools with a STEM-focused career and technical education (CTE) (Erdogan and Stuessy, 2015). CTE schools focus on preparing students to embark on STEM-related careers, often with the broader goal of increasing engagement to prevent them from dropping out of school.[4] Finally, STEM magnet schools, while also targeting STEM aligned themes and curricula, encompass a strong student diversity element.[5] Nonetheless, while not undervaluing this typology, it should be noted that it is framed in the K-12 American model.

Aside from school type classifications, a few STEM School frameworks have been developed and/or established, although again mostly applying to schooling in the United States. Among these, we should draw attention to the Wisconsin *STEM Education Program Self-Evaluation Rubric*,[6] the University of Chicago *STEM School Study: The Eight Essential Elements of Inclusive STEM Schools*,[7] the *Carnegie STEM Excellence Pathway*,[8] the *Arizona STEM immersion Guide*,[9] and the *Indiana STEM strategy*, from the Indiana Department of Education.[10] Most of these reference frameworks encompass similar key elements defining a STEM School (such as school leadership, community relations, curriculum development, instructional strategies and evaluation aspects). Only one European framework has been found, in the Flemish Community of Belgium. Entitled *STEM Framework for Flemish Schools: Principles and Objectives,* it has been created by the Ministry of Education and specifically designed for schools to make use of it.[11]

Other literature also identifies various criteria to classify STEM Schools. For instance, LaForce et al. (2016) use a typology that separates instructional, non-instructional and supporting elements. Another American approach separates

2 - *La main à la pâte* pilot schools. Accessible: https://www.fondation-lamap.org/fr/colleges-pilotes

3 - Science Learning Partnerships. Accessible: https://www.stem.org.uk/science-learning-partnerships

4 - STEM schools: Identification criteria, reference frameworks, self-evaluation tools or rubrics, certification. Yves Beernaert, Magda Kirsch. (2017) Educonsult.

5 - Magnet Schools of America. Accessible: http://magnet.edu/about/contact-us

6 - STEM Wisconsin. Accessible: http://www.wistem.org/

7 - Chicago STEM School Study. Accessible: http://outlier.uchicago.edu/s3/

8 - Carnegie STEM Excellence Pathway. Accessible: http://www.carnegiesciencecenter.org/stemcenter/carnegie-stem-excellence-pathway/

9 - Arizona STEM immersion Guide. Accessible: http://stemguide.sfaz.org/

10 - Indiana STEM strategy. Accessible: https://www.doe.in.gov/ccr/indiana-stem-education-science-technology-engineering-and-mathematics

11 - STEM Framework for Flemish Schools Principles and Objectives. Accessible: https://onderwijs.vlaanderen.be/sites/default/files/atoms/files/STEM-kader%20%28Engels%29.pdf

components related to curriculum, instruction, assessment, and professional development, in an attempt to define what we can consider a STEM School. (STEM Smart brief (2016)). Other classifications prefer to identify very specific dimensions – such as the acquisition of 21st century skills or the strategic use and development of technology – as necessary elements to define a STEM School. It is also interesting to point out how contextual factors are highlighted by some authors such as Slavit et al. (2016) and Erdogan and Stuessy (2015), mostly referring to external learning standards, such as the curriculum or instructional practices, as key elements in the development of a STEM School.

HOW TO VALIDATE STEM SCHOOL KEY ELEMENTS AND CRITERIA

3.1 SURVEY OF SELECTED SCHOOLS ADVANCED IN STEM

With the information extracted from the literature review, a number of key elements and criteria were selected and a survey of schools was designed to complement and validate them. The objective of the survey was to validate a set of key elements existing in schools advanced in STEM and identified from the literature review, and to adjust these key elements to school practices to make sure they were representative and exhaustive of a STEM School strategy.

3.1.1 Survey methodology

3.1.1.1 Analysis framework and respondent sample

The respondent sample included the organisations of the four project partner countries (Serbia, Portugal, Lithuania and France), as well as schools from five additional countries (Romania, Iceland, Finland, Norway and Belgium (Flanders)), selected to ensure a variety of respondents. The schools in these five additional countries completed the survey with the assistance of teachers supporting the Scientix[12] project as Scientix Ambassadors[13] and acting as facilitators.

3.1.1.2 Survey design

The data for this survey was collected through the SurveyMonkey tool,[14] an easy-to-use online tool that considerably simplifies the survey and analysis of results. The survey included a combination of the following question types:

- **Multiple choice questions with comments,** allowing respondents to choose Yes/No answers. These included the possibility of providing additional details to justify their choice, so as to collect information about the perceived relevance of the various criteria for defining a STEM School.
- **Open questions** providing space for written statements: this type of questions allows participants to provide more in-depth comments regarding the key characteristics of the school selected for the survey.

Concerning the type of information collected, the survey was designed in two parts. The first part included general questions about the school (name, address, type, etc.) and about the reasons why it is considered (or considers itself) a STEM-oriented school or a school advanced in STEM. The second part of the survey included particular questions related to characteristics of a school advanced in STEM, organised in five major areas of interest (key elements) and defined after the literature review. Within each key element, a set of criteria were set out. They are the following:

12 - Scientix (http://scientix.eu), the Community for Science Education in Europe, promotes and supports a Europe-wide collaboration among STEM (science, technology, engineering and maths) teachers, education researchers, policymakers and other STEM education professionals. Scientix has been running since 2010, organizing teacher training activities, dissemination conferences and events, and supporting the exchange of knowledge and experiences in STEM Education via its portal, publications and events. Scientix is funded by the European Union's Horizon 2020 research and innovation programme and coordinated by European Schoolnet.

13 - Scientix ambassadors are STEM teachers supporting the dissemination of Scientix, the Community for Science Education in Europe, and the exchange of good practices among science education stakeholders. A compulsory step in their selection is the Scientix Ambassadors Training course – an online course run on the Moodle platform specifically aiming to develop the participants' communication and presentation skills, project work, social media, and other soft skills.

14 - www.surveymonkey.net

Table 1: Initial proposed key elements and criteria

KEY ELEMENTS	CRITERIA
1/ Instruction, Curricula and Assessment: Instruction	Personalisation of learning (Instructional approaches intended to address the different learning needs, interests or cultural backgrounds of students)
	Problem-based learning (PBL) (Student-centred pedagogy in which students learn about a subject by solving open-ended problems)
	Inquiry-Based Science Education (IBSE) (Learning process in which questions, problems and scenarios are presented to students (including case studies, fieldwork, investigations or research projects, etc.))
1/ Instruction, Curricula and Assessment: Curricula	Specialised STEM curriculum (School developing a curriculum emphasising STEM subjects or topics)
	Interdisciplinary instruction (Teaching methodology aimed at giving instruction across different curricular disciplines)
1/ Instruction, Curricula and Assessment: Assessment	Continuous assessment (Assessment typology where students are examined continuously)
	Personalised assessment (Assessment typology framed to demonstrate whether pupils have met specific educational goals, according to their personal development)
2/ Professional development	Initial professional development (for teachers, Heads of School and/or career counsellors)
	Continuous professional development (for teachers, Heads of School and/or career counsellors)
3/ School leadership and culture	School leadership (existence of governing boards, management teams, etc.)
	High level of cooperation among staff
	Inclusive culture (Sharing of success, respect for colleagues' ideas, etc.)
4/ Connections with the community	With industry professionals
	With parents/guardians
	With other schools and/or educational platforms
5/ School infrastructure	Access to technology (Computer software and other ICT devices)
	Highly qualified professionals (specialisation in STEM)
	High-quality classroom instruction materials
	Existence of supporting (pedagogical) staff

In this second part, respondents were also offered the opportunity to indicate if there was any other significant criterion for a STEM-oriented school and to explain why this is relevant.

The survey was distributed via email, and participants were asked to complete the first part of the survey in an attached Word template. Afterwards, they were asked to complete the online survey (the link to which was included in the email). The online survey contained both survey parts. Participants were asked to copy and paste the section already completed in the word document, into the online survey. This had to be done to be able to complete the second part of the online survey.

This two-stage process was put in place to avoid participants using the second part of the online survey to guide their answers in the first section. Indeed, it was of great importance to ensure objectivity when respondents were first asked to describe the reasons why they considered the selected school to be a STEM-oriented school.

3.1.1.3 Survey distribution

The respondents included organisations from the four project partner countries (Serbia, Portugal, Lithuania and France). To distribute the survey in the mentioned countries, the STEM School Label project partner organisations were contacted, these being:

- Maison pour la science en Alsace (France);
- Ciencia viva (Portugal);
- Centre for the Promotion of Science (Serbia);
- Education Development Centre (Lithuania).

As already indicated, the questionnaire was also disseminated among five additional countries (Romania, Finland, Iceland, Norway and Belgium (Flanders)). For distribution purposes, Scientix Ambassadors (STEM teachers who have been actively working with the Scientix project) were contacted. These Ambassadors were given instructions to select compulsory education schools in their countries that were advanced in STEM, and to complete the questionnaire with information about these schools.

3.1.1.4 Sample participation

At the end of the survey process, 31 responses were collected from nine different countries. The country distribution of respondents is shown below in Table 2.

Table 2: Country distribution of respondents

COUNTRY	NUMBER OF SCHOOLS SURVEYED
Belgium	3
Serbia	3
Lithuania	11
Portugal	1
Iceland	2
Norway	1
Romania	4
Finland	2
France	4

Structure of the educational systems of surveyed countries

As understanding the national systems in which these schools operate is essential, we show, in this section, a few characteristics of the structure of compulsory education in Europe (with specifications about the surveyed countries) for the academic year 2016-17.

Overall, there are three core compulsory education models of organisation in European countries, according to the International Standard Classification of Education (ISCED 2011):[15]

- **Single structure education systems**, where there is no transition between primary and lower secondary education, and a common education for all pupils is provided throughout all compulsory schooling. Among the surveyed countries, Serbia, Norway, Iceland and Finland have developed this type of system.
- What is known as **common core curriculum provision** refers to a system where, after successful completion of primary education (corresponding to ISCED 1 of the International Standard Classification of Education), all students progress to the lower secondary level (corresponding to ISCED 2) where they follow the same common basic curriculum. Romania, Portugal, Belgium and France operate according to this system.
- **Differentiated lower secondary education**, where students who have successfully completed primary education are required to follow different educational paths or particular types of schooling, at the beginning of or during lower secondary education. Lithuania follows such a model.[16]

School level and type of survey respondents

Because the educational systems of the countries surveyed are all diverse, the educational levels and ages of students will also be dissimilar. Table 3 provides a summary classification of the schools surveyed, in four different categories (according to educational level, namely "primary school", "secondary school", "primary and secondary school" or "VET school"). In view of the disparities in the meaning of these terms, according to national background, the table also provides contextual information about the student ages they comprise.

15 - UNESCO Institute for Statistics (2012) International Standard Classification of Education ISCED 2011 http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf

16 - Lithuania follows a model similar to the differentiated lower secondary education model. In the 9th form (1st year of the gymnasium), pupils can choose subject modules and study elective subjects according to their interests and abilities (see more under: http://www.smm.lt/web/en/education_1/lower-secondary-education)

Table 3: Summary classification of schools surveyed

	PRIMARY EDUCATION	SECONDARY EDUCATION	VET SCHOOL	PRIMARY AND SECONDARY EDUCATION	TOTAL RESPONDENTS	EDUCATIONAL STRUCTURE
Belgium	1	1	1	0	3	• Primary education: 6 - 12 years old • Secondary general education: 12 - 18 years old • Secondary vocational education: 15 - 18 / 14 - 19 years old *Common core curriculum provision
Serbia	1	1	0	1	3	• Single structure education: 6 - 7 / 14 - 15 years old • Secondary general education: 14 - 15 / 18 - 19 years old • Secondary vocational education: 14 - 15 / 18 - 19 years old *Single structure education systems
Lithuania[17]	0	5	0	3 (+ 3)	11	• Primary education: 7 - 11 years old • Secondary general education: 11 - 15 / 11 – 17 / 15 - 19 years old • Secondary vocational education: 14 - 20 years old *Differentiated lower secondary education
Portugal	0	0	1	0	1	• Primary education 6 - 12 years old • Secondary general education 12 - 18 years old • Secondary vocational education: 15 – 18 years old *Common core curriculum provision
Iceland	0	1	1	0	2	• Primary education 6 – 16 years old • Secondary general education 16 – 20 years old • Secondary vocational: 16 – 20 years old *Single structure education systems
Norway[18]	1	0	0	0	1	• Primary education 6 – 16 years old • Secondary general education 16 – 19 years old • Secondary vocational education: 16 - 19/20 years old *Single structure education systems
Romania[19]	0	2	0	2	4	• Primary education 6 – 11 years old • Secondary general education 11 – 19 years old • Secondary vocational education: 15 – 18 years old *Common core curriculum provision
Finland	1	0	0	1	2	• Single structure: 7 – 17 years old • Secondary general education: 16 – 19 years old *Single structure education systems
France					4	• Primary education 6 - 11 years old • Secondary general education 11 – 18 years old • Secondary vocational education 15 – 18 years old *Common core curriculum provision

17 -The five schools classified as secondary education in Lithuania only cover upper secondary education and the (+3) schools included as primary and secondary education exclude upper secondary education.

18 -The schools classified as primary education in Norway cover only 6-to-13-year-old students.

19 -Primary and secondary education schools in Romania cover only primary and lower secondary stages.

All the data provided in this section has been gathered from the report *The Structure of the European Education Systems 2016/17: Schematic Diagrams. Eurydice Facts and Figures*.[20] The diagrams in this report also show the age of students, the educational level (e.g. primary, secondary, etc.) and the allocation to the ISCED 2011 levels.

3.1.2 Survey results

3.1.2.1 Overall results

Relevance of school key elements and criteria in a STEM-oriented school

As mentioned at the beginning of this section, each of the criteria belong to different key elements, namely *Instruction*, *Curricula*, *Assessment*, *Professional development*, *School leadership and culture*, *Connections with the community*, and *School infrastructure*.

Overall, if looking at the relevance of the different criteria in selected schools by country, it is easy to observe similar trends. However, it is interesting to see how the respondents in Serbia, Portugal and Iceland tend to rate all priorities higher than in the other countries surveyed.

A large majority of the respondents viewed most of the criteria as relevant. In fact, 16 out of the 19 criteria were considered relevant by at least 15 respondents; 14 of the total criteria were considered relevant for more than 20 respondents and seven were considered relevant for more than 28 respondents.

The criteria considered most relevant (by more than 15 selected schools) are the following, in descending order: *Interdisciplinary instruction*, *Inquiry-Based Science Education*, *Problem-Based Learning (PBL)*, *Continuous professional development*, *Access to technology*, *Connections with other schools and/or educational platforms* and *Highly qualified professionals*. Those qualified as less relevant are *Personalised assessment*, with a remarkably low score of only nine out of 31 respondents considering it relevant. Respondents from Belgium (3), Serbia (3), Norway (1) and Finland (2) were the ones answering positively. *Existence of supporting pedagogical staff*, *Connections with parents/staff* and *Initial professional development* are all considered relevant by less than half the respondents.

Additionally, discrepancies within the same country's respondents were found in the key elements *High level of cooperation among staff*, *Collaboration with industry professionals*, *Access to technology*, and *High-quality classroom instruction materials*.

3.1.2.2 Results by category

STEM-oriented school criteria with lower relevance

As we have already seen, a number of criteria are considered less relevant by respondents (i.e. with at least 15 respondents considering it non-relevant out of the total of 31). We look at them in detail in the following sections:

- **Personalised assessment**
  Only nine of the respondents considered personalised assessment to be relevant and none of the respondents from Lithuania, Portugal, Iceland, Romania and France did. However, all those from Belgium, Serbia, Norway and Finland classified it as relevant.

  Survey respondents mentioned that in some cases, students' personal development is monitored closely and individually. However, this often refers to personalised assessments of student's progress in the form of grading, which is done less often and depends on the discretion of the teacher, in situations where it is considered necessary. Also, highlighted in the survey results is that personalised assessment is already being implemented in many schools. For example, the current Lithuanian curriculum focuses on individualisation and differentiation, and personalisation of learning is the main target in the renewed curricula (2020) of this country. Moreover, as mentioned by one respondent from Serbia, since students are developing multidisciplinary projects, teachers prefer continuous assessment, allowing them to better understand content and skills achieved. Nevertheless, it should be noted that continuous assessment is not necessarily opposite to personalised assessment and can also include peer assessment by pupils.

20 - https://webgate.ec.europa.eu/fpfis/mwikis/eurydice/images/9/9d/Structure_of_education_systems_2016_17.pdf

- **Existence of supporting (pedagogical) staff**
  Respondents from Serbia, Lithuania, Portugal and Iceland considered the criterion *Existence of supporting (pedagogical) staff* non-relevant. However, no further explanations were provided about the reason for this and, in particular, whether they considered it non-relevant because there are no supporting pedagogical staff in the schools surveyed or because they do not consider it relevant in the definition of a STEM School.

- **Connections with the community: with parents/guardians**
  According to respondents, there is still not much cooperation with parents/guardians in Lithuania, Portugal and Iceland, as all respondents assessed this criterion as non-relevant. In Belgium, while two out of three respondents considered the criterion relevant, the difficulty in connecting with parents was expressed, mainly because of student demographics and despite efforts from schools. Thus, it was regarded as still a work in progress. In most Lithuanian schools surveyed, parents are informed about the activities carried out; nevertheless, they are not included in the organisation of activities, nor is there any active participation by them.

- **Initial professional development**
  For 16 schools, the criterion *Initial professional development* was regarded as non-relevant, in particular in Lithuania, Portugal and Iceland, although no further explanations were provided.

  It should be noted that all of the criteria mentioned in this section and considered non-relevant include all Lithuanian responses. Taking into account that this country gathered the highest number of responses (11 out of 31), almost a third of the total, it is easy to see how the results can be biased, making these criteria seem less relevant overall, instead of just in a particular country. For this reason, a further consultation is needed in order to exclude or keep these key elements initially identified.

STEM-oriented school criteria with higher relevance

As previously stated, respondents considered most of the criteria set out in the survey to be relevant. However, some made comments related to the definition of the criteria considered most relevant. These are summarised as follows:

- **Personalisation of learning**
  Doubts over the specificities of personalisation of learning were expressed, as this can be defined as instructional approaches intended to address the different learning needs, interests or cultural backgrounds of students. In addition, some schools perceived this criterion as relevant (17), while others did not. However, 11 out of the 14 schools that considered it non-relevant are from Lithuania. This result can be explained by the fact that in Lithuania, there is no clear definition and agreement on the definition of personalised learning.

- **Inclusive culture**
  For the majority of the schools surveyed, the criterion *Inclusive culture* was considered relevant. In the cases where it was considered non-relevant, respondents mainly indicated that they did not have specific information about it.

- **Continuous assessment**
  A large majority of respondents considered *Continuous assessment* relevant. One of the Finnish respondents mentioned that students are not examined continuously. Evaluation is done twice a year and parents are seen once a year. In addition, it is up to the teacher to decide how many exams should be set. However, it should be noted that, in Finland, local autonomy in education is extensive and individual schools and teachers enjoy a lot of freedom in curricula and instruction design and implementation.[21]

- **Connections with the community: with industry professionals**
  While 23 of the schools surveyed considered this criterion relevant, only one respondent in Finland indicated that industry visits have been arranged. However, there is no on-going collaboration between any industry and the school in question to and it is up to the teachers to approach industries. It was also explained that the type of industry collaboration was quite diverse as, for instance, some form of

21 - OECD (2017) Education Policy Outlook Finland: Finland. Accessible: http://www.oecd.org/education/highlightsfinland.htm

collaboration has taken place with energy suppliers, a chocolate factory, and recycling centres and other members of civil society (e.g. NGOs).

- **High level of cooperation among staff**
  Cooperation is definitely a key element in most schools responding to this survey, as all those from Belgium, Lithuania, Portugal, Norway and Finland considered it relevant. However, it was also indicated that this criterion corresponds to very different realities (although no further specificities regarding the "different realities" were given).

- **High-quality classroom instruction materials**
  According to most respondents, a variety of classroom materials is used in schools (laptops with appropriate software, drones, etc.) and the main obstacle to providing high-quality classroom instruction materials is budgetary. In addition, survey comments explained how classroom materials used in STEM activities are usually chosen and prepared by STEM teachers. Nonetheless, it was also explained that, sometimes, open education resources are used and pedagogical materials from other STEM actors or other schools engaged in STEM networks are shared. The data cross-analysis highlighted a disparity in the form of the materials used in the schools surveyed, which varies widely, from intellectual resources to technology materials.

- **Specialised STEM curricula**
  Most respondents agreed on the relevance of a specialised STEM curriculum. In most of the cases where this criterion is considered relevant, schools integrate STEM curriculum options into modules and optional subjects, or in non-formal classes. In some cases, respondents referred to a specific STEM-focused programme (mostly in VET schools and high schools).

- **School leadership**
  School leadership was considered relevant by 26 respondents. However, it was pointed out that this criterion can be implemented in many different ways. For instance, in some schools, STEM projects are led by specialised teams; in other schools surveyed (especially in Lithuania) a two-year STEAM (STEM + Arts) plan is implemented, showing the existence of a clear STEM School strategy and leadership.

- **Connections with the community: with other schools / educational platforms**
  The data gathered suggests that in almost all schools surveyed, strong connections are established with other schools, sometimes with universities, or even between secondary schools and kindergartens. This collaboration allows schools to organise student visits, to develop collaborative projects (Comenius projects, etc.) and to participate in national and international STEM programmes or in cooperation initiatives (like Erasmus+[22] and eTwinning[23]). The main outcome of these connections is the creation of network structures,[24] which can involve efficient collective tools to support new STEM practices. Sometimes, these networks also use educational platforms like eTwinning or Edmodo.

- **Highly qualified professionals**
  A large majority of the schools selected employ highly qualified professionals (holding a Master's degree or a PhD) carrying out STEM activities. Some respondents also emphasised the possibilities of using informal education or professional development opportunities in STEM education to increase their skills in STEM.

- **Problem-Based Learning (PBL)**
  According to the survey data, Problem-Based Learning is often referred to in relation to projects carried out outside of regular classes (extracurricular competitions, fieldwork, hands-on activities, etc.). A respondent from Norway (a primary school with students aged 6 to 13) mentioned how students are led to evaluate themselves and to set new goals while being encouraged to explain how they think, through

22 - EU Programme for Education, training, youth and sport. Accessible: http://ec.europa.eu/programmes/erasmus-plus/node_en

23 - eTwinning, the community for schools in Europe. Accessible: https://www.etwinning.net/en/pub/index.htm

24 - Network structures can be understood as learning networks. More information under European Commission (2017). Networks for learning and development across school education: Guiding principles for policy development on the use of networks in school education systems. Brussels, Directorate-General for Education and Culture. Accessible: https://ec.europa.eu/education/sites/education/files/networks-wg_en.pdf

a learning process of their own. In this case, this criterion is used to favour students' reflection on their learning. However, it should also be noted that some respondents considered it a general state of mind within their school.

- **Continuous professional development**
  According to the information provided through the survey, there is no general format for qualifications at the level of Initial professional development. The cases are different according to country and level. We nevertheless observe that some of the respondents consider their staff qualified for STEM, whether through their previous studies, their diplomas, or through competitions or selections. It should be noted that in the relevant cases, continuous professional development is most of the time considered to be "encouraged" and "improved" for STEM (training, seminars, workshops, etc.).

- **Access to technology**
  Access to technology is relevant and well developed, according to most respondents in the schools selected, even though the equipment used is very heterogeneous (Internet access, tablets and even Lego Mindstorms, drones, Arduino software, 3D printers etc.). Nevertheless, access to laboratories in different pedagogical contexts was particularly highlighted in relation to this criterion: specifically, biotechnology laboratories, natural science laboratories, or computer laboratories, among others.

- **Interdisciplinary instruction**
  Interdisciplinary instruction covers a wide range of practices, according to respondents' answers. It can be integrated either in the curriculum (in a cross-curricular approach) or in concrete projects that allow different subjects to be articulated of. It also seems to be a very relevant opportunity for peer collaboration and knowledge integration. In addition, it was mentioned that it plays a role in giving sense to learning, and in getting closer to real-life experiences and concrete scientific situations that have an interdisciplinary component.

- **Inquiry-Based Science Education (IBSE)**
  A variety of practices overlap within the idea of Inquiry-Based Science Education, from respondents' comments: collective group work, meetings with science professionals and other school events, links between oral and written aspects of learning, extracurricular activities, development of STEM + Arts projects, etc. Furthermore, IBSE often involves the use of science equipment, including different approaches and tools "that give students different insight to (...) science".[25] Last, Inquiry-Based Science Education was also considered a conscious state of mind of the pedagogical teams that test innovative teaching tools.

Other variables

Survey participants were also asked to highlight any priority (not mentioned in the survey) they think is relevant in STEM-oriented schools and to explain the reasons behind it. The responses are listed below:

- For a respondent in **Norway,** the interaction among parents through "friends group", meaning different informal channels, is both significant and relevant.
- One respondent in **Finland** also highlighted some elements which should be included in the priorities:
  - The offer of additional STEM activities[26] is of particular importance, although not always included in the curriculum. It was mentioned in the survey results how in most STEM-oriented schools in Finland, there is a STEM-oriented class with extra STEM lessons, including an adaptive test for pupils who wish to enter that class.
  - Teachers' involvement in the development of the STEM national curricula (as parts of the national teams for curriculum or planning) was also highlighted. Specifically, teachers attend workshops voluntarily, take part in national debates, and help the National Board of Education/Ministry on STEM education initiatives. Many of these teachers join teams focusing on the writing and publishing of schoolbooks and teach pre-service teachers.

25 - Quote from survey sent to School Petro Kuzmjak, Serbia.

26 - Additional STEM activities can include formal STEM education and non-formal/ informal STEM education organised by STEM centres in most countries in Europe

- In **Romania,** the importance of participating in national and international STEM competitions and Olympiads was also mentioned as a key element to take into account.

3.1.3 Limitations in survey results

Last, it should be noted that this survey gathers useful data to shape a contextual understanding of existing European schools advanced in STEM. However, while providing quantitative data, the sample available is certainly small and the country distribution uneven. For this reason, the results of this survey will not be interpreted as representing the entire educational system in any country. Nevertheless, a country which has a STEM strategy usually facilitates the development of a STEM School strategy at the school level. In the next sections of this report, results from further consultations (with STEM teachers, Ministries of Education and industry representatives) to complement and validate these initial results will be presented.

3.2 SURVEY OF STEM TEACHERS

In addition to the school survey, a second consultation was carried out among STEM teachers, aiming to include auxiliary comments about the key elements and criteria highlighted in previous sections. The objective of this consultation was to determine whether these could all be included in the definition of a STEM School and if they represented an exhaustive list.

3.2.1 Survey methodology

3.2.1.1 Analysis framework and respondent sample

Teachers specialising in Science, Technology, Engineering and Mathematics, referred to in this report as "STEM teachers", were those approached. As it was intended to contact a relatively large and varied group of STEM teachers, connections were made with the Scientix project, as this involves a large number of STEM teachers acting as project collaborators. Indeed, STEM teachers appointed as Scientix Ambassadors (currently a total of 502), in a volunteer capacity, support the dissemination of Scientix and the exchange of knowledge and practices in 44 countries around the world. The comments from Scientix Ambassadors were collected via the SurveyMonkey tool,[27] which is an easy-to-use online tool that these teachers often use as a working tool within their Scientix-related tasks.

3.2.1.2 Survey design

The survey included a combination of the following question types:

- **Multiple choice questions with comments,** allowing respondents to choose Yes/No answers. These included the possibility of providing additional details to justify their choice, collecting information about the perceived relevance of the various criteria for defining a STEM School.
- **Open questions** providing space for written statements: this type of questions allow participants to provide more in-depth comments regarding the key characteristics of the school selected for the survey and any possible missing criteria.

Concerning the types of information collected, the survey was short and composed of five questions in order to allow teachers as much as possible to give their opinion on the selected key elements and criteria. The survey was distributed through the Scientix Ambassadors Basecamp group to all 502 of them. Emails relevant to all members of this group are sent via this platform and arrive in their individual inbox.

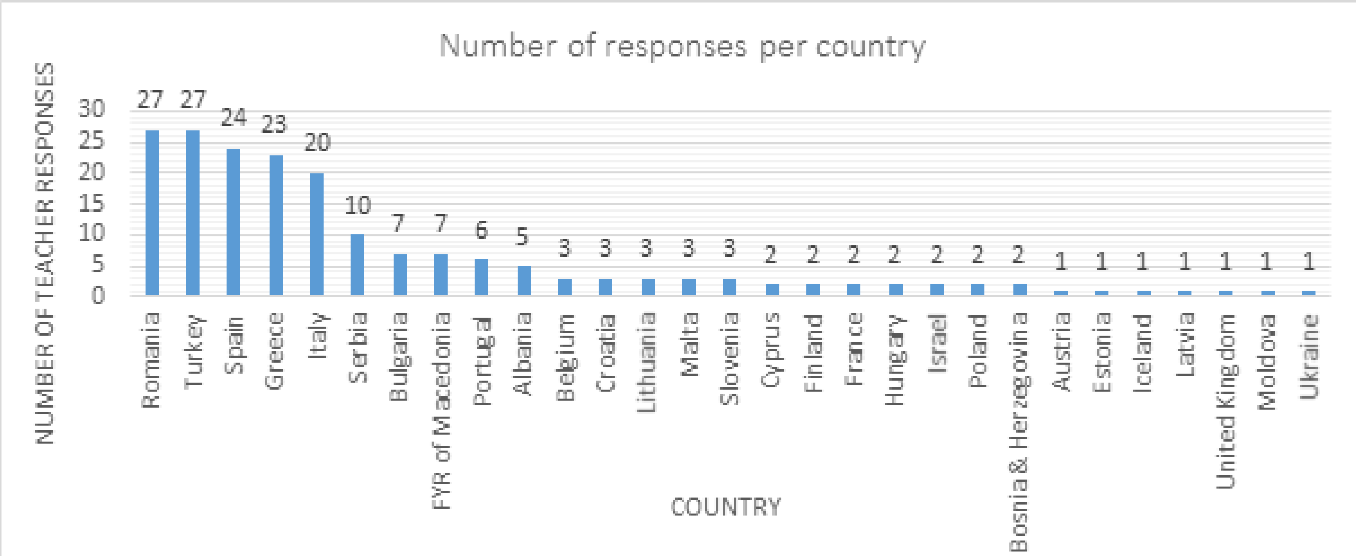
The full survey can be found in Annex 2: STEM Teachers survey. It should be noted that in the question "*Please indicate the age of your students in the checkboxes below*", respondents were allowed to select multiple answers. Therefore, as can be observed in the section below, the number of responses to this question will not align with the overall number of survey respondents.

27 - Survey Monkey. Accessible: www.surveymonkey.net

3.2.1.3 Survey distribution

195 Scientix Ambassadors from 31 different countries completed the survey (192 respondents from 29 European countries and three from three non-European countries, namely Zambia, the United States and India). The distribution of survey respondents from European countries is shown in Figure 1.

Figure 1: Country distribution of Scientix Ambassadors surveyed



3.2.1.4 Sample participation

Structure of the educational systems of surveyed countries

As understanding the national systems in which these teachers operate is essential, we show, in this section, a few characteristics of the structure of compulsory education in Europe (with specifications about the surveyed countries) for the academic year 2016-17.

Overall, there are three core compulsory education models of organisation in European countries, according to the International Standard Classification of Education (ISCED 2011):[28]

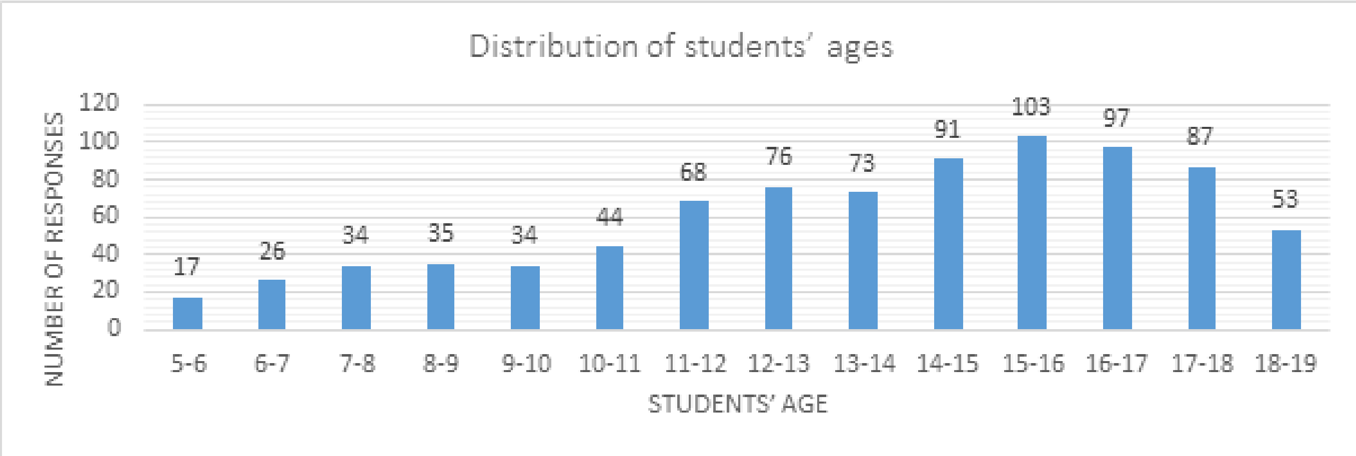
- **Single structure education systems**, where there is no transition between primary and lower secondary education, and a common education for all pupils is provided throughout all compulsory schooling. Among the surveyed countries, Bosnia and Herzegovina, Slovenia, Finland, Serbia, Bulgaria, FYR of Macedonia, Albania, Croatia, Estonia, Iceland and Latvia have developed this type of system.
- What is known as **common core curriculum provision** refers to a system where, after successful completion of primary education (corresponding to ISCED 1 of the International Standard Classification of Education), all students progress to the lower secondary level (corresponding to ISCED 2) where they follow the same common basic curriculum. Romania, Turkey, Spain, Greece, Italy, Portugal, Belgium, Malta, Cyprus, France, Poland and the United Kingdom operate according to this system.
- **Differentiated lower secondary education**, where students who have successfully completed primary education are required to follow different educational paths or particular types of schooling, at the beginning of or during lower secondary education. Lithuania and Austria follow this model.
- Hungary follows a **mixed model** and Moldova, Ukraine and Israel **were not classified** according to this model.

Type of survey respondents

European STEM teachers who answered the survey teach to a wide range of students' ages, as seen in Figure 2. However, most teachers surveyed stated that they taught pupils aged between 12 and 18, the peak being at age 15-16. Therefore, it is safe to say that most respondents are secondary education teachers.

28 - UNESCO Institute for Statistics (2012) International Standard Classification of Education ISCED 2011 http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf

Figure 2: Distribution of students' ages



3.2.2 Survey results

3.2.2.1 Overall results

As mentioned, 192 European teachers responded to the survey. Of these, 185 concurred with the STEM School Label criteria, representing 96% of the total and leaving only seven of them (4%) in disagreement.

Out of the 185 affirmative answers, 151 also agreed that the list of key elements and criteria was exhaustive enough and that no additional criteria should be added. Nevertheless, 30 teachers said that additional criteria could be integrated and 21 of these made specific comments about this. These are shown below, classified by key element and criteria.

3.2.2.2 Comments on necessary additional key elements and criteria

- Within the key element **Instruction**, the following comments were made concerning *Personalisation of learning*: First, the benefits of differentiated instruction were highlighted as a subset of and a step to achieving personalisation of learning. In addition, the way students work (e.g. in mixed or same-ability teams, etc.) was considered of relevance as, for instance, team work might offer extra benefits for students, not only in relation to cognitive learning but also to social and emotional growth. This last comment is also related to a school's culture or the way the staff of a school works.
- Concerning the key element **Curricula**, several suggestions came up. Among them, the study of the epistemology of STEM disciplines, the application of students' knowledge to everyday life and the creation of curriculum through the European framework of educational competences. Also brought up was the addition of new subjects to the curriculum (some examples are the introduction of a school programme about safe and responsible use of technologies[29] or the addition to the curricula of a subject related to ecological skills). No specific mentions were made directly in respect to the criteria *Emphasis on STEM topics* and *Interdisciplinary instruction*.
- About the key element **Professionalisation of staff**, collaboration among teachers (whether to develop cross-curricular topics or projects) was mentioned as a crucial indication of staff professionalism (for this reason, it was considered by one respondent to be more suitable in relation to this key criterion than within School leadership and culture). Besides, in several countries specific Continuous Professional Development providers exist.

  Further observations were made about the key element *Support for (pedagogical) staff*. Specifically, the setting up of communities of practice (teachers having time allocated to plan collaboratively, besides sharing of ideas and resources) was considered quite relevant. In this manner, these communities are considered part of teachers' Continuous Professional Development, which can end up being most effective if embedded in the school context.

  Furthermore, in qualifying what defines *Highly qualified professionals*, the importance of teaching and developing an independent judging attitude was noted. Also, it was stated that high professionalism could be applied to non-STEM disciplines (for instance, grammar and language structure analysis to develop logic

29 - Responsible research and Innovation(RRI) can also address ethical issues in the classroom.

and a structured learning attitude, as well as the ability to translate from written language to mathematics and vice versa). It was also suggested that the use of different foreign languages should be encouraged to develop different ways of thinking, aside from its practical value. Finally, no comments were made about *Professional development*.

- **Connections**, including universities, research centres and school networks, were considered a good addition. Other ideas were mentioned, such as featuring connections that give direct input to the school or to related educational institutions (for example, participation in "Science Days"; promotion of sponsorship of school-led projects, funding of national science contests for teachers; giving support to science centres, etc.). Connections that directly benefit staff (and provide them with training) should be taken into account, and international cooperation was also featured as something that facilitates collaboration among teachers and students.

  While having been mentioned in relation to other key elements, within Connections, the organisation of STEM-oriented events (open to parents and local institutions, such as science workshops or technology fairs) and the promotion of schools working as professional learning communities (who can plan their own evolution in terms of teachers' learning, decision making, etc.) was brought up.

  As stated before, connections with scientists, universities and informal education organisations, in order to enlarge collaboration with local stakeholders and to help schools in teacher training or support STEM events was deemed relevant.

- Regarding **School infrastructure**, inclusion of classrooms with versatile furniture to work with different methodologies was brought up. Specifically, the key element *Access to technology* was considered too general. It was suggested to complement it with some explanation referring to the existence of more than one well-equipped classroom (with Internet access, tablets, projectors, or digital data collecting devices, among others).

- General comments (not directly connected with any of the key elements or criteria) were also expressed through the survey. Classified per topic:

  - STEM education awareness and promotion:

    Increase in student awareness of the significance of STEM as means to improve students' interest in STEM working fields; promotion of a positive public perception of the historical value of STEM discoveries and encouragement of gender equality in STEM education were all criteria that survey respondents considered significant.

  - Participation in European projects:

    Participation in European projects was repeatedly considered relevant, by many survey respondents and for a number of reasons, among them, to launch schools internationally and to ensure that different tasks and student skills are developed while excellence is ensured.

  - Students' skills:

    In relation to students' learning experiences, it was deemed important for pupils to learn how to use local resources, disseminate results or share experiences, among others.30

    Mistake-driven learning was mentioned as a way to help students learn, observing their own mistakes in order to detect what caused them while learning how to fill any gap in experience and/or knowledge.

    Promotion of soft skills in order to understand one another's emotions, points of view, etc. was brought up. STEM education indeed contributes strongly to the promotion of soft skills.

  - Teachers' abilities:

    Improvement of teachers' time management abilities, to help implement curricula, was mentioned as important.

  - Promotion of research:

    A number of ideas were cited regarding of promotion of linkages between schools and the world of research. Among them were: support for the advancement of teacher and school involvement in STEM research; encouragement of connections between research and STEM curriculum to improve

30 - In this sense, STEM education contributes to developing pupils' active citizenship.

student engagement, skill building processes, and the sharing of findings to promote exchanges with other schools.

No specific comments were made in relation to the rest of the key elements and criteria. However, a couple of the non-European teachers who responded to the survey made comments. The respondent from India mentioned – while agreeing with all key elements – that missing criteria should be added. It was particularly referenced how teachers (and curriculum implementation) should be connected to researchers and to industry, in order to build students' skills and improve students' engagement.

Last, the respondent from the USA (who did not agree with the criteria selected) highlighted that, within the key element *Curricula*, the criterion *Emphasis on STEM topics* is vague and could be better defined by using broader categories such as sustainability, environment, or quality of living. In addition, it was suggested that the key element *School infrastructure* could be made more specific, by listing essential tools and space for a model STEM School.

3.2.2.3 Comments related to disagreements with key elements and criteria selected

It is also worth mentioning that seven teachers (4% of the respondents) did not agree with the set of key elements and criteria suggested. The main changes requested clarifications regarding the definition of each criterion. These can be seen below:

- The key element *Connections* should include connections with tertiary education, research institutes and non-profit organisations having STEM goals. Another respondent also mentioned the inclusion of the school's social environment – that is, local schools, municipal authorities, other institutions (hospitals, retirement homes, etc.).
- The criterion *Emphasis on STEM topics* needed to be further specified. It was suggested by one respondent that it could be better defined using broad categories like sustainability, environment, or quality of living.
- The key element *School Infrastructure* also needed to be further specified.
- The criterion *Professionalisation of staff* was perceived as unclear, in particular regarding *Highly qualified professionals*, as the offer of professional development courses often does not depend on the teachers but on the educational authorities.

Other comments focused on doubts regarding the relevance of specific criteria and key elements as being part of the definition of a STEM School. For example, under *Assessment*, one respondent considered that Continuous Assessment limited students' opportunities to make mistakes and could be a source of stress for students. Another respondent, while expressing the importance of assessment *per se*, also mentioned the relevance of weighing a schools' skills progression in the teaching of STEM and the importance of teachers' contribution to improving students' interest in STEM (for instance, by using criteria in a rubric that allow the monitoring of the transformation of the school).

Another respondent focused on how Problem-Based Learning and Inquiry-Based Learning are not perceived as relevant indicators to define a STEM School, as methodologies have a limited impact. However, it was mentioned that students' enthusiasm for STEM should be more relevant.

One last comment focused on funding, as a concern as to how a school could be responsible for this criterion and evaluate some actions (e.g. the part listing school infrastructure elements can be a very restrictive element for schools which do not have the budget for it).

3.3 CONSULTATION OF INDUSTRY REPRESENTATIVES

3.3.1 Analysis framework and industry representatives contacted

In order to further corroborate the information collected following the literature review and the survey of schools, industry representatives were contacted to provide feedback on the key elements and criteria defining a STEM-oriented school. These companies were approached on the basis of their interest and involvement in STEM education and in projects promoting its improvement. For this reason, the companies contacted were selected among active members of two European Schoolnet-led projects: the STEM Alliance[31] and SYSTEMIC.[32] This was the last consultation developed in order to validate the STEM School Label key elements and criteria.

3.3.2 Consultation design

Company representatives were emailed and requested to react to the key elements and criteria (set out in Annex 1: STEM Schools survey). These were enclosed in an email, in PDF format. This email contained the following two questions, as body text:

1. Do you agree that a STEM School can be defined by all the key elements and criteria mentioned in the document attached?
2. If not, thank you in advance for letting us know which of these elements you disagree with and if there is any element that should be added.

Companies were asked to provide their feedback on the two questions within seven days

3.3.3 Observation from participating industry representatives

Four company representatives (Obitec,[33] ICE Cubes,[34] Texas Instruments[35] and Axalta[36]) reacted. Of these, both Texas Instruments and Axalta are members of the STEM Alliance. The first one seeks, through strategic investments, long-term relationships and partnerships with educators and their organisations to develop and support proven, successful education programmes that can be scaled and replicated. Therefore, they focus on programmes related to STEM education science, technology, engineering, and mathematics. As a SYSTEMIC partner, Obitec has contributed to the development of STEM MOOCs by providing access to experts and professionals aiming to foster school-industry collaboration. Last, ICE Cubes is currently working with European Schoolnet on a space education-related project proposal, aiming to make ICE Cubes' knowledge and resources on space flights available to primary and secondary education teachers and students.

The representative of ICE Cubes gave quite an extensive response. First highlighted was the definition of STEM Schools: it was observed that these should be schools with a different approach compared to the rest. In addition, it was commented that they should be attentive to the teaching of problem-solving skills, the use of class materials in a variety of projects, the introduction of community and team work and the promotion of interdisciplinary and inter-age level tasks rather than the following of curricula subjects and same-age classes. Additionally, while the exhaustiveness of the key elements defining the strategy of a STEM School was confirmed, the need to include more detailed information within the definition of some criteria was accentuated. In particular:

- **Instruction:** Some doubts were expressed regarding *Personalisation of learning*, as an inherent key element of a STEM School, although it was also stated that does seem appropriate to keep it into account. In addition, it was mentioned that Inquiry-Based Science Education should not only highlight the learning process, but also the teaching process.
- **Curricula:** While STEM curricula are important, it was mentioned that it is important not to neglect the other subjects. The *Interdisciplinary instruction* criterion should be highlighted when making connections across several disciplines but also different classes/age-levels and with connections with industry, as STEM Schools connect the curricula with everyday social, community and world issues and problems.
- **School leadership and culture:** Some doubts were expressed regarding *School leadership* as a key element defining a STEM School. However, *High level of cooperation among staff* was deemed very relevant, especially when it comes to interdisciplinary teamwork and/or collaboration among teachers of different subjects.

31 - The STEM Alliance (http://www.stemalliance.eu/home) – inGenious Education and industry, brings together Industries, Ministries of Education and education stakeholders to promote Science, Technology, Engineering and Maths education and careers to young Europeans and address anticipated future skills gaps within the European Union.

32 - SYSTEMIC (http://www.stemalliance.eu/stem-initiatives/detail?articleId=736815) is a project to increase young Europeans' interest in maths, science, engineering and technology education and careers and to provide teachers with the appropriate pedagogical tools to enable them to teach STEM topics differently and in a more attractive way.

33 - http://www.obidosparque.com/?p=3197

34 - http://www.icecubesservice.com/

35 - http://www.ti.com/

36 - http://www.axaltacs.com/corporate/en_US.html

Texas Instruments also provided an extensive response, especially in terms of similar initiatives to the STEM School Label. The following were mentioned as relevant:

- The *MINT-freundliche Schule*[37] (STEM-friendly school), a label for schools with a basic STEM profile. Schools apply by completing a relatively simple form; applications are open to any school from elementary to Gymnasium.
- "MINT EC" (STEM Excellence Centre) concerns the elite, the spearhead of STEM Schools. The application process is tough, as a school needs to have a very strong STEM profile and show many STEM activities. It is also understood as a network of schools, and collaboration amongst these some 300 schools is very important.[38]

A number of additional comments were made regarding the criteria selected. They are the following:

- The definition of *High-quality classroom instruction materials* was considered unclear, in terms of whether these are developed by the teachers, within the school, or sourced elsewhere.
- In regard to *Connection with other schools and/or educational platforms*, further explanations were requested, concerning the typology of connections and exchanges with the other schools and/or educational platforms.
- It was suggested that the term *Assessment* be specified, to be understood as formative assessment as opposed to summative assessment.
- The **representatives from Axalta** and from **Obitec** also highlighted the exhaustivity of the proposed criteria and key elements.

3.4 CONSULTATION OF MINISTRIES OF EDUCATION

3.4.1 Analysis framework and Ministries of Education contacted

To ensure the representativeness of the co-creation process and also the validation of the set of key elements and criteria previously mentioned and set out in Annex 1: STEM Schools survey, a similar email to the one for industries was sent to Ministry representatives in the Ministries of Education STEM representatives Working Group (MoE STEM WG). This is a platform for discussion and exchange among Ministries of Education regarding their STEM education policies. The overall objective of this initiative is to help lay the foundations for medium and long-term strategies and activities between Ministries of Education and European Schoolnet in the field of STEM education, and especially within the Scientix project, following an agenda that addresses the Ministries' priorities and main interests. By May 2017, 19 Ministries[39] (from 18 different countries) had joined the MoE STEM WG and started promoting STEM activities at the national level in collaboration with Scientix. The members of the MoE STEM WG are directly appointed by the Ministries of Education.

3.4.2 Consultation design

Ministry representatives were requested to react to the key elements and criteria set out in Annex 1: STEM Schools survey and enclosed in the email they received, by answering the two following questions by email:

1. Do you agree with these key elements and criteria which define a STEM School strategy? If not, thank you in advance for letting us know which of these elements you disagree with and if there is any element that should be added.
2. Do you have any report/research at the national level on STEM Schools, STEM leadership at the school level or STEM knowledge framework? If yes, can you please provide us with the URLs?

An email was sent to all representatives. They were asked to provide their feedback within seven days.

37 - https://mintzukunftschaffen.de/mint-freundliche-schule-2/

38 - https://www.mint-ec.de/

39 - The list of countries represented in the Ministries of Education working group is the following: Austria, Belgium (Flanders), Belgium (Wallonia), Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Israel, Lithuania, Luxembourg, Malta, Portugal, Romania, Slovakia, Turkey

3.4.3 Observation from participating Ministries of Education

Four Ministry representatives requested clarifications and/or offered suggestions:

- The **MoE STEM WG representative in France** suggested including Project-Based Learning (interpreted as both a collaborative and individual methodology for students) under the *Instruction* key element. Besides, it was suggested that STEM competences should be highlighted in more detail under the key element *Assessment* (emphasising assessment of specific competences, including the languages of the sciences, critical thinking, data analysis, etc.) and *School leadership and culture*, considering the inclusion of pedagogical thinking in the definition. Finally, under the key element *Connections*, contacts with research centres and with industries were referred to as relevant.
- The **MoE STEM WG representative in Hungary**, while generally agreeing with all the key elements presented, referred to its lack of specificity in relation to STEM. This was specially emphasised in relation to the key elements *Curricula*, *Professionalisation of staff*, and *Connections*.
- The **MoE STEM WG representative in Turkey** made some recommendations regarding the key elements and criteria, such as adding *Project-Based Learning* when defining instructional methodologies for STEM education, as a way to identify and encourage future scientists and engineers among current students. He also highlighted the importance of underlining the interdisciplinary character of STEM education in all STEM-teaching activities.
- The **MoE STEM WG representative in the Czech Republic** also responded with specificities to add to the selected key elements and corresponding criteria. In particular, concerning the criterion *Personalisation of learning*, gender was selected as a possible variable to take into account (given that some topics might be more interesting for girls/boys). Regarding the criterion *Interdisciplinary instruction*, the importance of connecting lessons with real-life situations was mentioned as very relevant; however, it was also acknowledged that this variable could be part of *Inquiry-Based Science Education* and *Problem-Based Learning*. On the criterion *Assessment*, self or peer assessment was mentioned as a possible addition. On the criterion *Professionalisation of staff*, some comments were made in relation to the variable *Professional Development*. Specifically, while Initial Teacher Training is important, it usually falls under the responsibility of Ministries of Education or universities. For this reason, it must be considered that schools cannot much influence this matter, and more emphasis should be put on selecting relevant/specialised teachers (which would fall under the criterion *Highly qualified professionals*).

It is important to note also the reaction from the representatives of the Ministries in Austria, Romania and Israel, who really appreciated the development of these STEM School criteria.

Last, representatives of MoE were also asked to share any reports or research on STEM Schools, STEM leadership in schools or STEM knowledge frameworks, at national level. The contributions received are not directly addressed in this report but will be further used in the development of the STEM School Label.

3.5 FINAL REMARKS

In addition to the consultations described above, two experts on STEM education, composing an Advisory board, provided extensive reference documents, which helped to build up the rationale and literature review of this report. These experts also provided feedback about the selection of key elements and criteria.

Specifically, within the key element *Curricula*, one of the experts mentioned how *Emphasis on STEM topics* and *Interdisciplinary instruction* are more connected to instruction than to curricula. Suggestions to fix the issue ensued, these being a change from *Interdisciplinary instruction* to *Interdisciplinary approach*.

In addition, it was also proposed to refer to STEM competences or to 21st century skills and to define specific learning outcomes. Finally, taking into account and promoting the idea of the school as a collaborative learning environment within schools was highlighted.

CONCLUSIONS:
WHAT DID WE LEARN AND WHAT IS THE WAY FORWARD?

SUMMARY OF THE CONSULTATIONS

Thanks to the information collected via the literature review, a set of key elements and criteria defining a school advanced in STEM was constructed. These were completed and validated through the 31 responses gathered through the survey of schools.

While this set of key elements and criteria provided a solid framework to define a STEM-oriented school, the already acknowledged limitations of the survey needed to be addressed and compensated for with additional consultations that would not only validate the criteria, but also complete them.

The various consultations that followed revealed extensive satisfaction with and approval of the initial set of key elements and criteria defining a STEM School. These results are relevant to a large extent, given that these impressions were collected from key stakeholders in the provision and development of STEM education.

Nevertheless, these consultations revealed that a number of key elements and/or criteria could also be refined. From the survey of teachers, four key elements were consistently regarded as not being clear or specific enough, these being: *Assessment*, *Professionalisation of staff* (particularly in relation to *Highly qualified professionals*), *Connections*, and *School infrastructure*. Through the survey evidence, it was made especially clear that respondents had interpreted differently what each of the criteria within *Assessment* (that is, continuous and personalised or differentiated) meant. Moreover, the criterion *Highly qualified professionals* will have to be developed in a more specific manner, since it seems for the moment to be up to the respondents' discretion, which appears to be quite subjective. In relation to the key element *Connections*, promotion of linkages with higher education institutions was repeatedly mentioned. Paired with several responses that emphasised the importance of integrating research into STEM education, it seems appropriate to consider the inclusion of this criterion.

Finally, concerning school infrastructure, the boundaries between *Access to technology and equipment* and *High-quality instruction materials* were not clear enough and/or the criteria were too general.

The industry representatives approached also noted the need for a better definition of some of these criteria. This was especially relevant regarding *Assessment*, *Connections* (specifically with other schools and/or educational platforms) and *School infrastructure* (particularly *High-quality classroom instruction materials*). Crucial to note is the fact that the results of this consultation and the previous one (the survey of teachers) mostly concur. Finally, the term "interdisciplinary" was repeated throughout the consultation results, stressing the importance of criteria not operating alone but being connected to one another.

STEM School Label partners, especially Ciencia Viva, also noted that the links with local communities should also be detailed as they include residents, associations, stores, small companies and other groups that in one way or another can make important contributions to a STEM-oriented learning process.

Ministry of Education representatives suggested some additional criteria to better define STEM Schools, which confirmed the results from the previous consultations with STEM teachers and with industry representatives. The key elements *School infrastructure*, *Professionalisation of staff*, *School leadership and culture* and *Assessment* were deemed to need a more in-depth and clarifying definition, and in regard to the criterion *Connections*, linkages with universities were once more mentioned as relevant. In addition, the key element *Instruction* was repeated a number of times as being of great importance but in need of further clarifications (it should be noted that this was also acknowledged in the survey of teachers, in relation to the importance of better characterising the pedagogical approaches stated and of a better contextualisation[40] of STEM disciplines). Lastly, Ministries of Education also stressed the relevance of stating the interdisciplinary character of STEM education in all the criteria set out.

FINAL SELECTION OF KEY ELEMENTS AND CRITERIA DEFINING A STEM SCHOOL

The remarks from schools and teacher respondents and the consultations with Ministries of Education and industry representatives led to some adjustments of the initial key elements and criteria that should be included in the definition of a STEM School. These modifications are the following;

- *Project-Based Learning* was included under *Instruction*, alongside *Problem-Based Learning*;
- *Connections with universities and research centres* and *Connections with local communities* were both criteria added under the key element *Connections*;
- The wording of the *School infrastructure* key element was improved. Particularly, it was specified how *Equipment* was inherent to the criterion *Access to technology*;
- Contextualisation of STEM teaching, referred to as *Connection of the lessons in the classroom to real-world experiences*, was added under the key element *Curricula*.

The remarks from the Pedagogical Advisory Board members led to the following modifications

- The key element *Curricula* was changed to *Curriculum implementation;*
- The criterion *Specialised STEM curriculum* was changed to *Emphasis on STEM topics and competences (school developing a curriculum emphasising STEM subjects or topics and STEM key competences).*

These changes are carried over into the final set of key elements and criteria, which can be found in Figure 3: Final set of key elements and criteria (on the next page). Regarding the rest of the key elements and criteria that needed further specifications and a much-improved definition, this will be addressed in further stages of the development of the STEM School Label, as will become clear in the final self-assessment tool.

40 - Contextualisation can be understood here as the promotion of research in STEM education in order to have a STEM education based on research findings.

Figure 3: Final set of key elements and criteria

STEM School = School with a clear STEM strategy

STEM School Key Elements And Criteria*

Instruction

- **Personalisation of learning** (Instructional approaches intended to address the different learning needs, interests or cultural backgrounds of students)
- **Problem and project based learning (PBL)** (Student-centred pedagogy in which students learn about a subject through solving open-ended problems and/or projects, either individually or collaboratively)
- **Inquiry Based Science Education (IBSE)** (Learning process in which questions, problems and scenarios are presented to students, including case studies, field-work, investigations or research projects, etc.)

Curriculum implementation

- **Emphasis on STEM topics and competences** (School developing a curriculum emphasizing STEM subjects or topics and STEM key competences)
- **Interdisciplinary instruction** (Teaching methodology aimed at giving instruction across different curricular disciplines, STEM subjects, including the preparation within interdisciplinary teacher groups.)
- **Contextualization of STEM teaching** (Connection of the lessons in the classroom to real world experiences)

Assessment

- **Continuous assessment** (Assessment typology where students are examined continuously)
- **Personalised assessment** (Assessment typology framed in demonstrating whether pupils have met specific educational goals, according to their personal development)

Professionalisation of staff

- **Highly qualified professionals** (Specialisation in STEM)
- **Existence of supporting (pedagogical) staff**
- **Professional development** (Initial and continuous professional development for teachers, Heads of School and/or career counsellors)

School leadership and culture

- **School leadership** (Existence of governing boards, management teams, etc.)
- **High level of cooperation among staff**
- **Inclusive culture** (Sharing of success, respect for colleagues' ideas, etc.)

Connections

- **With industry**
- **With parents/guardians**
- **With other schools and/or educational platforms**
- **With universities and/or research centers**
- **With local communities**

School infrastructure

- **Access to technology and equipment**
- **High quality instruction classroom materials**

**It must be noted that all criteria mentioned do not operate alone but are connected to each other. When referring to a "STEM School", these criteria should always be considered in regards to STEM education. When the criteria are fulfilled for all subjects and at whole school level, we would be referring to a "Leading School".*

Finally, and according to the comments received from the consultations, it should be noted that all the criteria mentioned do not operate alone but are connected to one another and STEM Schools should have it in their plan to re-evaluate their STEM strategy on a regular basis. When referring to a "STEM School", these criteria should always be considered in regard to STEM education. When the criteria are fulfilled for all subjects and at whole-school level, it was decided that we would be referring to a "Leading School".

LOOKING AT THE FUTURE OF THE STEM SCHOOL LABEL PROJECT AND THE NEXT STEPS OF DEVELOPMENT

Overall, the STEM School Label's mission for its next stage of evolvement should be to develop the reference framework for schools to complete in order to be labelled a STEM School. This will be done using the aforementioned key elements and criteria and expanding the definition of them according to the comments received from the survey and the consultations carried out in this report. These key elements should be integrated in the management strategy of STEM-oriented schools in Europe and evaluated via the online self-assessment tool to be developed with this project.

It should also be noted that, following the consultations, the responses on most criteria mentioned in the survey outlined the great heterogeneity of situations among respondents and, in particular, among the schools and teachers assessed. Therefore, it seems important to consider the STEM School Label as an open tool, used to provide schools with ideas and guidelines, but which also allows flexibility in the criteria that will be assessed.

Last, it should be taken into account that these key elements and criteria could also be used to encourage other schools in developing a change management strategy regarding STEM in their own specific context. The STEM School Label should also have different effects on schools, including:

1. The promotion of partnerships between schools and educational centres;
2. The development and sharing of resources among educational stakeholders;
3. The engagement of schools in a European STEM network, with the possibility of evolving through a mentoring process.

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ANNEX 1:
STEM SCHOOLS SURVEY

Section 1:

Are there any initiatives/pilots at your national level that you could identify as STEM Schools?

a. If the answer is yes, please describe the initiative briefly, including its main objectives, as well as any references to relevant reports/URLs/evaluation studies.

Please answer in 300 words max

b. If the answer is no, please explain why this is the case, and whether it is likely to exist in the future.

Please answer in 300 words max

Section 2:

1. In the box below, please indicate if each of the following school priorities is relevant in a good STEM School. Please describe in the "comments" box if those apply to any initiative in your country regarding STEM Schools, and how.

1/ INSTRUCTION, CURRICULA AND ASSESSMENT		
Instruction		
Interdisciplinary instruction *(Teaching methodology aimed at giving instruction across different curricular disciplines)*	☐Yes ☐No	Comments: how is this criterion applied in your country/initiatives? *Please answer here in 200 words max:*
Personalisation of learning *(Instructional approaches intended to address the different learning needs, interests or cultural backgrounds of students)*	☐Yes ☐No	Comments: how is this criterion applied in your country/initiatives? *Please answer here in 200 words max*
Problem-based learning (PBL) *(Student-centred pedagogy in which students learn about a subject by solving open-ended problems)*	☐Yes ☐No	Comments: how is this criterion applied in your country/initiatives? *Please answer here in 200 words max:*
Inquiry-Based Science Education (IBSE) *(Learning process in which questions, problems and scenarios are presented to students (including case studies, fieldwork, investigations or research projects, etc.)*	☐Yes ☐No	Comments: how is this criterion applied in your country/initiatives? *Please answer here in 200 words max:*
Curricula		
Specialised STEM curriculum *(School developing a curriculum emphasising STEM subjects or topics)*	☐Yes ☐No	Comments: how is this criterion applied in your country/initiatives? *Please answer here in 200 words max:*
Assessment		
Continuous assessment *(Assessment typology where students are examined continuously)*	☐Yes ☐No	Comments: how is this criterion applied in your country/initiatives? *Please answer here in 200 words max:*
Personalised assessment *(Assessment typology framed to demonstrate whether pupils have met specific educational goals, according to their personal development)*	☐Yes ☐No	Comments: how is this criterion applied in your country/initiatives? *Please answer here in 200 words max:*

2/ PROFESSIONAL DEVELOPMENT		
Initial professional development *(for teachers, HoS and/or career counsellors)*	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*
Continuous professional development *(for teachers, HoS and/or career counsellors)*	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*

3/ SCHOOL LEADERSHIP AND CULTURE		
School leadership *(Existence of governing boards, management teams, etc.)*	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*
High level of cooperation among staff	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*
Inclusive culture *(Sharing of success, respect for colleagues' ideas, etc.)*	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*

4/ CONNECTIONS WITH THE COMMUNITY		
With industry professionals	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*
With parents/guardians	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*
With other schools and/or educational platforms	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*

5/ SCHOOL INFRASTRUCTURE		
Access to technology *(Computer software and other ICT devices)*	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*
Highly qualified professionals *(specialisation in STEM)*	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*
High-quality classroom instruction materials	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*
Existence of supporting (pedagogical) staff	☐Yes ☐No	Comments: how is this criterion applied in your country/ initiatives? *Please answer here in 200 words max:*

2. In the box below, please indicate if there is any other criterion (not mentioned previously) that you think it is relevant in defining a STEM School and why.

ADDITIONAL CATEGORY	
Criterion:	**Comments:**

Section 3:

Please indicate below if you know other good practices related to STEM Schools identified in other European countries and explain the reasons why these good practices should be replicated in other European countries.

ANNEX 2:
STEM TEACHERS SURVEY

Q1: Please indicate the country you work in, in the dropdown list below (drop down menu)

- Austria
- Belgium
- Bulgaria
- Croatia
- Cyprus
- Czech Republic
- Denmark
- Estonia
- Finland
- France
- Germany
- Greece
- Hungary
- Iceland
- Ireland
- Israel
- Italy
- Latvia
- Lithuania
- Luxembourg
- Malta
- Netherlands
- Norway
- Poland
- Portugal
- Romania
- Slovakia
- Slovenia
- Spain
- Sweden
- Switzerland
- Turkey
- United Kingdom
- FYR of Macedonia
- Albania
- Montenegro
- Bosnia & Herzegovina
- Moldova
- Serbia
- Ukraine
- Georgia

Q2: Please indicate the age of your students in the checkboxes below (drop down menu)

- 5-6
- 6-7
- 7-8
- 8-9
- 9-10
- 10-11
- 11-12
- 12-13
- 13-14
- 14-15
- 15-16
- 16-17
- 17-18
- 18-19

Q3: Please indicate if you agree with the criteria displayed in the document attached to the email you received

a. Yes, I agree with all the criteria
b. No, I don't agree with all the criteria

Q4: If your answer is "YES, I agree with all the criteria", do you think there are any other missing criteria?

a. No
b. Yes

Q5: If you think "yes, there are other missing criteria", indicate which are the missing criteria and why these are relevant. Please provide as many details as you can.

Q6: If your answer is NO, please indicate which criteria you do not agree with and why. Please add as many details as you can.

ANNEX 3:
LIST OF SCHOOLS RECOGNISED AS STEM-ORIENTED SCHOOLS BY RESPONDENTS

SCHOOL NAME	COUNTRY
GO! Spectrumschool	Belgium
Campus De Vesten	Belgium
Willem Tell Olen	Belgium
Kytopuisto koulu	Finland
Käpylä Comprehensive school	Finland
Technical College Reykjavík	Iceland
Menntaskólinn í Reykjavík (Reykjavík Junior College)	Iceland
Alytus Jotvingiai Gymnasium	Lithuania
Gymnasium of the President Valdas Adamkus	Lithuania
“Silas” Gymnasium of Juodsiliai	Lithuania
Kaunas Jonas and Petras Vileisis School	Lithuania
Kedainiai “Bright” Gymnasium	Lithuania
M. Mazvydo progymnasium	Lithuania
Lyceum of Engineering of Kaunas University of Technology	Lithuania
Vladas Jurgutis basic school	Lithuania
Panevezys Juozas Balcikonis Gymnasium	Lithuania
Vilnius Engineering Lyceum	Lithuania
Vilnius Lyceum	Lithuania
Smestad Skole	Norway
Escola Profissional de Almada (EPA)	Portugal
Şcoala Gimnazială nr. 9 “Nicolae Orghidan”	Romania
Colegiul National de Informatica “Tudor Vianu”	Romania
Colegiul Național “Mircea cel Batrân”	Romania
Scuola Gimnazială nr79, academican Nicolae Teodorescu	Romania
Racunarska gimnazija	Serbia
Petro Kuzmjak	Serbia
Branislav Nusic	Serbia
École élémentaire de la Coquille	France
Collège Pfeffel	France
École élémentaire de Willer sur Thur	France
Collège de Wingen sur Moder	France

ANNEX 4:
STEM-ORIENTED SCHOOLS' GOOD PRACTICES

Portugal

Escola Profissional de Almada (EPA)

Escola Profissional de Almada (EPA) is a Portuguese Vocational Educational Training school, focused on providing technological and industrial training courses. Since its beginning, EPA has participated in several competitions on electronics, robotics, and science as well as in the entrepreneurship area. Examples of this are its participation in Robotop, Roboparty, the Portuguese Robotics Open, in the CANSAT competitions supported by ESERO-PT (European Space Agency), in MARCH - Making Science Real in Schools (Comenius project), in Junior Achievement and in AstroPi. The school has won honourable mentions, as well as several prizes in many of these competitions and in particular the First Portuguese Robotics Society prize.

Additionally, in September 2014, EPA became part of the European project Go-Lab, as a pilot school. Within the project, EPA's teachers built and shared over 47 Inquiry Learning Scenarios on its online platform. During the same year, the school joined the MARCH project where pupils studied actively using Arduino or building an energy-efficient model house with energy insulation. In the beginning of the 2016/2017 school year, EPA launched its Laboratório de Inovação e Aprendizagem (LIA), inspired by European Schoolnet's Future Classroom Lab.

Partly due to these experiences, the teaching of subjects such as Physics and Chemistry has been modified to include Inquiry-Based Science Education (IBSE) methodologies. Likewise, English, Portuguese and Civics teachers modified their practices and methodologies, and adapted them to the usage of new technologies in their classes while developing cross-curricular projects. Overall, **the school curriculum is based on the idea of educating students in an interdisciplinary and applied approach integrating Science, Technology, Engineering and Mathematics into a cohesive learning paradigm based on the real world.**

Norway

Smestad Skole

Smestad Skole has developed an interesting and realistic perspective in science teaching, shown through different areas of action. At Smestad, students in the 7th grade are allowed to investigate and complete **self-chosen projects in science**. Deriving from this approach, **students are taught how to work with hypotheses, how research can be documented through reports and how results can be published using posters**. These activities are valuable for students, as they not only learn scientific content but also how to explain and share it with peers. Additionally, the school organises coding courses for fourth graders, taught by students/instructors from the Oslo School.

Iceland

Technical College Reykjavík

Technical College Reykjavík offers students who have graduated from comprehensive school a three-year study programme preparing them for further academic studies. The programme suits students who want an intensive yet modern and unconventional programme designed to prepare them for university studies in technology and science.

Each term is divided into three study periods with two courses being taught in each period. The K2 programme has **a high emphasis on subjects such as mathematics, programming and a broad spectrum of diverse natural science subjects**. Besides, the programme also stresses **Project-Based Learning** and provides students with an opportunity to use their skills, solving real-life problems. Furthermore, teachers of various subjects strive for **interdisciplinary cooperation**. As the programme is mainly project-based, the studies are considered quite demanding, meaning that they require a **high degree of independence and total commitment**.

The study programme is organised in collaboration with Reykjavík University (RU) as well as with leading technology companies and is specially designed to meet admission requirements for the Schools of Computer Science and Science and Engineering at RU. Besides, parts of these studies take place on campus at RU.

Elective subjects are part of the study programme and students choose a “trade” option at the Technical College Reykjavík. This gives them insights into various fields of vocational education as they gain skills in the chosen “trade”, as part of their programme. Furthermore, the business sector plays an important role in the study programme setup and students write final papers at the end of each term in cooperation with businesses.

Overall, the unique K2 study programme of Smestad Skole aims to provide students with a distinctive opportunity to prepare students for university degrees in science, technology, engineering and mathematics; to get challenging assignments and to practise thinking outside the box; to connect with the university environment and strengthen their network of contacts in the business sector.

Further information (in Icelandic) is available through the following links:

1. www.tskoli.is/k2
2. https://www.youtube.com/watch?v=gOGAIBWR6hI&list=PL90IyzTDDUF18yqsxiQWTvBHb3sdCFqhc

Romania

Colegiul National de Informatica “Tudor Vianu”

Colegiul National de Informatica “Tudor Vianu” is a secondary school specialised in Computer Science where students acquire programming competences, which enables them to work as programmers right after graduation. However, most of them continue their studies either in prestigious universities in Romania – such as the Polytechnic University of Bucharest (Faculty of Automation, Faculty of Electronics, Faculty of Economic Engineering), the University of Bucharest (Faculty of Mathematics, Faculty of Mathematics - Informatics) or the Academy of Economic Studies (Cybernetics Faculty) – or abroad. This school is ranked third out of all the secondary schools in Bucharest (according to admission grade).

Around 2% of school graduates specialise in architecture, literature or foreign languages, and they combine knowledge of computer science with knowledge of these future specialisations.

Colegiul National de Informatica “Tudor Vianu” has achieved outstanding results in national and international STEM contests and projects http://portal.lbi.ro/educatie/rezultate/ and https://www.facebook.com/OficialCNITV/. Some of the contests and projects in which they have participated are the following: NASA Space Settlement Design Contest; Odysseus Contest- international runner-up; NASA-ESA Cassini – Scientist for a Day Essay Contest; First Tech Challenge Robotics competition; International Olympiads Informatics Teams; Hands On Universe, organised by Bucharest University, the Physics Faculty and “NASA Space Settlement Design”, 2016 edition. Students from the school were ESA AstroPI winners. Finally, the school also participates in ICT focused Comenius projects.

Additionally, the school provides the possibility of acquiring the **ICT Certification for the European Computer Driving Licence (ECDL) and CERTIPRO. It has a modern media and documentation centre** http://ioit.altervista.org/news.html **and a robotics club**.

Teaching practices at the school are developed using **hands-on experiments** such as the Eratosthenes Experiment or **experiments developed at competitions**, like the Zero Robotics competition, launched by NASA and ESA, in collaboration with MIT and DARPA.

Serbia

Branislav Nušić

The primary school “Branislav Nušić”, in Belgrade, provides a very good example of a school advanced in STEM since, although a large number of its students come from **marginalised groups, school results** in STEM disciplines remain high.

There are several elements to highlight from the schooling at Branislav Nušić. For a start, personalised learning is offered, including pedagogical profiles for students with developmental difficulties and individual and individualised plans for each student, which are created at team meetings for inclusive education. Finally, teachers develop their educational materials for all students and upload them to different learning platforms (such as Sophia, Edmodo or Moodle). There are also one Pedagogical Advisor and one Pedagogical Associate among the school staff.

The school's teachers go to **seminars for professional development**. The school director organises (at least once a year) a seminar (in the school) for all employees from the field of education, with the aim of improving in those areas that the staff consider require it. Several teachers from the school hold their own training seminars, professional discussions and lectures and they are authors of numerous published works at both international and national level.

There are several teams in the school specialising in specific domains (inclusion team, development planning team, violence prevention team, professional orientation, student parliament, etc.). There is also a team for projects dealing with teaching innovation, connecting students and teaching contents horizontally and vertically, by implementing international activities in the classroom.

The school also uses **innovative pedagogical approaches**. For instance, theme days are organised at class level or concerning study topics. In addition, subject-based projects from different angles are being implemented in schools and among schools (such as "Experiments in the Neighbourhood", "Women builders of Belgrade" or "Hello Physics"). Furthermore, it is a priority for the school to ask students to **work independently (or in groups) conducting research**, thus learning by **IBSE**. Results of student research and its conclusions are presented during class, school events, and extracurricular activities. Finally, teachers upload student papers to their own websites or to the school website. Some of the examples are available through the following links: http://fizicarskeposlasticenbg.weebly.com/ http://nusicv.blogspot.rs/p/blog-page_1.html - http://knjizevnostuoku.weebly.com/.

Finland

Kytopuisto koulu

Kytopuisto school is a public school situated in Vantaa, with 420 pupils aged 6 to 13, covering 1st to 6th grade. The school has a strong STEM programme, particularly in technology, and has been especially active in STEM education during the last five years.

Pupils are taught robotics and coding from 1st and pupils from 4th to 6th grade are introduced to robotics, 3D programming and printing. Those interested can also choose extra courses in technology (such as robotics, movie making, Arduino, etc.) and many have attended several competitions in coding.

As extra activities, a **coding club for volunteers** has been set up and, within the Guru Café project, a special group of 6th graders teaching younger pupils with tablets during breaks. Furthermore, a special group of mentor-teachers has been set up in Vantaa (including one teacher from Kytopuisto) circulating around schools and teaching new technology and skills for teachers.

The city of Vantaa has also been giving tablets and Chromebooks to each pupil, for use at school. This means that schoolteachers can use classroom apps during their teaching and pupils collect their work in Drive files.

Partnerships with other educational organisations have been put in place. The school is working with Aalto University and its students visit classes, give lessons, and organise extracurricular activities such as clubs. Besides, teachers at Kytopuisto School work with the National Department of Education (OPH) preparing the new National Curriculum, within the science team. This results in many international visitors year visiting Kytopuisto School each year.

Finally, Kytopuisto School is active in different national and international projects and the staff attend many conferences and training events, annually. Kytopuisto School has been a pilot school for the InGenious project and has current Scientix ambassadors.

Lithuania

Lyceum of Engineering of Kaunas University of Technology

The Lyceum[41] follows a very interesting approach to STEM education. It supports **interdisciplinary** education, by developing **integrated lessons**. Examples of these lessons are **Ethical principles of engineering** (including ethics, history and engineering) or Essential plants, their diversity and prevalence (mixing biology, chemistry, technology, and

41 - Lyceum website http://inzinerijoslicejus.ktu.edu/

engineering). It also supports events, such as the Engineering Experiments Day-Lab, the Engineering Projects and Career Day, the Madi (Maths day), etc.

Besides, the Lyceum has developed a **STEAM** (STEM + Arts) **implementation group**, integrated by a deputy director and STEAM subject teachers. It has also developed a two-year STEAM plan. During lessons students use open education resources (project Mascil, Engage; from Ugdymo Sodas platform). The teachers are responsible for the quality of classroom materials.

In terms of *Access to technology*, the Lyceum has a Centre of Biotechnology; a Robotics centre; 4 ICT classrooms; 2 mobile ICT classrooms; 2 classrooms for technology with 3D printers and a photo studio.

The Lyceum is also characterised by its **fruitful collaboration** with industry. Indeed, a cooperation agreement has been signed with Kaunas Technological University; the Lithuanian Engineering Industry Association “LINPRA”; the Vytautas Grand University; the Kaunas Technical Creativity Centre for students; the Kaunas Technical College and the Kaunas Mechanical School.

Belgium

Campus De Vesten

The main aim of this school is to make a difference in content and approach, combining knowledge and investigative and practical skills in its STEM projects. For this reason, it **cooperates with five other primary schools** in the region and actively **collaborates with companies** and experts in the field. Moreover, **STEM-related projects** are organised at school level for students from the ages of 11 to 18. In particular, the following are put in place:

- Proeftuinen “experimental labs” in primary schools. 2 hours/week
- Talentmodules “talent modules” for 12-to-14-year-olds. 4 hours/week (STEM module included).
- Keuzemodules “elective modules” for 11-to-14-year-olds. 2 hours/week (STEM module included) combining a mixed group of students from general and technical secondary education.

Moreover, the school’s STEM teachers combine different areas of expertise in mathematics, sciences and technology. They have a growth mind-set and keep on learning about **new STEM trends and challenges**. Because the school has STEM teachers with a technical/ICT background as well as teachers with a scientific/mathematical background, all STEM areas can be combined in each grade of education. As an overview, the school participates in the following projects, classified by theme:

Maths/science projects

- Planetwatch about research for air quality.
- Geocaching, where students learn about geocaching, GPS, Galileo, triangle geometry, coordinates and timing and location.
- Plastic lab, a project about recycling plastics. It includes a practical session where students make a car of recycled pet bottles.
- SPACE project, where students learn about space, planets, the sun and the moon, satellites, etc.
- The magic of the eye, where students learn to make a preparation under the microscope. They make their own microscope and make optical illusions.
- Lichaam van Coppens, where students experimentally study the difference between acids and bases using red cabbage juice.

Technology

- 3D printer project. During this project, students not only learn about 3D printing, but they also make objects. The school was among the pilot schools within the 3Dkanjers project (in the Netherlands) to build with a 3D printer and it eventually became the first in Belgium to complete the project
- Basic programming, where students learn how to programme with “code.org”, Scratch, Microbit and Lego Mindstorms.
- Arduino, where 14-year-old students learn to use this programme.

- LEGO GBC is an engineering project where students do experiments about gears, transmissions, construction, etc. The previous year, students built 30 modules aiming at entering the Guinness Book of Records.

France

Collège Pfeffel in Colmar

Inspired by the principles applied to primary schools and *collèges* (lower secondary schools) for several years, the Foundation *La main à la pâte* and the network *Maisons pour la science* have launched the pilot *collèges* network at national level. This project aims to develop privileged relationships with researchers, engineers and technicians. The pilot *collèges* network started in 2016 with 50 establishments, half of them located in priority education zones or in rural areas. In 2017, there were 100 colleges in the network.

Innovation is developed at the levels of the pedagogical team and the class: **by collaboration among disciplines and among teachers, instead of individual work; by inquiry-based approaches, by professional development, etc**.

The pilot *Collège* Pfeffel in Colmar, located in a priority education zone, focuses primarily on increased educational offer for a 7^{th} grade robotics science class (one hour per week, co-intervention of two or three 3 teachers following activities).

This *collège* is also involved in an interdisciplinary project entitled “City of Tomorrow”, for 6^{th} grade classes.

For the 7^{th} grade robotics project, the pedagogical team is composed of:

- a project coordinator, who is a Technology teacher,
- a Physical Sciences teacher,
- a Mathematics teacher.

Each of these teachers has a specialty that fully contributes to the practices of STEM - science, technology, engineering, and mathematics:

1. In Technology: the teacher is the initiator of a pedagogical approach to construct “a rover on Mars”. In these technology workshops pupils will build 13 rovers by assembling the various elements, by inquiry-based learning. Pupils will design and build a Mars lander rover, during the *La main à la pâte 3D Challenge* project, with a 3D printer. The pilot *collège* of Colmar will be linked with another *collège* in Alsace, to compare the technical solutions found in each 6^{th} grade class.
2. In Mathematics, pupils are introduced to Scratch and Arduiblock programming and algorithms. They will programme the robot and optimise rover movement strategies.
3. In Physical Sciences, pupils are trained to use the Arduino acquisition board and sensors and actuators that enable the robot to interact with its environment. The rover will be equipped and programmed by Arduiblock. The pupils will test, in ISBE, the setting of the parameters to improve the movements of their rover (obstacle avoider and line tracker). Interdisciplinary teaching in Maths & Science-Physics for programming can be chosen by all 7th grade pupils, with continuous evaluation.

Added to this main STEM programme for the robotics project, other disciplines are including robotics aspects in their courses: the French teacher is addressing the issue of humans’ place in nature in the face of technological progress (“What place for robots in our society?”); in Biology, History and Geography courses, teachers will co-drive interdisciplinary classes about the use of robots in the exploitation of agricultural, energy, forestry, fishery and water resources. Their observations will be used to develop a robot project adapted to the exploitation of one of the resources, through an Internet radio broadcast; In Art, linked with the “picture and fiction work” programme, pupils will imagine a robot’s head as an extraordinary machine. All these courses are continuously assessed.

At the institutional level, the director of the *collège* highlights the achievements of pupils and the pedagogical team’s engagement: exhibition of scientific projects for parents and pupils, communication to local journalists, development of links between local schools and the pilot *collège*, partnerships with local industries, scientific and professional conferences of invited experts, partnerships with the Foundation *Main à la pâte* and the *Maison pour la science en Alsace, etc.*

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STEM School Label

ABOUT THE STEM SCHOOL LABEL PROJECT

Having recognised the importance of promoting STEM studies in schools, a number of organisations specialised in STEM education have joined forces to address the current lack of pupils embarking on STEM studies and STEM careers in a true multi-stakeholder approach. This joint commitment gave birth to the STEM School Label project.

Within this project, supported by the Erasmus+ programme, school representatives will be able to evaluate their school's performance in STEM via an online self-assessment tool according to a set of criteria defining a STEM School.

This self-assessment tool will identify required areas of development and provide suggestions of resources for applicant schools to improve their STEM activities at school level. The purpose of this strategic partnership project is to enable as many schools as possible to benefit from the STEM School Label, by also engaging the support of Ministries of Education.

European Schoolnet UGDYMO PLĖTOTĖS CENTRAS CIÊNCIA VIVA CENTER FOR THE PROMOTION OF SCIENCE Maison pour la science AU SERVICE DES PROFESSEURS en ALSACE

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