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Education Practices in Europe

SCIENTIX OBSERVATORY REPORT - DECEMBER 2018

European Schoolnet

Texas Instruments

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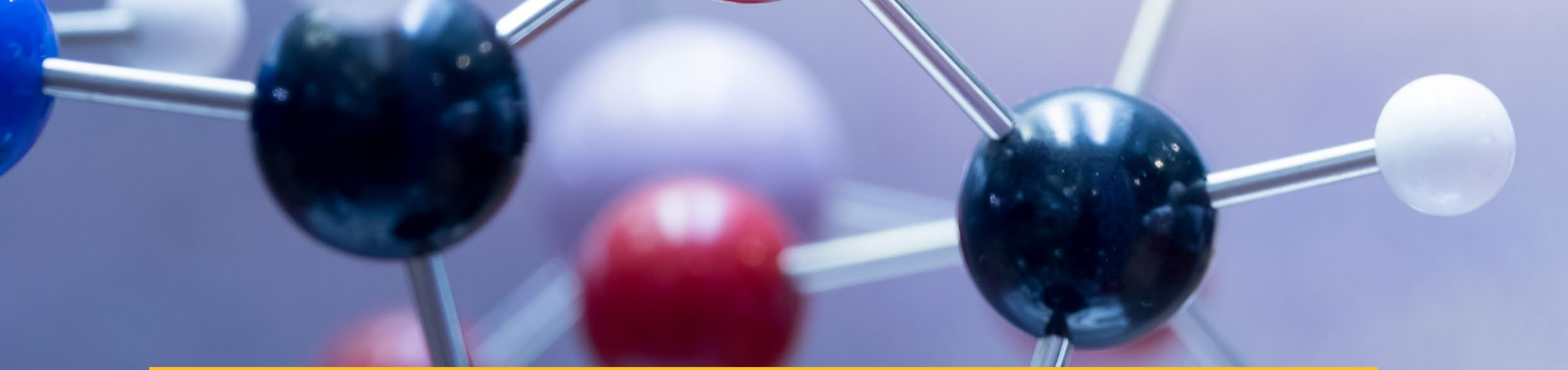

Executive summary and recommendations

Increasing the motivation of students towards studying Science, Technology, Engineering and Mathematics (STEM) subjects and raising achievement in these areas are important challenges faced by European education systems; the way STEM is approached in schools is key to addressing them. To complete the findings of the STEM Education *Policies report*[1] published in October 2018, Scientix launched, with the support of Texas Instruments, the STEM Education Practices Survey, looking to collect information about how STEM teachers throughout Europe organise their teaching practices.

The present STEM Education *Practices* in Europe report draws on the analysis of 3,780 responses (representing over 4,500 classes) to the STEM Education Practices Survey, answered by educators in 38 European countries. Its aim is to provide a grassroots, European-wide perspective on how STEM teachers organise their teaching, in terms of resources and pedagogical approaches used, on the current state of teachers' professional development and support, and on their opinions and attitudes, particularly in relation to their school environment and their openness to cooperation with STEM industries.

KEY FINDINGS

The report's key findings are divided into five main areas, covering: [1] pedagogical approaches used in STEM teaching, [2] access to and use of resources and materials, [3] professional development and support for STEM teachers, [4] experience and educational level in STEM teaching, and [5] teachers' attitudes and influence of the environment.

[1] Pedagogical approaches

Traditional direct instruction remains among the most highly reported pedagogical approaches in STEM teaching. This trend slightly increases in high frequency classes (classes which are taught over three or more sessions per week), an indication that, if more classroom time is available to teachers, it is not used to bring more innovative approaches into teaching.

A prevalent subject in European curricula, Mathematics was identified in the STEM Education Policies Report (October 2018) as being "a key lever to transforming STEM teaching and learning". The present study found that the subject appears to be taught more often through teacher-focused, less diverse and less contextualised pedagogies than the other, STE subjects. At the other end of the spectrum, ICT teachers[2] appear to be using student-centred pedagogical approaches to a much higher degree, reporting the lowest use of traditional teaching, as well as the highest use of project/problem-based learning and collaborative learning.

[2] Resources and materials

With the exception of ICT subjects, teachers report an extensive use of paper-based materials in their teaching, alongside mainly presentation aids (slideshow presentations and audio or video materials), a finding in line with the high reporting of teacher-led instruction highlighted above.

Science and technology teachers also point to insufficient access to experimental labs, an indication that pupils may not be given sufficient opportunities to do practical work as part of their science learning.

1 European Schoolnet (2018). Science, Technology, Engineering and Mathematics Education Policies in Europe. Scientix Observatory report. October 2018, European Schoolnet, Brussels, http://www.scientix.eu/observatory/stem-education-practices-europe

2 The ICT teachers surveyed reported teaching the following aspects of ICT: computer use only (105 responses), database & network design and administration (10 responses) and software, applications development & analysis (91 responses).

[3] Professional development and support for STEM teachers

The majority of STEM teachers surveyed have not taken any ICT-related professional development or training related to innovative STEM teaching in the last two years. When they do follow training, teachers tend to update their knowledge online and in their own time.

In terms of supporting groups, most teachers rely on their colleagues of the same subject for updating their knowledge. In general, a divide can be observed between the teachers' high use of collaboration in the classroom, and their own professional practice (38% of STEM teachers surveyed report having received little or no support, even from their colleagues of the same discipline).

[4] Experience and educational level in STEM teaching

With more experience, teachers are more willing to integrate constructivist pedagogical approaches in their classes and limit the use of direct instruction. This trend can be observed in all other subjects, except Mathematics, where traditional instruction remains high, with little variation according to experience.

As national end-of-secondary-education exams approach, it appears that more diverse pedagogies increasingly give way to traditional teaching, with instructional practices such as Inquiry-Based Science Education, project/problem-based learning and personalised learning being particularly affected.

[5] Teachers' attitudes and influence of the environment

Three out of four of the surveyed teachers share a positive vision of innovative STEM teaching with their colleagues and head of school, and this is linked positively with the amount of innovation brought into the classroom. Teachers appear open to collaborating with STEM industries in various domains to enhance teaching and learning.

RECOMMENDATIONS FOR POLICY-MAKERS

The analysis of the STEM Education Practices teachers' questionnaire provides a good insight into how teachers in Europe approach STEM teaching. The results of the survey reflect a diverse landscape, with STEM teachers trying their hand at new pedagogies and diversifying the resources and materials used, but also indicate that there is still a need for support on a number of actions in order to advance effective STEM education at the European level.

1. Supporting innovative STEM teaching practices and networks based on Inquiry-based Science education (IBSE), and other student-centred pedagogies

The high frequency of reported traditional instruction and of paper-based materials in STEM teaching, contrasted with the notably lower reporting of student-centred approaches, such as inquiry-based or problem/project-based approaches, suggests that there is still a lack of confidence, at the level of STEM teachers, in approaching more innovative pedagogies, an aspect particularly notable among less experienced teachers.

The STEM Education *Policies* report proposed the development of a common European framework of reference for STEM education, to evaluate and integrate curriculum and pedagogical innovation.

On a similar line, the results of the STEM Education Practices study call for actions in supporting European networks of exchange and assistance for STEM teachers to build confidence in approaching innovative teaching inside and outside the classroom. The fact that teachers tend to turn primarily to their peers for professional support shows the important impact teacher networks can have. Programmes should also address initial teacher education to ensure that new teachers are appropriately trained to approach innovation in their practice.

2. Offering relevant professional development opportunities for STEM teachers and strengthening school-industry collaboration

The report's findings raise concerns regarding the professional development of STEM teachers. There is a clear need to support the development and dissemination of relevant STEM training programmes which encourage teachers to build their subject and pedagogical knowledge as well as their confidence in using new technologies in the classroom. Appropriate mechanisms to recognise and support teachers' efforts to improve their teaching should be put in place.

Educators appear to be open to school-industry collaboration – a very positive sign, as school-industry exchanges can provide valuable opportunities for teachers to develop professionally. Indeed, the STEM Education Policies in Europe report highlighted that STEM industries are increasingly involved in actions that support teachers to produce educational content. However, STEM teachers report rare use of industry-based educational materials, an indication that their general openness towards collaborating with STEM industries is not being met with an appropriate response. Strengthening school-industry collaboration is essential to ensure that teachers are in a good position to help their students develop relevant skills, and for companies to support the improvement of the labour force of tomorrow.

3. Innovating the STEM education curriculum and assessment

Pressure to prepare students for final exams is the main factor affecting STEM teaching, and the impact can be observed in the overall decrease in the use of student-centred pedagogies as students advance to higher educational levels. An important factor is the way the curriculum is written and expected to be taught. Assessment policies that give sufficient weight to formative evaluation methods are needed so as not to inhibit the use of innovative pedagogies in the final years of education. Evidence-based initiatives that develop and test new assessment methods compatible with innovative teaching practices should also receive appropriate support.

4. Supporting the development and implementation of whole-school STEM-oriented strategies

The school context plays an important role in advancing the STEM agenda. The report provides evidence to suggest that teachers appear more confident in approaching pedagogical innovation when they have the support of their peers and the school administration. Developing a clear STEM strategy at the school level to promote and support innovative STEM teaching can play an essential role in coordinating efforts to improve the quality of STEM teaching and to ensure that STEM teachers benefit from the appropriate support to improve their practice.

5. Strengthening trans-disciplinary collaboration to encourage the uptake of integrative STEM teaching

Integrative STEM teaching should also be addressed. The teachers surveyed report a relatively high use (68%) of "integrative learning", but only 53% coordinate their teaching with teachers of other disciplines. An integrative approach to STEM education cannot be carried out in isolation and without curriculum flexibility. The STEM Education Policies report encouraged the uptake of pragmatic initiatives directed at breaking down the barriers between STEM subjects. Such initiatives should also consider strengthening teachers' collaboration and encouraging the exchange of good practices across disciplines to ensure that the conditions are met for a meaningful integrative STEM education in classrooms across Europe.

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Introduction

The Science Technology, Engineering and Mathematics Education *Practices* in Europe report is developed by Scientix, the community for science education in Europe, with the support of Texas Instruments and European Schoolnet. The report follows the Science Technology, Engineering and Mathematics Education Policies in Europe report[3] (European Schoolnet, 2018), published in October 2018 and produced following a consultation with STEM education representatives from 14 European countries, as well as a series of interviews with university and industry experts. The report highlighted the main trends of public education policies carried out in Europe in favour of STEM and proposed general observations and a set of recommendations for future actions.

Over five sections, the present report provides an up-to-date overview of Science, Technology, Engineering and Mathematics teaching practices in Europe; the pedagogical approaches, resources and materials used by STEM teachers in their professional practice; the main deterrents to implementing an effective STEM education; the status of STEM teachers' professional development and support; and teachers' attitudes towards innovating their teaching.

The instrument used to collect the information for the report is a large-scale quantitative survey, made available in 25 European languages and published on the Scientix portal.[4] The questionnaire received 3,780 valid responses – representing a convenience sample – from teachers in 38 European countries. The present report provides an overview of the methodology of the study, the key results, conclusions, and recommendations for future research. Exemplary case studies highlighting innovative STEM teaching are included in Appendix 1 of the report, to showcase good practice in STEM teaching, carried out in different countries in Europe.

It must be noted that the conclusions presented in this document are based on teachers' self-reporting regarding their practices, needs and opinions on various aspects of STEM education. Whereas the previous *Policies* report looked at the European situation from the policy-makers' point of view, the Practices report takes a grassroots view of STEM education. Links between the two reports are highlighted wherever these two perspectives meet.

Abbreviations

STEM	Science, Technology, Engineering and Mathematics
STE	Science, Technology and Engineering
M	Mathematics
IBSE	Inquiry-Based Science Education
EUN	European Schoolnet

Defining innovative teaching

Throughout this report, we use "innovation" and "innovative teaching" with the meaning proposed by Ferrari et. al. (2009), specifically, "the process leading to creative learning, the implementation of new methods, tools and contents which could benefit learners and their creative potential." In this understanding, innovative teaching does not equate with simply the introduction of new tools in teaching practice (although it can be argued that this is also an aspect of innovation), but rather puts emphasis on "learner empowerment and centeredness". The authors take the view that innovation in teaching and learning is necessary to respond to current challenges in STEM education such as improving overall STEM literacy and maintaining student interest in STEM fields, while also acknowledging the role of traditional instruction in transmitting disciplinary knowledge to students.

3 For ease of reference, the executive summary of that report is included in Appendix 3 of the present document. The full STEM Education Policies in Europe Report can be accessed online: http://www.scientix.eu/observatory/stem-education-practices-europe

4 http://www.scientix.eu/

1. Questionnaire methodology

1.1. AIMS AND DISTRIBUTION

The STEM Education *Practices* in Europe questionnaire was designed to collect information from secondary school teachers about the way they organise their teaching, and to focus on three particular aspects:

- pedagogical approaches used in the teaching of STEM
- type of resources used by teachers and students to facilitate STEM teaching and learning, including the use of Information and Communications Technology (ICT) in the teaching process, and
- teachers' professional development activities and needs.

Made available in 25 languages,[5] the survey was launched on 13 June 2018 and was online for four months. Among others, the dissemination channels of Scientix, European Schoolnet and Texas Instruments were extensively used to maximise data collection. To make sure that the news about the survey permeated at national levels, the networks of Scientix partners – members of the Ministries of Education STEM Representatives Working group,[6] the Scientix National Contact points and the Scientix Ambassadors – were also encouraged to share the survey. The dissemination efforts resulted in a coverage of 38 European countries, but the use of national networks also produced a data sample with an uneven distribution, largely dependent on the voluntary efforts of the various actors engaged in disseminating the survey. In the attempt to reduce any sample bias, in the cases where the uneven distribution of data is observed to influence the overall results, additional observations are made to describe these effects. In addition to increasing the validity of results, this treatment of the data sample also allows for a closer observation of the outliers, and for extracting richer conclusions throughout the report. A more detailed account of the methodology is provided in the section on addressing the sample bias below.

The total number of unique responses to the questionnaire was 3,794, 14 of which were from teachers working in countries outside Europe,[7] and were therefore not included in the analysis. The final analysis is therefore based on a total of 3,780 responses. The data sample is described in more detail in the next sections.

1.2. THE QUESTIONNAIRE

One of the main difficulties of carrying out a cross-national quantitative analysis of educational practices is to ensure that the questions (and the answer options) are generic enough not to pose any difficulties to respondents coming

5 Responses were received for all language versions of the questionnaire: Turkish, Romanian, Danish, Portuguese, French, German, Italian, Slovenian, English, Lithuanian, Croatian, Spanish, Bulgarian, Macedonian, Serbian, Greek, Slovak, Estonian, Polish, Dutch, Finish, Czech, Swedish, Hungarian and Norwegian.

6 The Ministries of Education Science, Technology, Engineering and Mathematics (STEM) representatives Working Group (MoE STEM WG) 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 (EUN) in the field of STEM education, and especially within the Scientix project, following an agenda that addresses the Ministries' priorities and main interests. EUN coordinates the working group.

7 Information about STEM teaching practices from countries outside Europe was not the focus of the present study. Nevertheless, the authors wish to express their gratitude to the teachers in Australia (1), Indonesia (1), India (4), Kenya (1), United States (2), Uruguay (1), Mexico (1), Peru (1), Senegal (1) and Brazil (1) who took the time to participate in the survey.

from different European educational systems, but detailed enough to provide accurate information about the various items to investigate. For this reason, before the launch, the questionnaire underwent a conventional pre-testing phase during which testers were asked to fill in the questionnaire and provide feedback on its content (in terms of clarity of language used and the perceived efficacy in reaching the intended goals). The feedback, provided freely during a debriefing session with all testers, was implemented in a subsequent version of the questionnaire. Randomly selected language versions were additionally tested, to identify any further issues, and assess common shortfalls in the quality of translations.[8] These were necessary steps in ensuring that the different language versions of the survey were collecting comparable data, and that teachers from diverse educational systems could select options which accurately described their subjects and practices.

The final questionnaire consisted of 27 closed questions, of which 23 required an answer (were compulsory), and four were optional, all presented under headings indicative of the areas of interest covered, as shown in Table 1.

Table 1: Structure of the STEM Education Practices questionnaire for secondary school teachers

SECTION HEADING	QUESTION ITEMS	DATA OBTAINED
1. Class-specific information	Q1-Q4 [Compulsory, Class-specific]	Class description (including subject taught, students' ages and gender distribution, number of classes per week), types of pedagogical approaches and teaching strategies, and materials used for the teaching of the class.
2. Your STEM teaching in general	Q5-Q7 [Compulsory, General]	Access to STEM teaching resources.
3. Obstacles to implementing effective STEM teaching	Q8 [Compulsory, General]	Factors perceived as negatively affecting STEM teaching.
4. Support for STEM teaching	Q9 - Q13 [Compulsory, General]	Professional developments and overall support available to STEM teachers.
5. Teacher opinions and attitudes	Q14 - Q15 [Compulsory, General]	Perceived impact of innovative STEM teaching and the use of ICT.
6. Personal background information	Q16 - Q23 [Compulsory, General]	Demographic data and other basic characteristics of survey respondents.
1´. Class-specific information (1-3 additional classes)	Q24 - Q27 [Optional, Class-specific]	Class description (including subject taught, students' ages and gender distribution, number of classes per week), types of pedagogical approaches and teaching strategies, and materials used for the teaching of the class [repeating Q1-Q4 for up to three additional classes taught].

The question types and analysis scales are briefly described below, and the full English questionnaire is included in Appendix 2.

1.2.1. Question types and analysis scales

All questions included were closed, offering a limited range of answers, presented either in a matrix form, single or multiple-choice options or in the form of various Likert-type scales.

8 The pre-testing was carried out with eight secondary school teachers from Finland, Greece, Spain, Belgium, Romania, Italy and the Czech Republic; 15 additional teachers contributed to testing 14 randomly selected language-versions of the questionnaire.

4-level Likert scales prompted participants to rate various question items with values ranging from 1: Not at all / Strongly disagree, to 4: A lot / Strongly agree. For simplicity of interpretation, Levels 1+2 and 3+4 have been combined and redefined as "Low / Unfavourable and High / Favourable" degrees (see Table 2). "Not applicable" (N/A) was also introduced as an answer choice in some questions – N/A answers are interpreted on a case-by-case basis.

Table 2: Redefined scales for data analysis

LIKERT SCALE	REDEFINED SCALE
1 – Not at all / Strongly disagree	Low / Unfavourable
2 – Very little / Disagree	
3 – To some extent / Agree	High / Favourable
4 – A lot / Strongly agree	
N/A (Not applicable)	

1.3. SAMPLE DESCRIPTION

1.3.1. Profile of the respondents

Age, gender and teaching experience

As mentioned, the questionnaire received a total of 3,780 responses which were considered valid for the present analysis. The respondents were STEM[9] teachers from 38 European countries, almost two thirds of them female (62%). The gender split is unsurprising and is somewhat reflective of the overall gender imbalance in the teaching profession, considering that "teaching is a job largely exercised by women" (European Commission, 2015).

Most respondents are quite experienced teachers, with 67% of the sample having more than 11 years' teaching experience. It can be observed that the data sample is evenly distributed from this perspective; a similar distribution can be observed when analysing the respondents' ages (see Figure 1 and Figure 2).

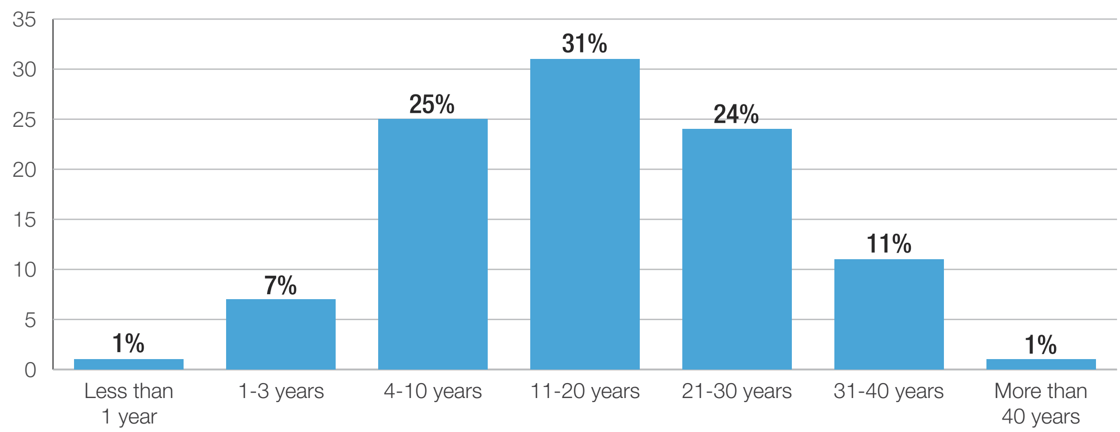


Figure 1: Sample description: Teaching experience [n=3780]

9 As can be deduced from the report's findings, approaches to STEM teaching vary greatly across European educational systems. For simplicity of reference, by STEM teachers we mean teachers of any subjects included under the four domains of Science, Technology, Engineering and Mathematics in the national educational system. When STEM teaching is specifically understood as being an integrative approach, the term "integrative STEM teaching" will be used.

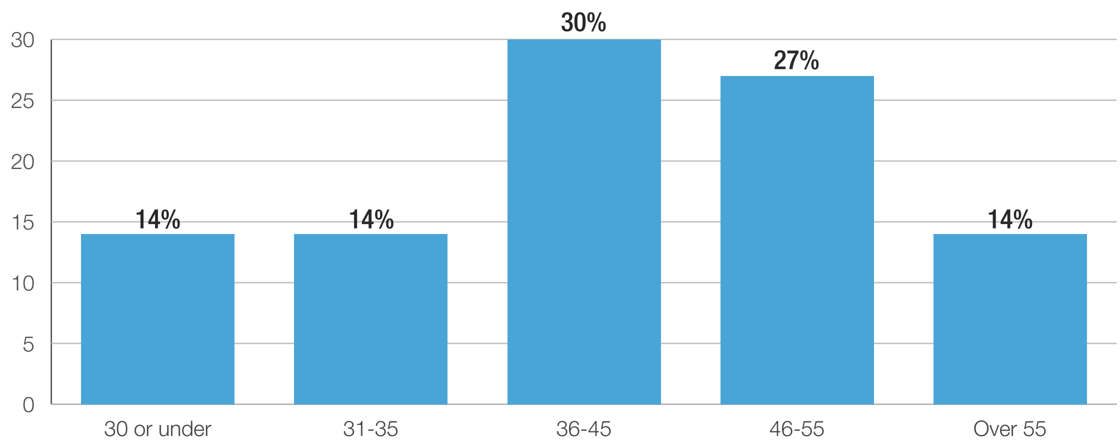


Figure 2: Sample description: Age of respondents [n=3780]

Use of technology outside the classroom

Perhaps unsurprisingly, considering that the questionnaire was distributed exclusively online, when asked how frequently they use a computer, smartphone or tablet for purposes other than work, a great majority of respondents (83%) reported a daily use of such technologies (Figure 3). Only 18 respondents stated that they "Never" use these technologies outside work.

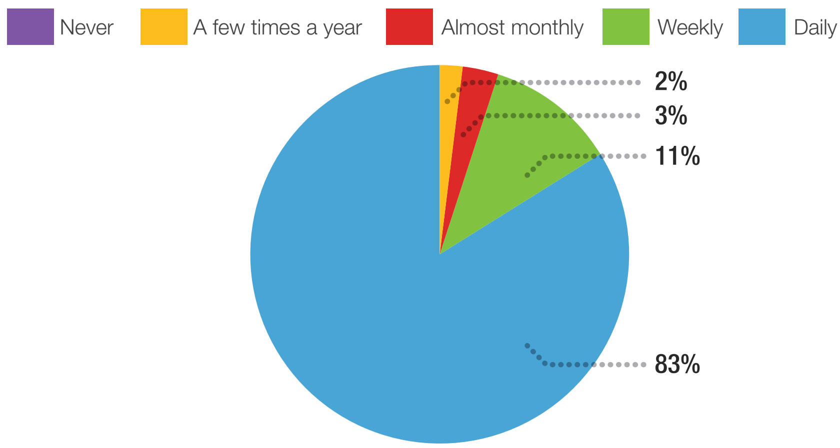


Figure 3: Sample description: Frequency of technology use [n=3780]

Geographical coverage

Respondents from 38 countries in Europe filled in the questionnaire, and the distribution of responses by country is shown in Figure 4. Significant numbers of responses came from teachers in Turkey (1,662), Romania (406) and Denmark (346). Other countries fairly significantly represented in the sample are Slovenia (156), Portugal (152), France (144) and Italy (136). All other countries included in the sample are represented by fewer than 100 teachers. The additional steps taken in the data analysis to ensure that this uneven distribution of responses across countries does not affect the results of the study are described in the following section.

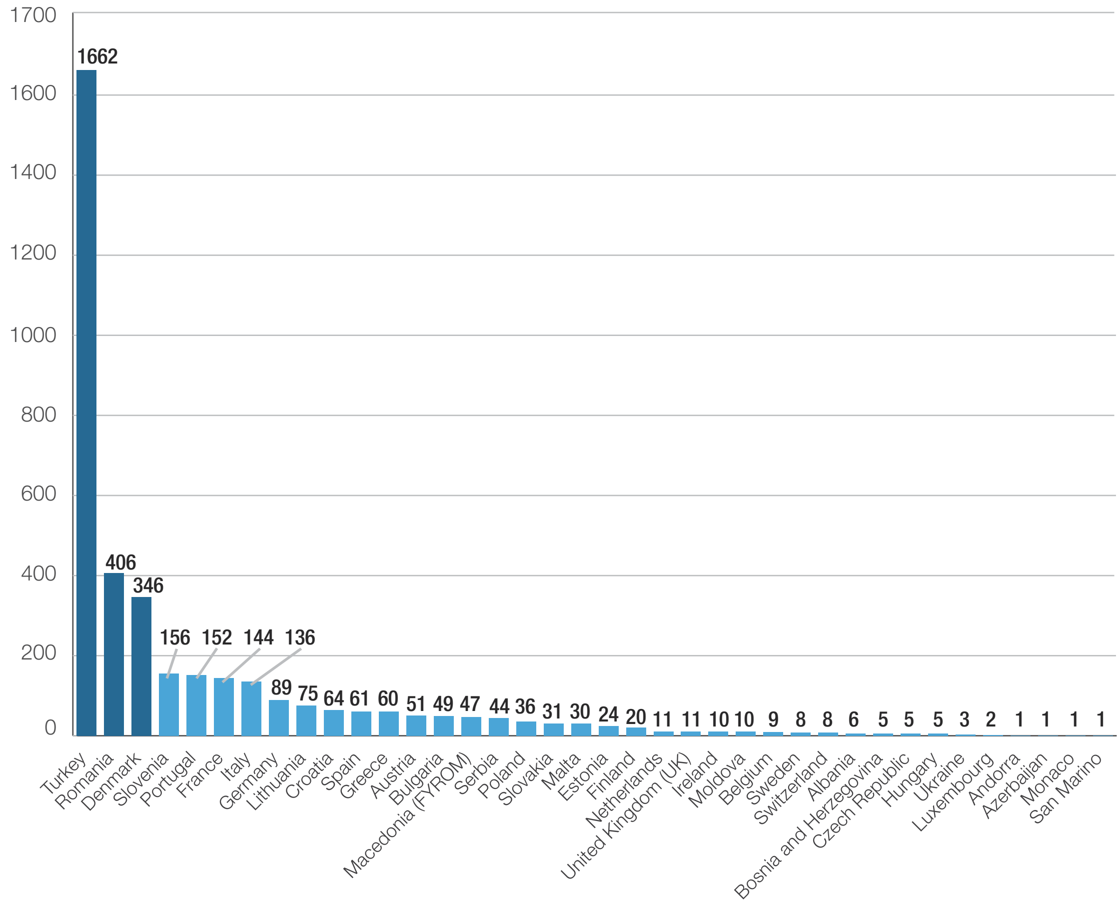


Figure 4: Sample description: Number of responses per country [n=3780]

Subjects covered

The questionnaire allowed respondents to provide information on more than one class they teach if they wanted to (via the four optional questions at the end of the survey). For the purpose of the analysis, "classes" were defined as particular groups of students which attended a specific lesson. This meant that educators who teach more than just one school subject could report on the different approaches, resources and materials used in each subject, but also that a teacher who would teach the same subject (for example, Mathematics) to two or more groups of pupils of roughly the same age, was given the possibility to report on how they practise their teaching in each of these classes. Respondents reported on a total of 4,584 classes.[10]

Respondents could select from a list of 25 subjects the one applicable to their class. The list of subjects that teachers reported on and the number of responses per subject are shown in Figure 5. The most commonly reported subject in our sample is, by far, Mathematics, with 42% of respondents reporting about their Maths teaching, followed by Integrated STEM (13%), Physics (12%), Biology (8%) and Chemistry (8%). Special consideration will also be given to the teaching of these subjects in the section analysing the key results. In addition, the teaching of Information and Communications Technology (ICT) will also be considered, by accumulating the responses under the three aspects of ICT teaching reported on (a further 5% of the data sample): "ICT (computer use only)", "ICT (database & network design and administration)" and "ICT (software, applications development & analysis)."

10 In the optional section of the questionnaire, respondents were asked to provide information about up to three additional STEM classes they taught. Through this section, information about 804 classes was collected, including a number of incomplete/partial responses. For simplicity of analysis, responses which provided only the class characteristics (i.e. subject taught, number of girls/boys per class, etc.), but did not provide any additional information on the pedagogical approaches or materials used for the teaching of this class were discarded.

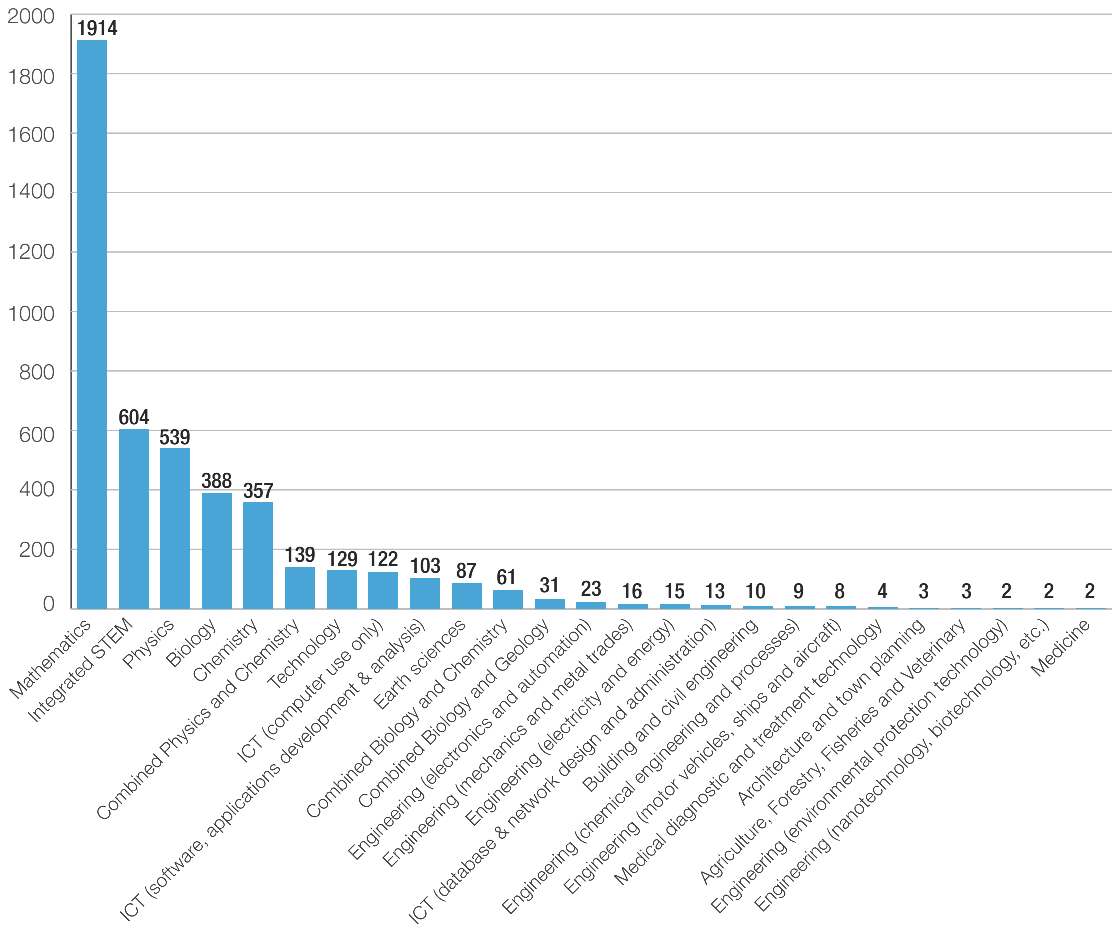


Figure 5: Sample description: List of subjects. In green, we represent subjects representing more than 5% of the data sample; responses corresponding to the three ICT-related subjects are analysed as a whole [n=4584].

1.3.2. Addressing sample biases

Three potentially significant sources of bias can be observed in the data sample: the first, concerning the uneven distribution of responses per country; the second having to do with the preponderance of Mathematics among the STEM classes; and the third concerning the high reporting of Integrating STEM teaching.

Several steps were made in the data analysis to address the potential bias derived from the uneven distribution of countries. First, responses coming from Turkey (1,662), Romania (406) and Denmark (346) were identified as outliers. To ensure these responses do not significantly change the results of the study, the data was analysed separately as follows: first, the full set of data was considered and compared with the overall data excluding the three outliers. Responses from each of these three countries were subsequently analysed to ensure that no significant differences (defined as statistical variances of 10% or more) occur among the different results. It was found that only in specific cases did the country coverage impact the overall results. Throughout the report, the conclusions will therefore refer to the full set of data collected, except in the cases where statistical differences of 10% or more have been observed. These cases will be further illustrated by data extracted from the sample excluding any of the three outliers observed to influence the results in a significant way, and enriched, where relevant, with additional observations specific to each of the three countries excluded from the analysis.

A similar treatment was applied to address the potential bias caused by the high number of Mathematics classes that teachers reported on. Three sets of data were compared to identify significant statistical differences: the full set (including all the valid survey responses: 3,780), only responses from teachers (also) reporting on Mathematics classes (a total of 1,914) and the full set of data excluding all responses (also) reporting on Mathematics classes. Additional information is provided in the report where significant differences (of 10% or more) have been observed following the comparison between these three datasets. In these cases, we refer to Science, Technology and Engineering classes as STE, and as M, the Mathematics classes.

The high reporting of Integrated STEM teaching classes (604 classes reported through the questionnaire) also drew our attention, as Integrated STEM teaching is a subject that is only starting to be introduced in some countries, but still rarely used at the European level. Moreover, 93% of the Integrated STEM classes reported on are represented by Turkish responses. Interestingly, at the moment of writing, there are no interdisciplinary STEM courses included in the educational curricula at the primary or secondary school levels in Turkey, to the best of our knowledge. One possible explanation for the high number of "Integrated STEM teaching" responses from Turkey is that respondents chose this option to refer to the "Science" course taught in lower-secondary school, which is likely to require a certain degree of integration, but is taught separately from other STEM subjects included in the curriculum (such as Mathematics, Technology and Design, or ICT). Another possible explanation is that teachers who may be using integrated STEM approaches in the teaching of curriculum subjects may feel that the "Integrated STEM" method defines their practice more accurately than the subjects included in the curriculum. Since we cannot be sure of the reason for their choice, to control for the bias due to this over-representation, these responses will be excluded from the analysis of class-specific information (Q1 – Q4 and Q24 – Q27 in the questionnaire).

1.3.3. Rounding of numbers

Because of rounding, some figures might not add up exactly to the totals; likewise, percentages might not add up to 100%. Percentages are always calculated on the basis of exact numbers and are rounded only after calculation.

2. Key results

SECTION 1: PEDAGOGICAL APPROACHES

One of the main goals of the survey was to better understand how teachers organise their STEM teaching and a particular focus was given to pedagogical approaches and teaching strategies most commonly used in educational settings.

Two survey questions were introduced to address these aspects. First, respondents were asked to indicate, from a list, the extent to which they were using particular pedagogical approaches in their STEM teaching for each class they were reporting on. To avoid variations in interpretation, short definitions of each pedagogical concept accompanied each answer choice, as indicated in Table 3.

Table 3: Pedagogical approaches: Answer choices & definitions

	PEDAGOGICAL APPROACH	DEFINITION
1.	Traditional direct instruction	Lessons are focused on the delivery of content by the teacher and the acquisition of content knowledge by the students.
2.	Teaching with experiments	Experiments are used in the classroom to explain the subject matter.
3.	Project/Problem-based approach	Students are engaged in learning through the investigation of real-world challenges and problems.
4.	Inquiry-Based Science Education	Students design and conduct their own scientific investigations.
5.	Collaborative learning	Students are involved in joint intellectual efforts with their peers or with their teachers and peers.
6.	Peer teaching	Students are provided with opportunities to teach other students.
7.	Flipped classroom	Students gain the first exposure to new material outside of class, and then use classroom time to discuss, challenge and apply ideas or knowledge.
8.	Personalised learning	Teaching and learning are tailored to meet students' individual interests and aspirations as well as their learning needs.
9.	Integrated learning	Learning brings together content and skills from more than one subject area.
10.	Differentiated instruction	Classroom activities are designed to address a range of learning styles, abilities and readiness.
11.	Summative assessment	Student learning is evaluated at the end of an instructional unit and compared against a benchmark or standard.
12.	Formative assessment, including self-assessment	Student learning is constantly monitored and ongoing feedback is provided; students are provided with opportunities to reflect on their own learning.

A second question was introduced to assess the frequency of use of teaching strategies and to provide a deeper understanding of how the different pedagogies are being employed in teaching. Again, respondents were asked to rate the frequency of use of 21 aspects of teaching and learning on a four-point scale ranging from “Not at all” to “A lot”. The question also works as a validity check to mitigate the effects of possible social desirability biases in the respondents’ answers. It can be assumed that teachers would report a more frequent use of pedagogies which are perceived to be more positive or more innovative. The answer options provided to respondents were reflective of the various pedagogies listed in the previous question, so that, at the time of analysis, links could be drawn between the teachers’ self-reported use of pedagogies and their self-reported use of teaching strategies. Answer choices are displayed in the list below; in brackets we add the corresponding pedagogical approach (according to Table 3):

- I present and explain scientific ideas to the whole class (Traditional direct instruction)
- Students work alone at their own pace (Traditional direct instruction)
- Students work on exercises or tasks individually at the same time (Traditional direct instruction)
- I demonstrate a scientific idea to the whole class (Teaching with experiments)
- Students conduct experiments (Teaching with experiments)
- Students discuss ideas with other students and the teacher (Project/Problem-based approach)
- Student make decisions about how they learn (Project/Problem-based approach)
- Students conduct their own scientific study and research activities (Inquiry-Based Science Education)
- Students work in groups, with well-defined tasks (Collaborative learning)
- Students work collaboratively, working together to find solutions to problems (Collaborative learning)
- Students reflect on their learning (Flipped classroom)
- I support and explain things to individual students (Personalised learning)
- I use different types of materials (visual, audio, written) in my classes (Differentiated instruction)
- I use content from different subjects to explain scientific concepts (Integrated learning)
- I invite other STEM teachers of different disciplines to coordinate our teaching of certain common topics (Integrated learning)
- I organise field trips/visits to museums/company visits to contextualise scientific concepts (Integrated learning)
- Students take tests and assessments (Summative assessment)
- I give feedback to my students during a learning activity (Formative assessment, including self-assessment)
- Students participate in assessing their own work and the work of their peers (Formative assessment, including self-assessment)
- Students give presentations to the whole class (Peer teaching)
- I integrate Arts into my STEM teaching to increase student engagement (Integrated learning)

The analysis presented in this section draws from responses to these two questions.

STEM teachers report a high use of traditional direct instruction compared with other, student-centred pedagogies.

Figure 6 shows the pedagogical approaches most frequently used by respondents in their teaching (rated either as “To some extent” or “A lot”).

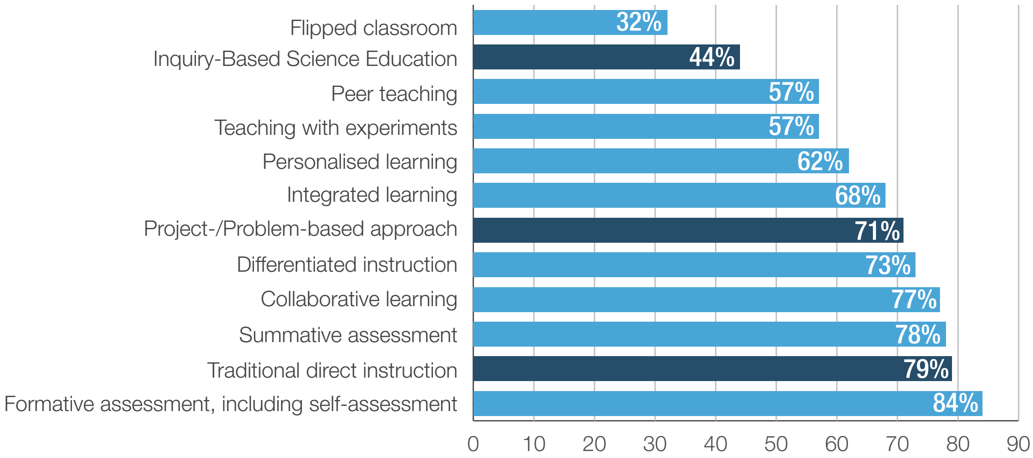


Figure 6: Frequency of pedagogical approaches used in STEM classes [n=3980, excludes 604 "Integrated STEM" responses]

Generally, the STEM teachers surveyed indicated using a variety of pedagogical approaches, with most elements listed being rated highly on the frequency scale. It is worth observing particularly the very high use of formative (84% high frequency) and summative (78%), assessment methods, collaborative learning (77%), differentiated instruction (73%) and project/problem-based approaches (71%). The high reporting of formative assessment is indeed encouraging, showing that teachers are generally mindful of constantly monitoring learning outcomes, instead of exclusively focusing on the final evaluations. The high rate of collaborative learning indicates that appropriate practices to support students in their learning processes are usually present in European classrooms.

At the other side of the spectrum, the flipped classroom approach is reported to be the least frequently used in classrooms (32%), an indication that, overwhelmingly, information tends to be transmitted inside the classroom, in the presence of instructors. With only 44% of the sample indicating a high use of Inquiry-Based Science Education (IBSE), this approach is the second least used in STEM teaching.

Contrasted with the low reporting of IBSE use, the high level of traditional instruction indicated by the survey respondents deserves particular attention. This contrast is maintained when removing Mathematics from the sample, with the overall use of IBSE increasing by 10%, but the amount of traditional direct instruction only decreasing by 5% (Figure 7). Another effect of controlling for the Mathematics bias is the 20% increase in the frequency of teaching with experiments, a somewhat expected result, as experimental learning is not a pedagogy particularly used in Maths teaching.

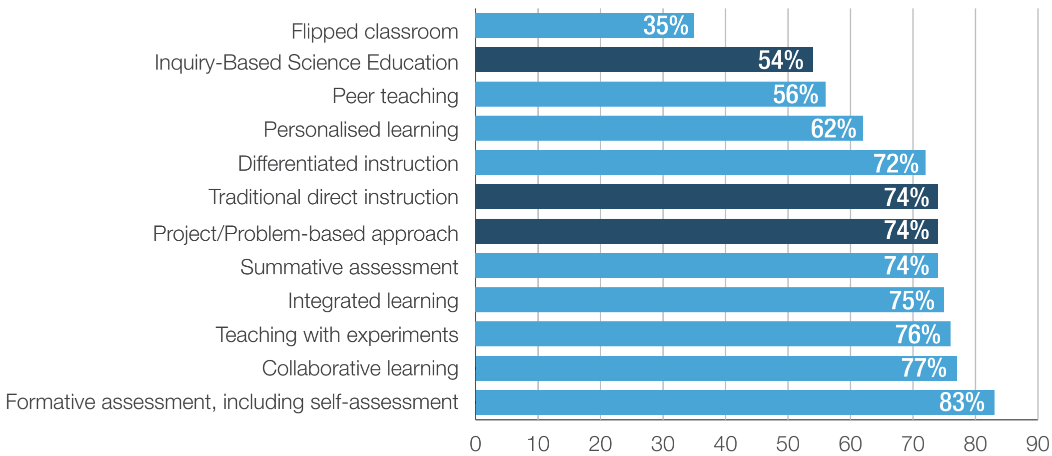


Figure 7: Frequency of pedagogical approaches used in STE classes (no Mathematics) [n=2066, excludes "Integrated STEM" (604) and Mathematics (1914) responses]

Indeed, research shows that using a variety of teaching practices in class and combining teacher-directed and constructivist approaches appears to be the most effective for classroom learning (Isac et. al., 2015), so a relatively high frequency of traditional instruction was expected. Yet, particular teaching strategies are shown to be more effective than others at reaching educational goals; among these, Inquiry-Based Science Education, where students are encouraged to effectively think like researchers, "diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments" is expected to increase student engagement and motivation in science and technology classes, while project- and problem-based approaches are expected to produce similar results in the teaching of Mathematics (European Commission, 2007). Moreover, recommendations issued elsewhere ([US] National Research Council, 2012) stress the importance of balancing scientific explanations with practices needed to engage students in scientific inquiry and engineering design in order to offer an effective science education.

The fact that STEM teachers seem to be reporting considerably more traditional instruction than IBSE is of particular concern.

Moreover, when looking at subjects taught over three or more sessions per week, the amount of traditional direct instruction slightly increases to 82%. This percentage falls to 77% when Mathematics classes[11] are removed from the sample, but still remains higher than the overall average. One possible cause is that subjects with a higher "weight" in the timetable tend to cover a more extensive curriculum, which does not allow enough time for pedagogical innovation.

The self-reporting on the frequency of use of particular pedagogies in classrooms is largely consistent with the overall reporting of different teaching strategies (see Figure 8).

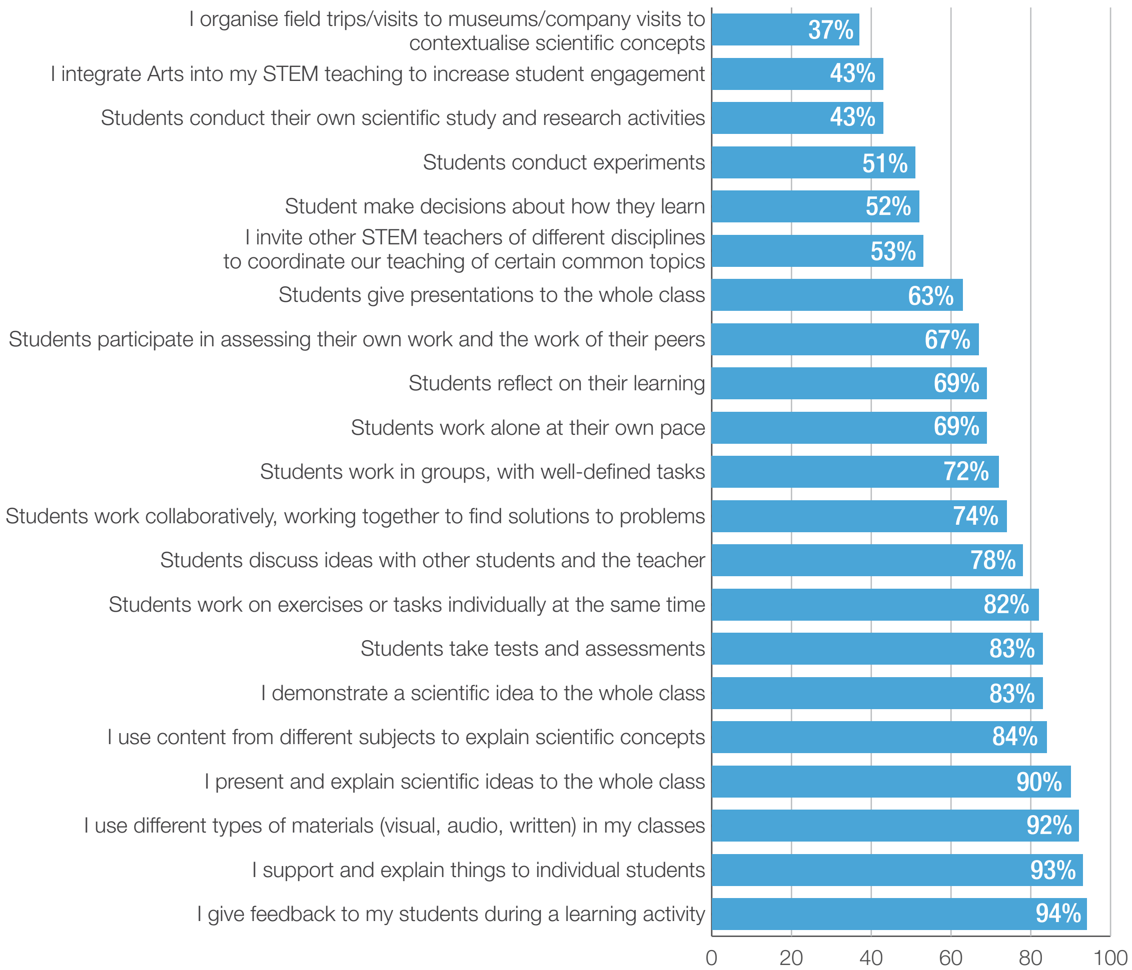


Figure 8: Frequency of teaching strategies used in STEM classes [n=3980]

11 67% of the so-called high-frequency classes in the sample (classes with three or more sessions per week) are mathematics.

It is, however, interesting to observe that, while integrated learning was among the relatively frequent pedagogical approaches used by survey respondents (68%), only 53% frequently coordinate their teaching with teachers of other disciplines and just 37% organise regular field trips or visits to museums or STEM companies to contextualise their teaching. In contrast, 84% of survey respondents indicate that they frequently use information from other subjects to explain scientific topics. In almost half the cases, integrated STEM learning appears to be carried out in isolation, with little cross-disciplinary exchange.

Are there any notable differences regarding the use of different pedagogies and teaching strategies when looking at individual subjects? We first direct our attention to the teaching of Mathematics, given its prevalence in the data sample and its overall weight in European educational systems (European Schoolnet, 2018). Figure 9 shows the specific pedagogies used in the teaching of Mathematics, cumulating high frequency answers ("To some extent" and "A lot") for the listed pedagogies, specific to Mathematics classes.

Mathematics classes appear to be taught more often through teacher-focused, less innovative and less contextualised pedagogies than STE subjects.

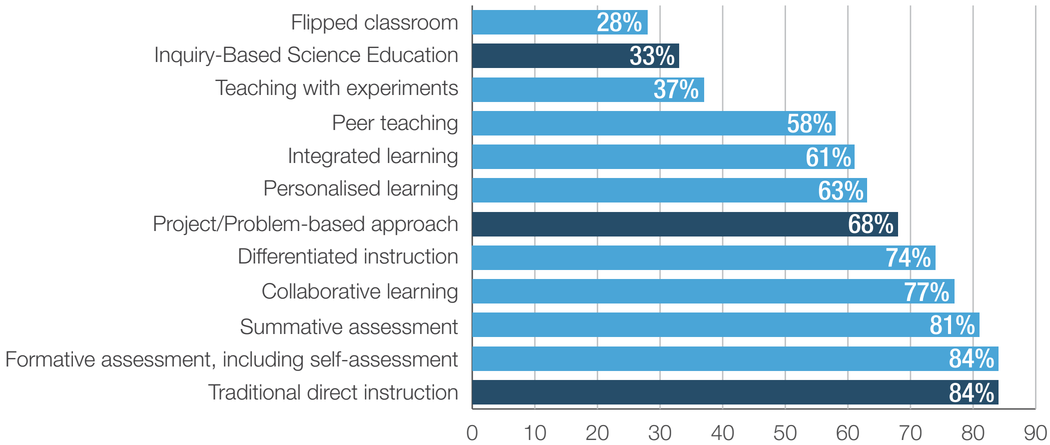


Figure 9: Frequency of pedagogical approaches used in Mathematics classes [n=1904]

Traditional direct instruction is the most frequently used pedagogy in the teaching of Mathematics, alongside "formative assessment, including self-assessment". Indeed, traditional pedagogies see an 11% increase in Mathematics classes, when compared with the cumulated data from all other classes. The only other pedagogy whose reported frequency increases by more than 2% is summative evaluation (6% increase). Conversely, IBSE decreases by 21%, and teaching with experiments by a staggering 39%; this decrease is not compensated by increases in teaching approaches generally seen as more appropriate for Mathematics instruction, such as Project/Problem-based learning, which also sees a decrease of 7%. Integrated teaching, which uses information from other subjects to support learning, is also used significantly less in the teaching of Mathematics (14% decrease), an indication that Maths teachers use less contextualisation, compared with teachers of STE subjects.

The different teaching strategies employed in Mathematics classes also tend to be less innovative and more teacher-centred, when compared with the overall average from the other subjects (Figure 10).

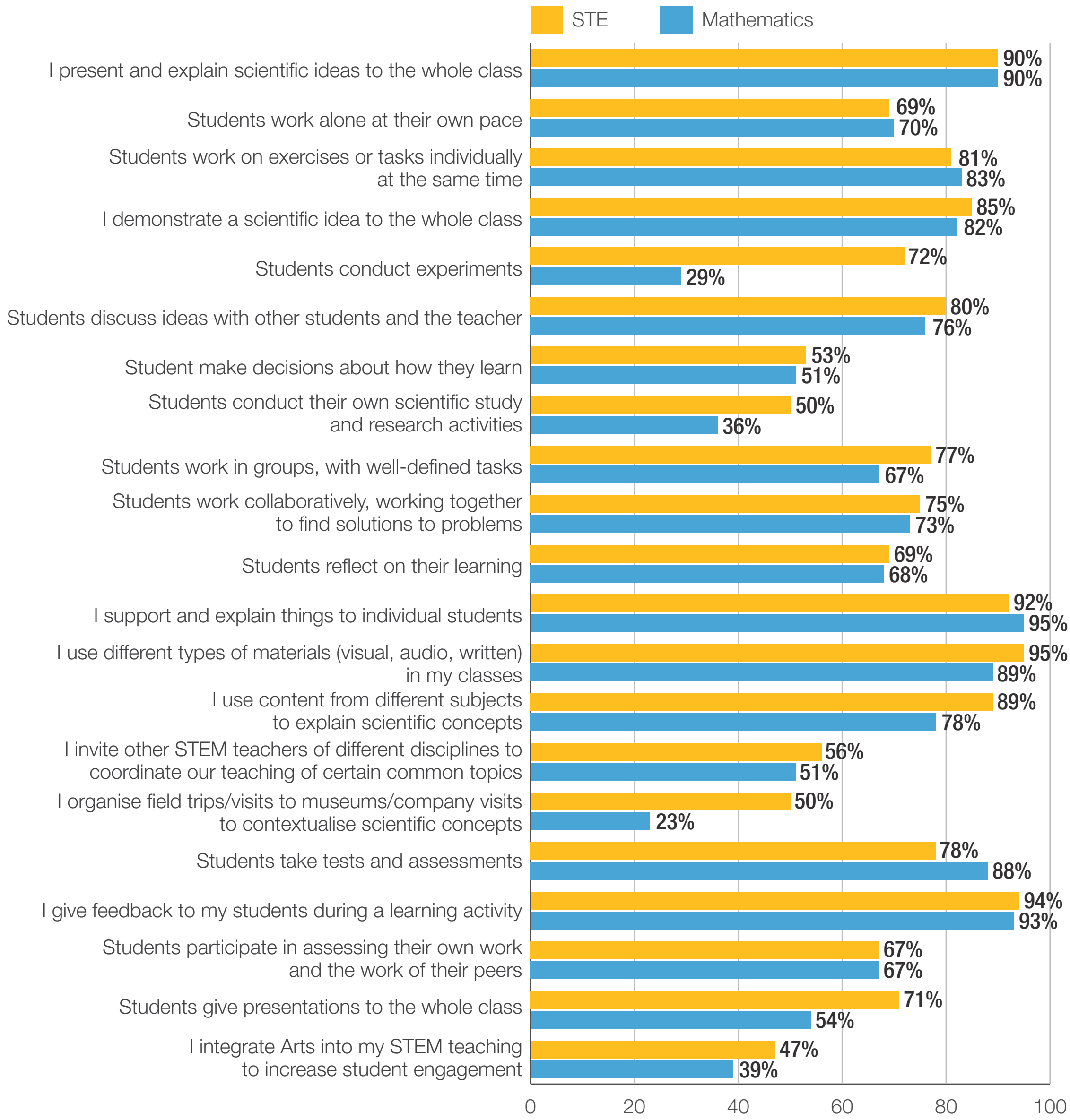


Figure 10: Frequency of teaching strategies for Mathematics [n=1898], compared with the other STE classes [n=2055]

That students conduct significantly less experimental work in Mathematics classes (a difference of 43% in favour of the other classes) was somewhat expected. But while attending these lessons, they also take more tests and assignments (10% higher frequency when compared with the STE average), work in groups 10% less than, on average, in the other STE classes, give fewer presentations in front of the whole class (18% lower frequency than the other courses), and conduct fewer student-led scientific study and research activities (14% less than in STE classes). When teaching Mathematics, teachers use "content from different subjects to explain scientific concepts" 11% less frequently, and "organise field trips/visits to museums/ company visits to contextualise scientific concepts" 27% less frequently than teachers of STE classes.

ICT is the most innovative subject of the STEM group.

Figure 11 displays comparatively the pedagogical approaches mostly used in the teaching of Mathematics (42% of the sample), Physics (12% of the sample), Chemistry (8%), Biology (8%) and ICT classes (5% of the sample, combining responses from three areas recorded through the questionnaire: the 105 responses for ICT (computer use only), 10 responses for ICT (database & network design and administration) and 91 responses for ICT (software, applications development & analysis).

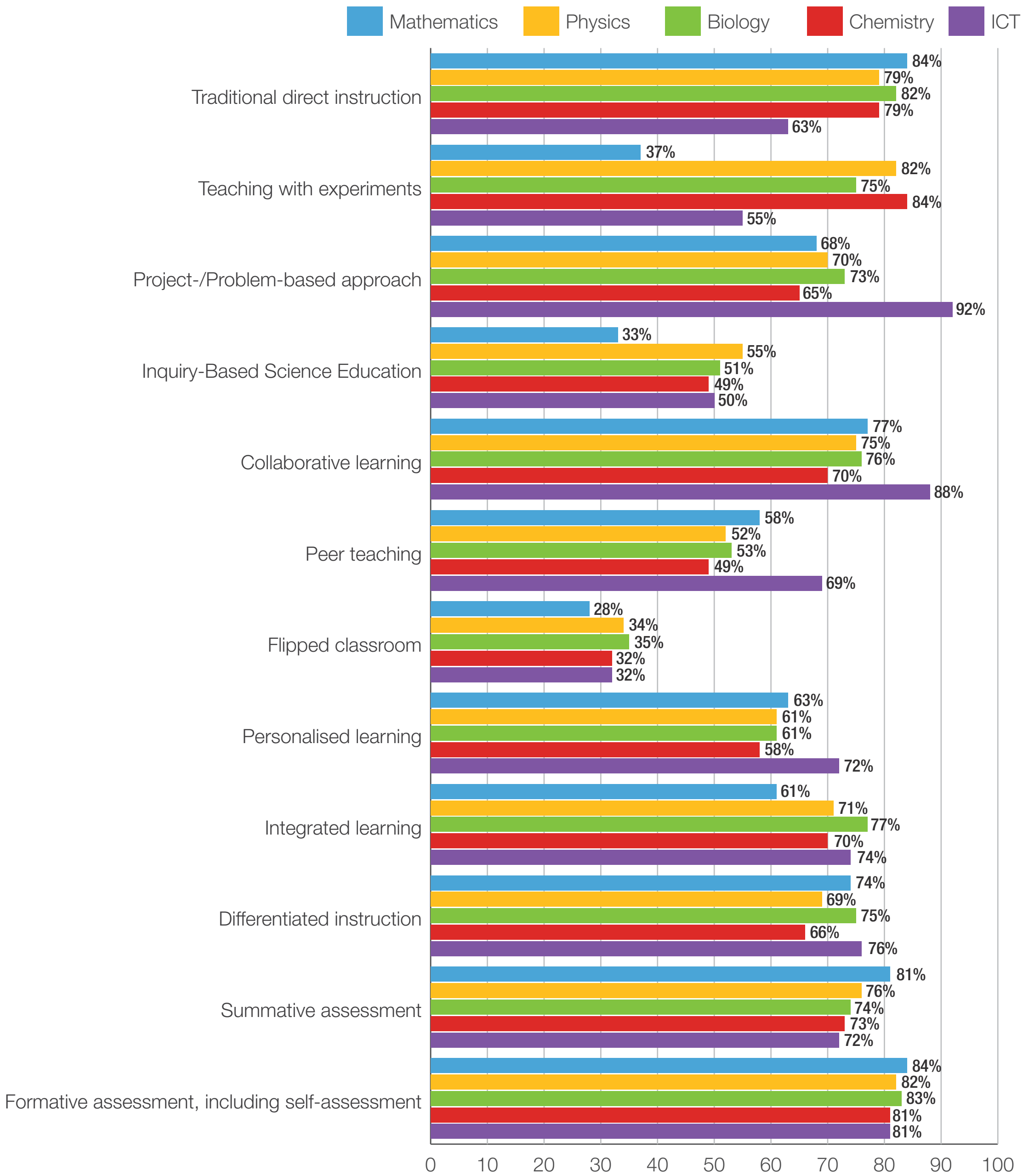


Figure 11: Pedagogical approaches in different STEM subjects [Mathematics: n=1904, Physics: n=535, Biology: n=384, Chemistry: n=354, ICT: n=236]

While still higher than for Mathematics, the uptake of IBSE remains relatively low among teachers of sciences, with 45% of Physics teachers, 49% of Biology teachers and 51% of Chemistry teachers reporting low use of IBSE in their classes. Interestingly, in the science classes where the frequency of teaching with experiments is higher (such as Chemistry and Physics), the reporting of traditional direct instruction also seems to decrease. This inverse proportionality is applicable to Chemistry, Biology and Physics classes, but not to ICT teaching, where innovation is brought most often through project/problem-based approaches.

Indeed, ICT teachers appear to be the most innovative of the group: they report the lowest use of traditional teaching (63% report a high frequency, 21% lower than the overall average), as well as the highest use of project/problem-based learning (92%, 24% higher than the overall average) and collaborative learning (88%, 11% higher than the overall average). It is difficult to assess solely on the basis of the questionnaire the reasons why ICT teachers self-report a more diverse range of pedagogical approaches. One possible explanation can be found in the topic's potential for stimulating students' creativity and innovation, or in its interdisciplinary nature (at the intersection of Mathematics and Technology) (Gander et. al., 2013).

SECTION 2: RESOURCES AND MATERIALS

Respondents were invited to provide information about which resources and materials they are currently using in their STEM teaching (Q4), how they usually learn about the teaching resources they are using (Q5), and what teaching resources or materials they would like to use, but do not have at their disposal (Q6). The information collected from these three questions is discussed in this section of the report.

We note that, while Q4 collects class-specific information (which can be linked to the teaching of particular subjects), Q5 and Q6 were included in the general section of the questionnaire, and correlations with the needs for resources for the teaching of particular subjects are therefore particularly weak.

Except when teaching ICT, teachers report extensive use of paper-based materials in their teaching.

Across all class data (Figure 12a), paper-based materials are the most widely used in teaching (88% of all responses), followed by audio/video materials (77%) and slideshow presentations (70%). Teachers also reported a moderately high use of word-processing software (58%) and Web-based or computer-based simulations (50%). At the other end of the spectrum, robots (9%) are the least frequently used in STEM teaching, alongside sensors/data loggers (19%) and resources published by STEM industries (25%).

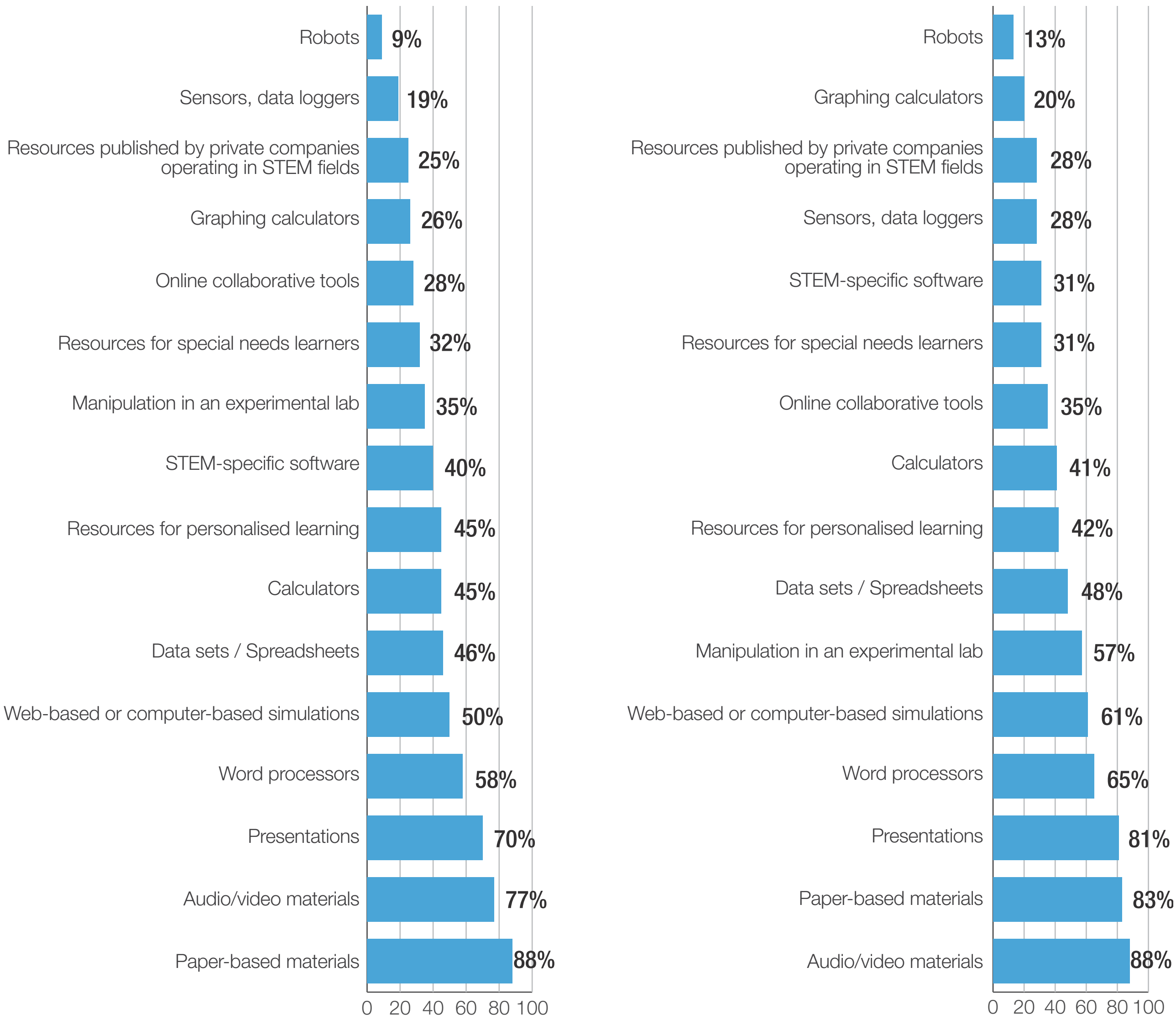


Figure 12: (a) Frequently used materials in STEM teaching (all classes, except Integrated STEM, n=3965); (b) frequently used materials in STE teaching (all classes, except Integrated STEM and Mathematics, n=2055)

When excluding Mathematics from the sample (Figure 12b), we observe that the top three most frequently used materials remain at the top of the list, with the notable difference that the overall use of audio/video materials increases significantly (by 11%). The use of Web-based or computer-based simulation also increases by 11%, as well as the frequency of use of manipulation in an experimental lab (by 22%). The frequent use of paper-based materials, however, remains high when controlling for the Mathematics bias, and across countries. Among the three countries with an exceptionally high number of responses (Turkey, Romania and Denmark), only teachers in Denmark report a higher use of word processors (79%) than of paper-based materials (74%).

When comparing (in Figure 13) the frequency of use of the different resources and materials in the five STEM classes most represented in the data sample (Mathematics, Physics, Chemistry, Biology and ICT), it can be observed that ICT teachers report the most frequent use of more diverse materials (with the unsurprising less frequent use of use of calculators in an experimental lab), and the least use of paper-based materials (64% of ICT teachers report using paper-based materials frequently in their classes, 24% less than the overall average). Conversely, apart from manipulation in an experimental lab, Mathematics teachers use less collaborative software in their teaching than teachers of any other STE subjects included in the sample, as well as the least use of: resources from STEM industries, Web-based or computer-based simulations, sensors and data loggers, and slideshow presentations and audio/video materials. Mathematics teachers report the highest use of paper-based materials among the five subjects compared, but also the highest use of graphing calculators (33%) and STEM-specific software (50%) in their classes. The use of these applications and technologies does not appear to be widespread, but their place in Mathematics classes is encouraging, particularly in the light of international research showing the benefits of integrating ICT tools that use representations and comparisons of symbolic expressions, for the development of students' understanding of mathematical structures and relations. (Nunes et.al., 2007).

Overall, respondents report using STEM-specific software infrequently in their teaching. Calculators are among the most often used hardware in STEM classes, with 45% of STEM teachers using them frequently. Conversely, only 26% of the overall sample report using graphing calculators, just 19% sensors and data loggers, and robots (just 9%). Despite much public discussion about introducing robotic platforms into the educational environment, their presence appears to be limited. This finding is in line with research carried out on the use of robots in K-12 STEM education by Karim et. al., who have identified the lack of teacher training as a pivotal cause contributing to the limited presence of robots in existing curricula (Karim et.al., 2015).

In general, teachers report extensive use of paper-based materials in their teaching, alongside mainly presentation aids (slideshow presentations and audio or video materials), a finding which is in line with the high reporting of teacher-led instruction highlighted in the previous section of the report. In addition to reporting low use of ICT tools and specialised software and equipment in their STEM classes, STEM teachers also indicate low use of resources for personalised learning and special needs learning, and of resources published by companies operating in STEM fields.

This last observation in particular illustrates that there is still much to do to build up collaboration between education and industry. The STEM Education Policies in Europe[12] report (2018) highlighted the increasing involvement of private companies working in STEM fields in supporting teachers in producing educational content. The fact that STEM teachers report only rare use of industry-based educational materials is of particular concern, and indicates that more effort is needed to ensure that industry-created resources reach the school level.

12 http://www.scientix.eu/observatory/stem-education-practices-europe

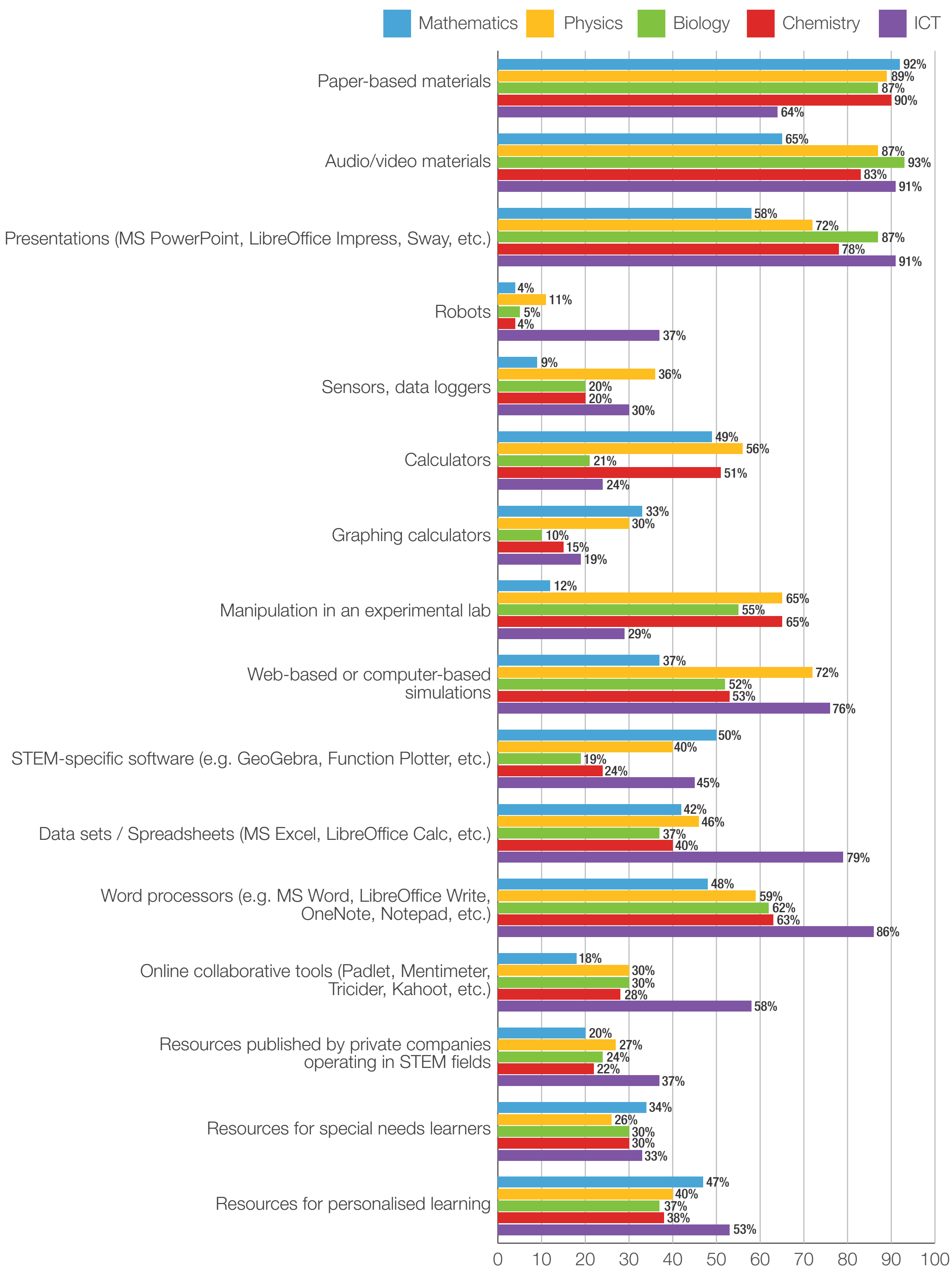


Figure 13: Materials and resources used in different STEM subjects (Mathematics n=1902, Physics n=536, Biology n=386, Chemistry n=356 and ICT n=235)

Resources needed in STEM teaching

If STEM teachers do not use more diverse materials in the classroom, this may be a result of their lack of knowledge/ training on how to integrate them in their teaching, their opinions and attitudes towards the usefulness of certain tools in their teaching, or lack of access to innovative tools. To better understand the needs of STEM teachers, respondents were asked to rate a list of teaching resources and materials on the following scale: 1: I will not use, 2: I could use, 3: I need and 4: I absolutely need and 5/0:[13] Not applicable (I already use). "Not applicable" is understood to point to resources/materials teachers are already using in their classes. Figure 14 illustrates respondents' answers across the data sample, after removing the responses associated with the teaching of Mathematics.[14] For the purpose of data analysis, answer options 3 and 4 were aggregated into the "Highly need" category. "I could use" is meant to indicate absence of resistance to the use of industry-based materials, and "I will not use" indicates the lack of need for the specific resource or material.

The majority of teachers reported a high need for resources for personalised learning (60%, based on aggregating "I need" and "I absolutely need" responses), resources for special needs learners (54%), and Web-based or computer-based simulations (51%). This information is largely in line with research carried out elsewhere (European Commission, 2015), which identified needs such as "teaching students with special needs", and "approaches to individualised learning", among others, as key training needs of teachers, regardless of the subjects taught.

At the other end of the spectrum, teachers indicate a low need in their teaching for: robots (34% of the sample would not use them in their teaching), sensors (23% of the sample) and graphing calculators (23% of the sample). However, teachers appear to be relatively open to including these materials in their teaching, with 35% of the sample indicating that they could use robots in their lessons, 34% choosing this option for sensors, and 29% for graphing calculators.

Little change is observed to these figures when controlling for the Mathematics bias; in fact, only for the need for an experimental lab and for sensors and data loggers do significant differences (more than 10%) appear: the share of respondents reporting that they "will not use" an experimental lab decreases by 13%, but this is compensated for by an 13% increase in the share of respondents expressing a high need for these facilities. A similar balance is observed for the case of sensors and data loggers; controlling for Mathematics bias there produces a 10% increase in the need for these devices, and a decrease of 11% in the number of responses stating "I will not use" them. 56% of the STE teachers in the sample state a high need (expressed as "I need" or "I absolutely need") for an experimental lab. When removing Mathematics and country biases, this need decreases slightly (to 48%), but still remains among the highest reported, alongside resources for personalised learning (54% aggregated), resources for special needs learners (48% aggregated), and augmented reality/virtual reality tools, including for example Virtual Labs (49% aggregated). Laboratory work should be at the heart of science learning; the fact that science and technology teachers point to insufficient access to experimental labs could mean that pupils may not be given sufficient opportunities to do practical work as part of their science learning.

13 "Not applicable" was coded as a 0 or a 5 in the data exports; this slight inconsistency, due to a technical error in uploading some of the language versions of the questionnaire, does not affect the results of the data analysis.

14 The question on teachers' needs in terms of resources was included in the general section of the questionnaire; to control for the Mathematics bias, all responses which reported on Mathematics subjects (in the compulsory or optional sections of the questionnaire) were removed from the sample [n=1666].

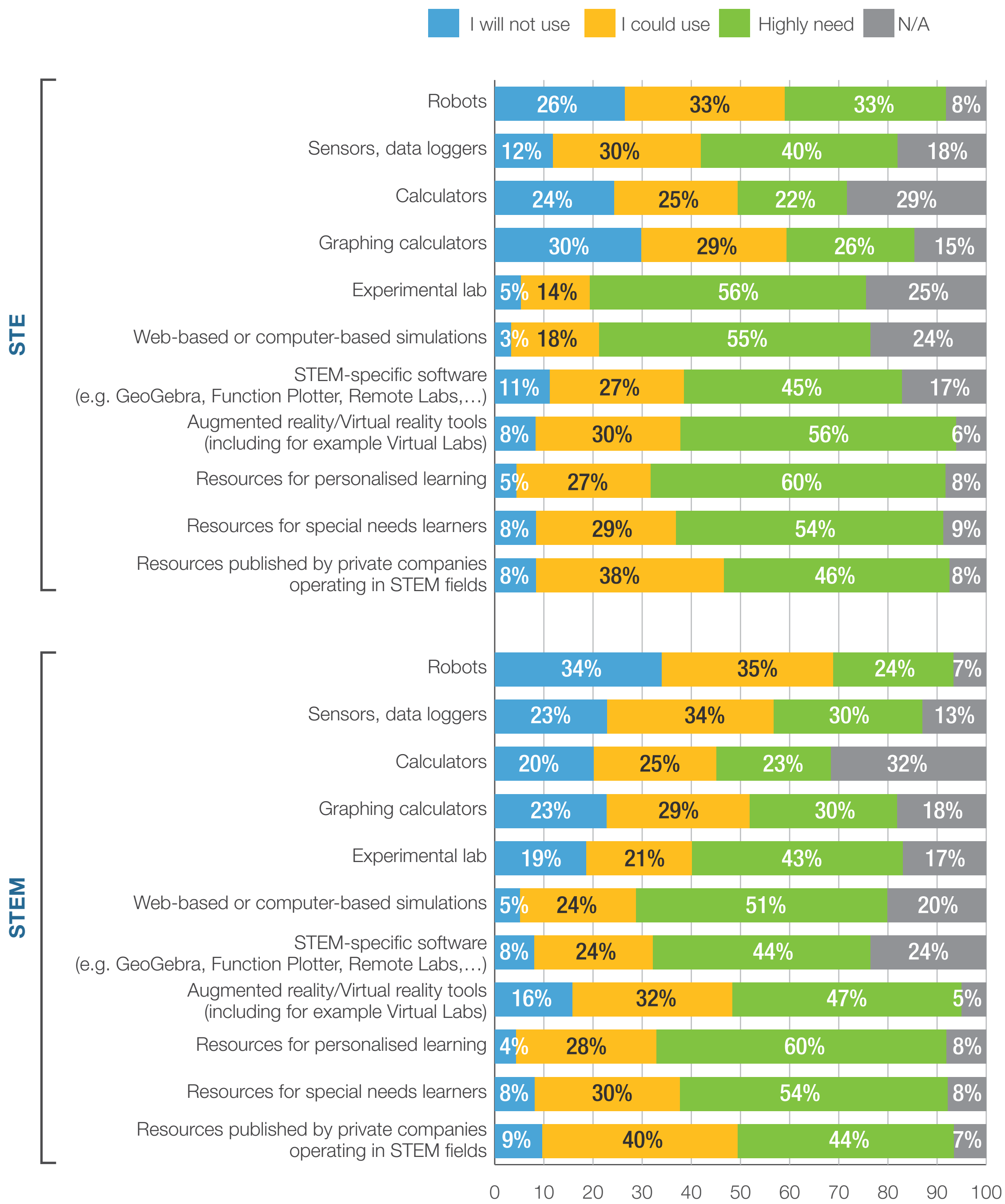


Figure 14: Resources and materials needed by STE teachers [n=2114], compared with those needed by STEM teachers [n=3780]

Respondents were also asked to choose, from a list, how they usually learn about the STEM resources they use in their classes (respondents could choose more than one answer). As can be observed in Figure 15, the most frequently used source of information, as stated by respondents, is Web search for relevant teaching resources, followed by the network of peers and the search for resources in repositories of educational resources. Over half of the respondents indicated they learn about educational resources through these being shared by educational authorities in their respective countries (53%).[15] The least frequent sources of information are subscriptions to information channels – either of national and international educational projects (just 30% of respondents indicated this source) or of private companies who publish STEM educational resources (the least frequent source of information, indicated by just 22% of the overall respondents).

15 An important exception here is represented by the respondents from Denmark, only 20% of whom indicated that in their classes they use resources shared by national educational authorities.

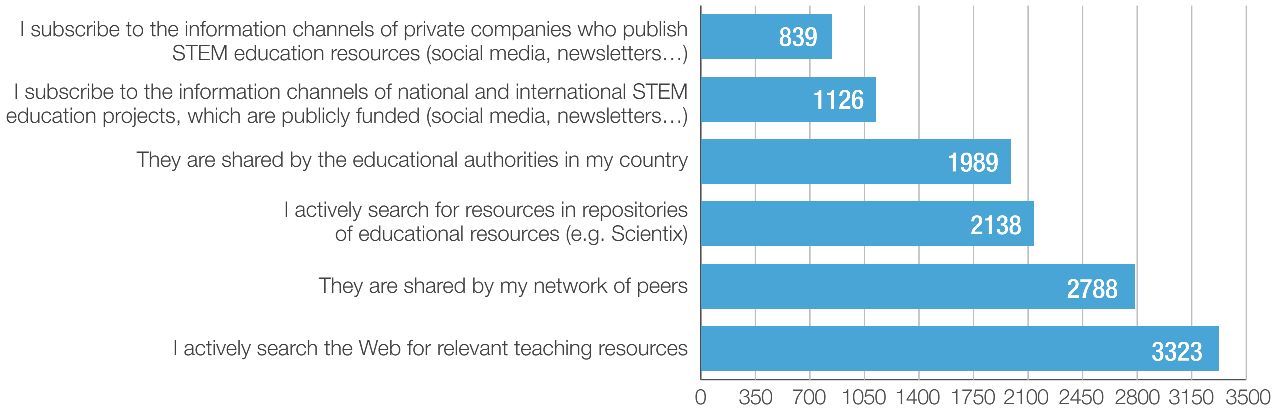


Figure 15: Sources of information about STEM resources [n=3780]

SECTION 3: PROFESSIONAL DEVELOPMENT AND SUPPORT FOR STEM TEACHERS

The majority of STEM teachers surveyed have taken no ICT-related professional development or training related to innovative STEM teaching. Teachers tend to update their knowledge online and in their own time.

According to the European Commission's Eurydice report on Teaching Careers in Europe (2018), in most European educational systems (with some notable exceptions, among them Turkey and Denmark), teachers' continuous professional development (CPD) is either compulsory or considered a professional duty (it is compulsory, but the number of hours is not defined). Additionally, in many educational systems, a certain number of hours or credits in CPD training is required for career progression. Schools play an active role in CPD planning in most national education systems,[16] usually in consultation with educational authorities at a higher level (European Commission, 2018).

It was of particular interest to understand the type and length of professional development activities taken by the STEM teachers surveyed. Since teachers in most European countries are required to take some kind of professional development throughout their career, the survey aimed to test, in particular:

a. If the STEM teachers surveyed took any ICT-related training, and of what kind;
b. If the STEM teachers surveyed took any kind of professional development courses related to innovative STEM teaching (in an institutional setting, offered either by teacher training institutions or by other educational providers), and of what kind;
c. If teachers used their personal time to update their knowledge, and how.

To do this, respondents were asked to indicate the length of professional development types from a list (on a 5-point scale, ranging from 1: "No time at all" to 5: "More than 6 days"); for each answer choice, the following options were also included to capture the type of professional development carried out, if any: "Online", "Face to face", "Both" and "Not applicable" (for the cases where no professional development was indicated).

Table 4 lists the 11 answer choices and the various items they intended to test.

16 Only in Greece, Croatia, Latvia and Turkey does the responsibility for determining CPD needs and priorities lie solely with the higher education authorities.

Table 4: Type of professional development taken by STEM teachers: answer choices

	ANSWER CHOICES	TESTING
1.	Introductory courses on Internet use and general applications (basic word-processing, spreadsheets, presentations, databases, etc.)	a. ICT-related training (institutional setting)
2.	Advanced courses on applications (advanced word-processing, complex relational databases, Virtual Learning Environments, etc.)	a. ICT-related training (institutional setting)
3.	Advanced courses on Internet use (creating websites/ homepage, video conferencing, etc.)	a. ICT-related training (institutional setting)
4.	Equipment-specific training (interactive whiteboard, laptop, etc.)	a. ICT-related training (institutional setting)
5.	Courses on the pedagogical use of ICT in teaching and learning	b. Innovative STEM teaching (institutional setting)
6.	Subject-specific training on learning applications (tutorials, simulations, etc.)	b. Innovative STEM teaching (institutional setting)
7.	Course on multimedia (using digital video, audio equipment, etc.)	a. ICT-related training (institutional setting)
8.	Participate in communities (e.g. online: mailing lists, Twitter, blogs; or face to face: working groups, associations, etc.) for professional discussions with other teachers	c. Professional development in own time
9.	Personal learning about innovative STEM teaching in your own time	c. Professional development in own time
10.	Cooperation with industry for the contextualisation of STEM teaching (joint development of learning resources, placement in industry, etc.)	b. Innovative STEM teaching (institutional setting)
11.	Other professional development opportunities related to innovative STEM teaching	b. Innovative STEM teaching (institutional setting)

A significant proportion of teachers (65% of the overall sample) indicated having taken no professional development of any of the kinds listed in the survey during the last two years, and only 15% of the overall sample had taken more than six days' professional development during this past time (figures detailed in Figure 16). The proportion of teachers indicating having allocated "no time at all" for professional development of the kind listed decreases to 56% when controlling for country biases, but still remains heavily dominant, with the other 44% of responses being divided between one to three days (26%) and more than four days (18%). It is interesting to note that, while for Romania the overall split remains largely consistent with the total sample, the percentage of teachers who indicated having taken no professional development of the type listed was 70% for Turkish respondents and 77% for respondents from Denmark, both countries where, at least until 2016-17, teachers' CPD was not compulsory (European Commission; 2018).

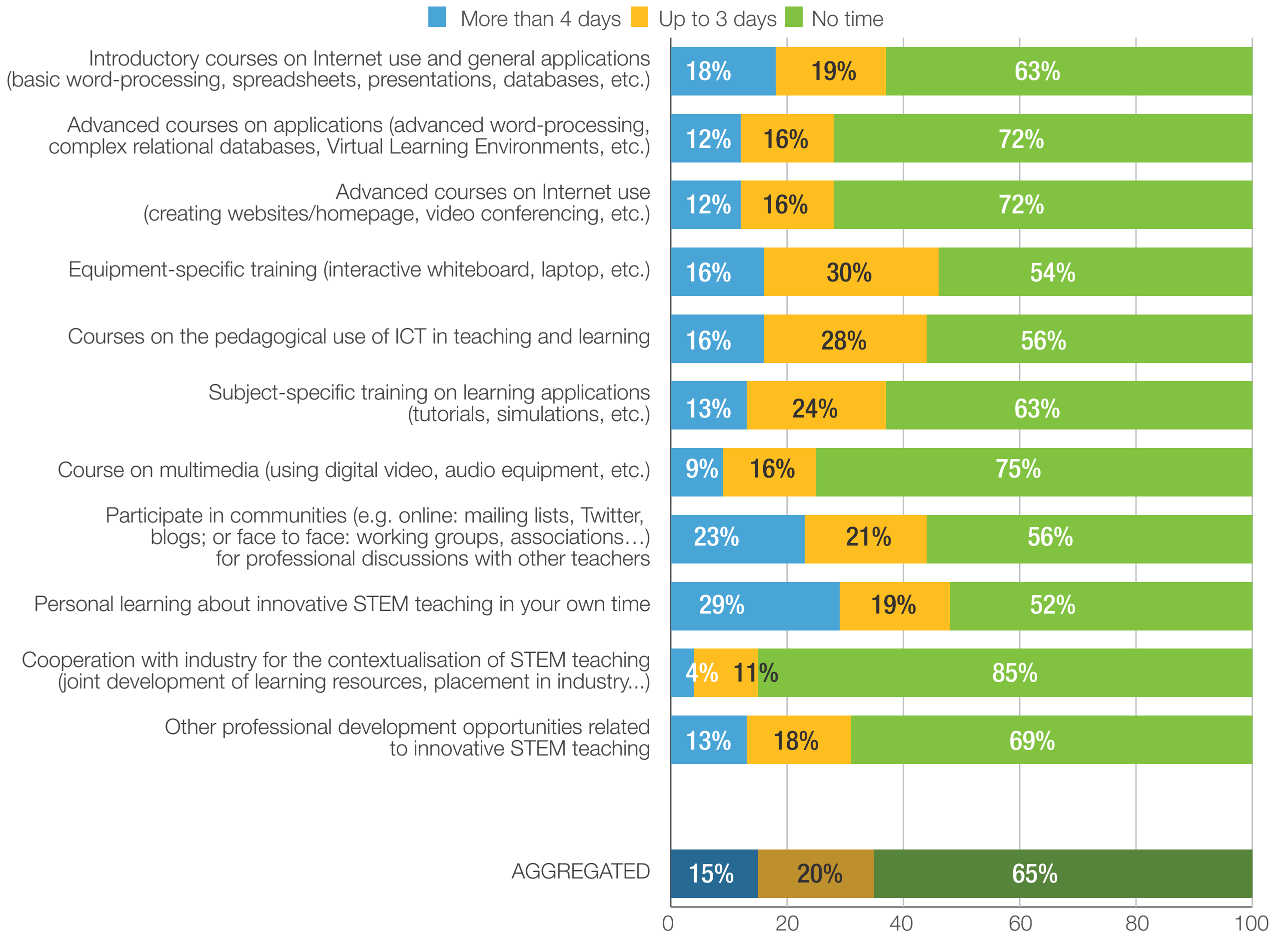


Figure 16: Types of professional development undertaken by STEM teachers in the last two years [n= 3780]

When aggregating the answers by the three training types (Table 5), we observe little difference between the amount of training related to ICT and innovative STEM teaching reported by respondents. Most frequently, teachers report updating their knowledge in their own time.

Table 5: Type of professional development taken by STEM teachers: aggregated responses

	NO TIME	UP TO 3 DAYS	MORE THAN 4 DAYS
ICT-related training (institutional setting)	67%	20%	13%
Innovative STEM teaching (institutional setting)	68%	20%	12%
Professional development in own time	54%	20%	26%

When it comes to ways of CPD delivery, teachers report a fairly balanced distribution of online and face-to-face training, with 32% of respondents who undertook some form of teacher training indicating online as a medium, 38% face to face and, overall 29% indicating both online and face to face. Slight variations can also be observed in the analysis, with “Equipment-specific training” and “Courses on the pedagogical use of ICT in teaching and learning” being attended more in person, and, unsurprisingly, “Participate in communities…” and “Personal learning about innovative STEM teaching in your own time” being carried out more often online.

Most STEM teachers rely on peer support to improve their STEM teaching.

If teachers do not rely on teacher training to update their knowledge, what kind of support are they receiving at the school level, or from experts outside the school?

When asked the extent to which they received the support of various groups to improve their STEM teaching (see Figure 17), more than half of the teachers surveyed reported having received little or no support from: “Other school staff”, “An online helpdesk, community or website”, "Experts from outside the school" and "Teachers of other, non-STEM subjects". Furthermore, 43% of teachers report this regarding their school/ICT coordinators, 46% point to no support from other teachers of different STEM subjects, and 38% indicate they do not benefit from the support of their colleagues in the same subject. On average, 55% of teachers report receiving little or no support from the groups listed.

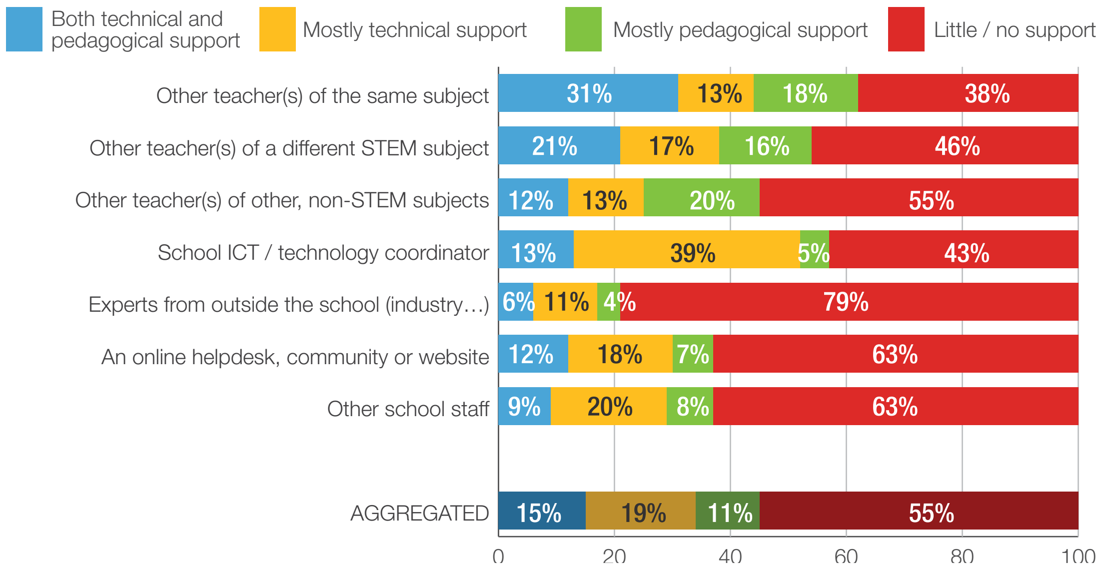


Figure 17: Responses to "To what extent do you receive the support of the following groups to improve your STEM teaching?" presented as percentages of the overall sample [n= 3780]

The results are largely consistent when data from Romania, Turkey and Denmark are removed: teachers tend to turn mostly towards their colleagues in the same subject for help (particularly pedagogical support), then to colleagues in different (but still STEM) subjects (for technical or pedagogical support), and to their school ICT/ technology coordinator, for mostly technical support. From these three countries, Romanian teachers reported working less in isolation (43% reporting, on average, "little or no support"), followed by Danish teachers (50% "little or no support"). Finally, Turkish teachers reported the least support: 61% of Turkish respondents indicated receiving little or no support, on average, from the groups listed.

Interestingly, the teachers who reported a low level of collaboration even with other teachers of the same subject do not report a significantly lower use of collaborative learning pedagogies in their classes,[17] an indication that low levels of support are not an indication that teachers themselves reject the value of collaboration.

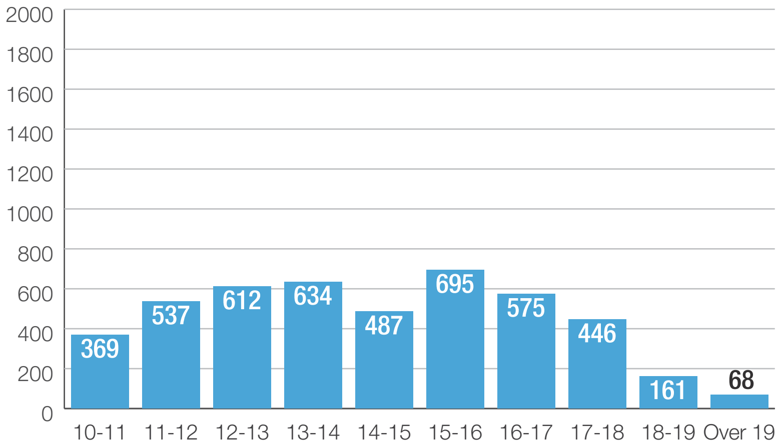
SECTION 4: EXPERIENCE AND EDUCATIONAL LEVEL

Is there a significant difference between the teaching practices of beginner teachers and those of more experienced teachers? Does the educational level count? This section discusses the influence of two parameters on the use of different pedagogical approaches in STEM teaching: the level of the students (be it primary or secondary education) and the teachers' years of experience.

The use of innovative pedagogies decreases as students transition to the next educational step.

For each class, respondents indicated the age of the students, with the 4,584 classes included in the sample being fairly evenly distributed through the ages of 10 to 19+ (see Figure 18a). To see a possible relationship between the age of the students and the pedagogical approach used by the teachers, we grouped the classes into three age intervals: 10-13, 14-16 and 16+ (see Figure 18b).

17 For this comparison, only the information on pedagogies used in the first STEM class reported on was used.



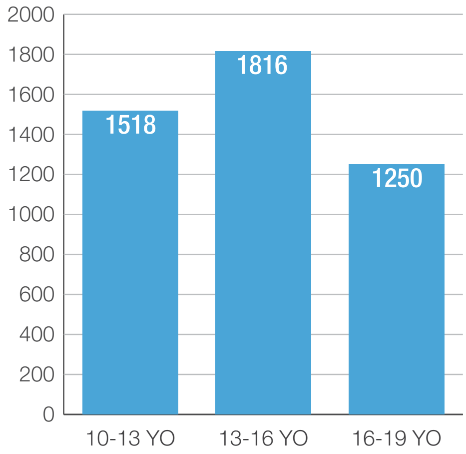


Figure 18: (a) Classes per age. (b) Classes grouped by age interval

In Table 6 we show the percentage of respondents who indicated high use ("to some extent" or "a lot") of the different approaches, by age group, including all subjects except Mathematics. On the right columns, we calculate the difference between age groups 1 and 2, and then from group 2 to group 3. Finally, we added the differences to facilitate the observations.

Table 6: Respondents who frequently use the different approaches in STE classes, by age group

ALL STE SUBJECTS	10-13 YO	13-16 YO	16-19 YO	G1->G2	G2->G3	SUM
Traditional direct instruction	68%	75%	76%	7%	1%	8%
Teaching with experiments	78%	74%	79%	-4%	5%	1%
Project/Problem-based approach	81%	74%	70%	-7%	-5%	-12%
Inquiry-Based Science Education	66%	53%	47%	-13%	-6%	-19%
Collaborative learning	84%	74%	78%	-10%	4%	-6%
Peer teaching	64%	56%	53%	-8%	-3%	-11%
Flipped classroom	43%	34%	33%	-10%	0%	-10%
Personalised learning	70%	62%	56%	-8%	-7%	-14%
Integrated learning	81%	74%	72%	-7%	-3%	-9%
Differentiated instruction	78%	73%	69%	-5%	-4%	-9%
Summative assessment	78%	78%	68%	0%	-10%	-10%
Formative assessment	88%	83%	80%	-6%	-3%	-8%

Overall, we observe significant decreases in the use of all pedagogical approaches, with the notable exception of "traditional direct instruction". As national end-of-secondary-education exams approach, it appears that more diverse pedagogies increasingly give way to traditional teaching, with instructional practices such as IBSE (19% overall decrease), Project/problem-based learning (12% decrease) and Personalised learning (14% decrease) being particularly affected. The decrease in use of project/problem-based and inquiry-based learning approaches are particularly problematic. The case of personalised learning also decreasing is interesting also in relation with the recent arguments for it (see for example Jenkins et al., 2018) and against it, especially following the announcements at the end of 2017 by Bill Gates and Mark Zuckerberg that they intended to promote it (see for example Herold, 2017 or Lynch, 2018).

In Table 7, we show again the percentage of respondents who indicated they use the different approaches frequently ("to some extent" or "a lot"), by age group, now only for Mathematics classes. The decrease in the use of different approaches, except traditional direct instruction, is now even more prominent.

Table 7: Respondents who frequently use the different approaches in Mathematics classes, by age group

MATHEMATICS	10-13 YO	13-16 YO	16-19 YO	G1->G2	G2->G3	SUM
Traditional direct instruction	82%	84%	88%	2%	4%	6%
Teaching with experiments	47%	35%	28%	-12%	-7%	-19%
Project/Problem-based approach	77%	69%	56%	-8%	-12%	-21%
Inquiry-Based Science Education	37%	35%	25%	-2%	-10%	-12%
Collaborative learning	81%	77%	72%	-4%	-5%	-9%
Peer teaching	62%	61%	49%	-1%	-12%	-13%
Flipped classroom	33%	27%	23%	-6%	-4%	-10%
Personalised learning	71%	62%	54%	-9%	-8%	-16%
Integrated learning	68%	61%	51%	-8%	-10%	-17%
Differentiated instruction	83%	74%	65%	-9%	-9%	-18%
Summative assessment	88%	82%	71%	-7%	-11%	-17%
Formative assessment	90%	84%	78%	-6%	-5%	-12%

While the difference in teaching with experiments is not as surprising as in science, the fact that less than 60% of classes use Project- and Problem-based learning approaches with students over 16 points to a disassociation of Mathematics from real life, at the moment when the subject "requires increasingly abstract levels of understanding" (de Lourdes Mata, 2012). It would be interesting to see if the increased abstraction of Mathematics in the later years of secondary school makes it more difficult for teachers to adopt student-centred pedagogies when teaching this subject.

More years in teaching mean more innovation in all subjects, except Mathematics.

From numerous observations in Scientix related to the participation of teachers in STEM events and projects, teachers with over 10 years' experience tend to be more willing to deviate from traditional direct instructions and include different strategies in their classrooms. Based on this, we expected teachers with more experience to be applying innovative pedagogical approaches more than less experienced teachers.

The years of experience of the teachers participating in the survey (see Figure 1), were split into five groups: less than four years, four to ten years, 11 to 20 years, 20 to 30 years, and more than 30 years.

Across all countries, we observe that, compared to those with less than 4 years' experience, STE teachers with more than 30 years' experience use more Teaching with experiments (21% difference), more Project/Problem-based approach (8% difference) and less Traditional direct instruction (12% difference). In Figure 19, we show the percentage of teachers of STE subjects from all countries except Turkey and Denmark who use the different approaches by the number of years of experience for those approaches in which differences of more than 9% were observed between the newer teachers and those with more than 30 years' experience. The approaches in which this was the case were Traditional direct instruction, Teaching with experiments, Project/Problem-based approach, Inquiry-Based Science Education, Collaborative learning, and Peer teaching.

With more experience, teachers are more willing to integrate more innovative (constructivist) pedagogical approaches in their classes and limit the use of direct instruction. It is not yet clear whether newer teachers are less eager to use these methodologies out of insecurity (using different approaches can be more time consuming and unpredictable) or lack of familiarity with them (for example, articles on introducing problem-based learning in pre-service teaching show that it is not yet a given in all pre-service training curricula: Barron et al. 2013, Ajmal et al. 2016). On the other hand, it is interesting to note how IBSE is the least used (besides Flipped classroom), and still needs to be introduced to all teachers, both at pre-service level and in-service.

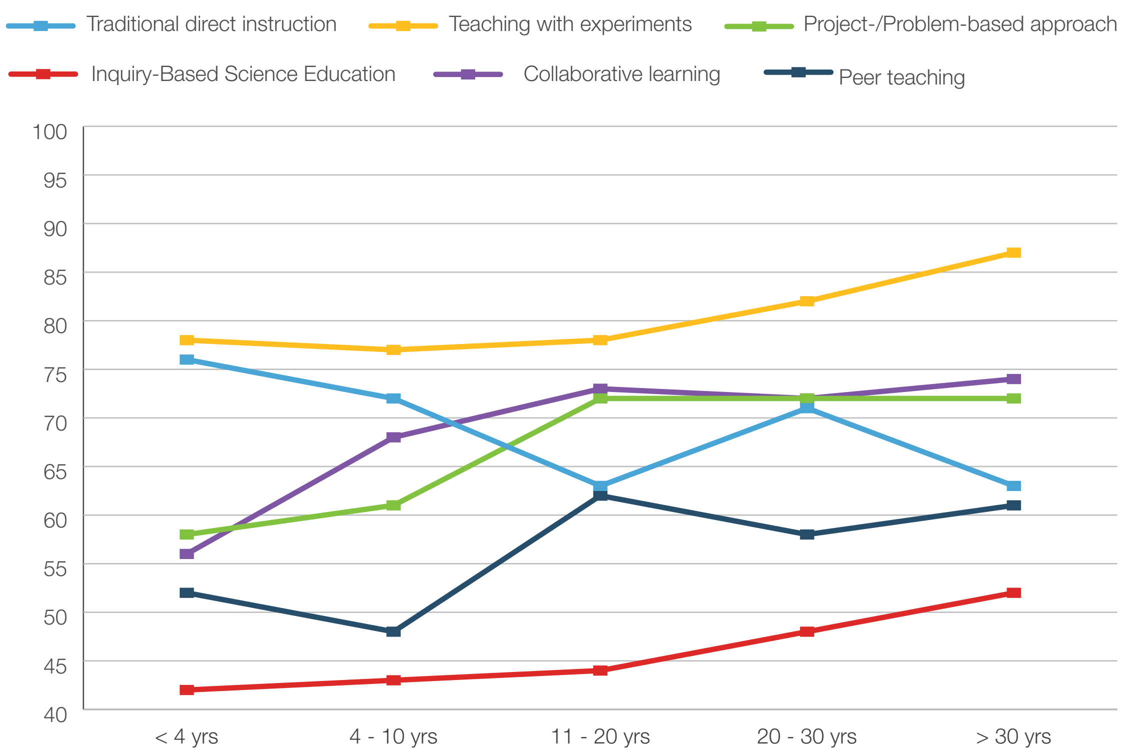


Figure 19: Percentage of teachers from STE subjects who use the different approaches, by number of years' experience (data from all countries except Turkey and Denmark) [n=913]

In Figure 19, we have included the data from respondents from all countries except Turkey and Denmark, as for these, the answers were significantly different. For Turkey, the use of the pedagogical approaches appears to be relatively constant regardless of years of experience. In the case of Denmark, from less than 70% of teachers saying they use a lot of Traditional direct teaching in their class, the proportion rises to over 90% as the years of experience increase, contrary to the other countries. In addition, the use of Inquiry-Based Science Education and Collaborative learning decreases significantly in direct opposition to the case of the rest of the countries. Interestingly, while in most countries, Differentiated Instruction remained constant, Danish teachers apply it more and more, as they gain experience (growing from a 50% of teachers applying it in their early years, to 85% for those with over 30 years' experience).

On the other hand, in Mathematics subjects, there seems to be little difference in the use of the different approaches depending on the number of years' experience. In Figure 20 we show the percentage of teachers of Mathematics who use the different approaches by number of years' experience (excluding the data from Turkey and Denmark) for Traditional direct instruction, Teaching with experiments, Project/Problem-based approach, Inquiry-Based Science Education, Collaborative learning, and Personalised learning. These are the only approaches where there appeared to be a significant variation depending on years of experience, but even these showed little difference when removing the initial group (those with less than four years' experience – which accounted for only 20 of the 652 responses). One exception could be Collaborative learning, which rises from 60% to 71% of respondents using it a lot, but the variations (positive with 11 – 20 years) and then negative again (with 20 – 30 years), before rising again, cast doubt on the existence of an overall significant increase depending on years of experience.

When looking at the data for Turkey for Mathematics classes (Figure 21), it initially appears that more and more teachers use Teaching with experiments, Inquiry-Based Science Education, Peer teaching, Flipped classroom, and Personalised learning, as their experience increases. But if one ignores the 30+ years' experience entries (which constituted 30 of the 783 submissions), there is only a slight increase in the use of IBSE and Teaching with experiments (of 9% and 14% respectively), as well as in the use of Flipped classroom (from 34% to 47%).

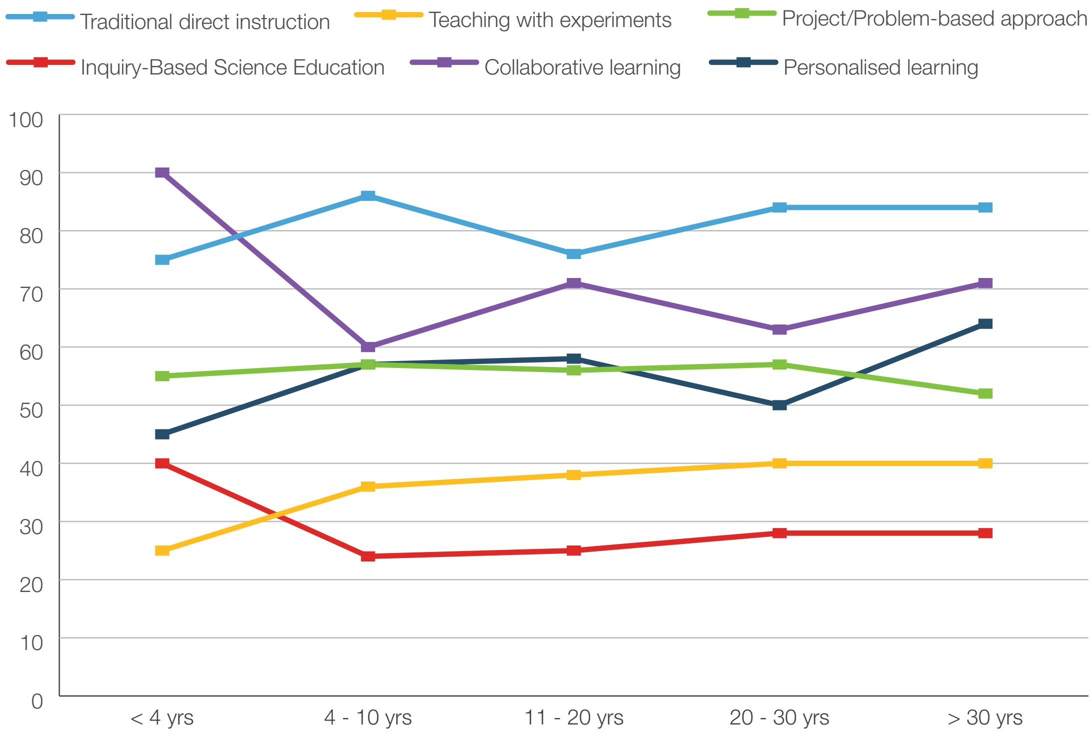


Figure 20: Percentage of teachers of Mathematics who use the different approaches by number of years of experience (data from all countries except Turkey and Denmark) [n=652]

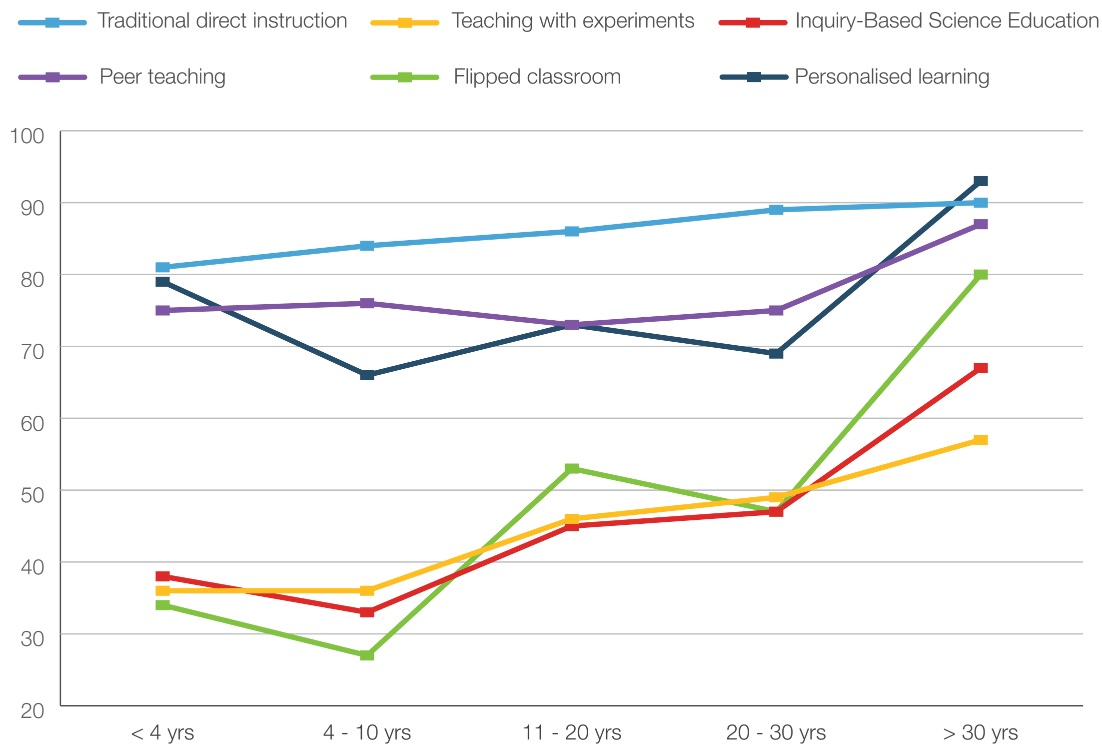


Figure 21: Percentage of teachers of Mathematics in Turkey who use the different approaches by number of years of experience [n=783]

Finally, for the case of Denmark, for Mathematics classes, the overall increase with years of experience of Traditional direct instruction, Integrated learning, Teaching with Experiments, and Peer teaching, is slightly more pronounced (see Figure 22).

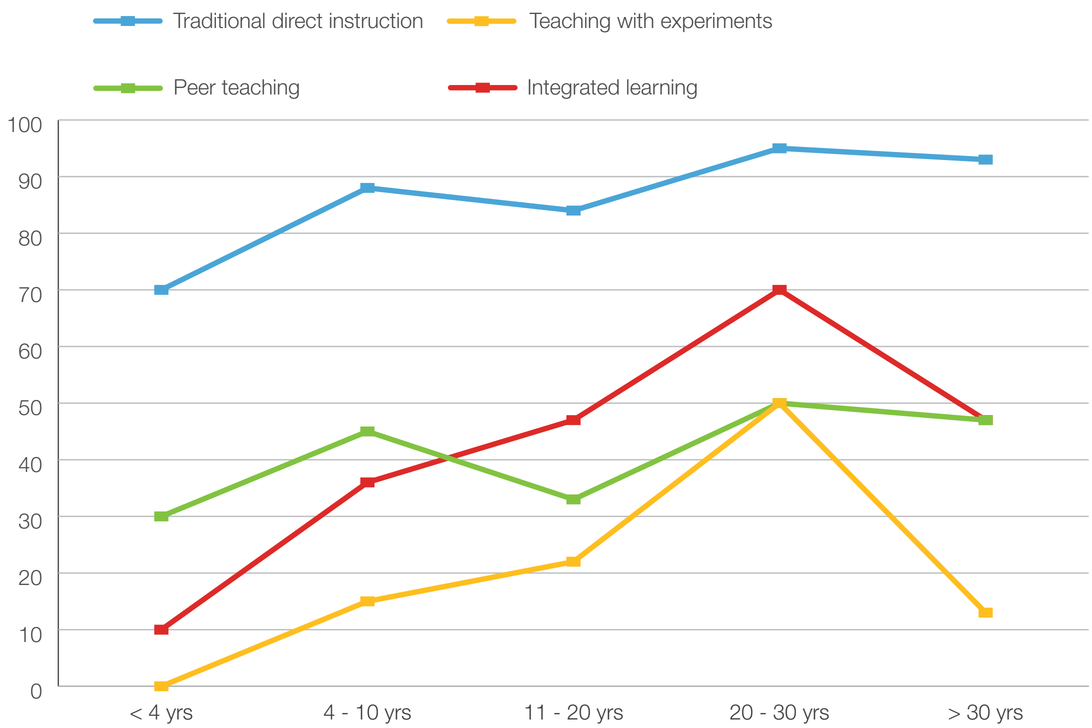


Figure 22: Percentage of teachers of Mathematics in Denmark who use the different approaches by number of years of experience [n=123]

SECTION 5: TEACHERS' ATTITUDES AND INFLUENCE OF THE ENVIRONMENT

Beyond the classroom, a number of factors can have an influence on the way STEM educators organise their teaching. Among these, in this section we give attention to teachers' opinions and attitudes, particularly in relation with the school environment, perceptions about the main factors which might negatively influence STEM teaching, and teachers' openness to cooperation with STEM industries to enhance teaching and learning.

More innovation is brought into classrooms where STEM teachers and their school administration are in synch over a positive vision about innovative STEM teaching

When asked whether their colleagues and head of school share a positive vision about innovative STEM teaching at their school, 74% of the respondents answered affirmatively.

We then looked at whether this shared positive vision translated into teachers using more innovative STEM approaches, specially Teaching with experiments, Project/Problem-based approach, Inquiry-Based Science Education, and Collaborative learning, which we have discussed in detail in previous sections.

In Figure 23a, we show the percentage of teachers who use 0 to 4 of the approaches in STE or M classes. 37% of the 2,042 STE classes use all four approaches, while in Mathematics, the peak is at 2 approaches (which is consistent with the limited use of Inquiry-based learning and Teaching with experiments in these classes, observed earlier in this report).

In Figure 23b, we have plotted the percentage of teachers who have colleagues / head of school who share the same vision, by the number of approaches used, in STE or M classes.

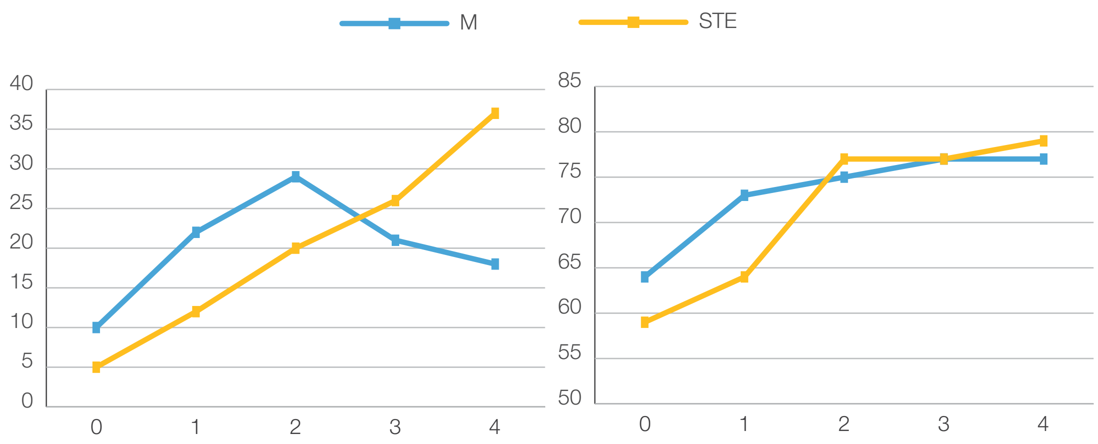


Figure 23:(a) Percentage of teachers who use 0 to 4 of the approaches in STE or M classes; (b) of these, the percentage of teachers who have colleagues / head of school who share the same vision, by number of approaches used, in STE or M classes.

In both STE and M classes, the use of innovative approaches increases alongside the shared vision of the school, especially when going from 0 to 2 approaches.

Factors affecting STEM teaching

We offered twenty possible factors that could affect STEM teaching, from lack of equipment (e.g. computers, whiteboards, graphing calculators, etc.), to training and support, time and space, or budget and exam pressure constraints.

In Figure 24, we show the percentage of respondents who considered that the different factors affected their STEM teaching considerably.

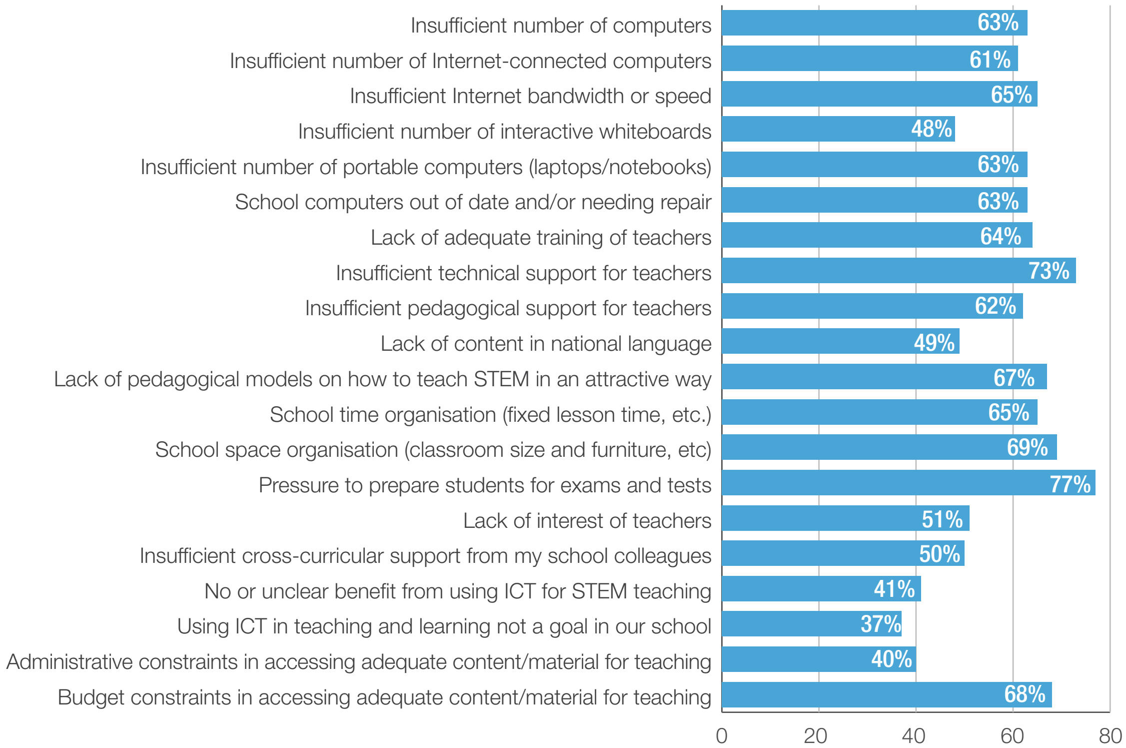


Figure 24: Factors affecting STEM teaching [n=3780]

Overall, the most important “problems” for teachers are the pressure to prepare students for exams, inadequate school space organisation, lack of pedagogical models to teach STEM in an attractive way and insufficient technical support for teachers.

Limited funding is also mentioned by 68% of the respondents and, among the equipment factors, it seems that only the lack of whiteboards is not seen as a problem in over 50% of the cases; 60% of respondents indicated that insufficient access to all the other technical equipment included as answer choices in the survey is affecting their STEM teaching.

It is worth noting that, looking at responses to the factors affecting STEM teaching, those who do not feel they share the same vision as their colleagues tend to be more likely also to lack other kinds of support (e.g. technical support, space organisation, or pedagogical support for teachers), as seen in Table 8.

Table 8: Percentage of respondents who consider the different factors affect their STEM teaching a lot, according to whether they have a shared vision with their colleagues or not.

IS YOUR USE OF STEM TEACHING AFFECTED BY THE FOLLOWING?	SHARED VISION	NON-SHARED VISION
Insufficient number of computers	59%	73%
Insufficient number of Internet-connected computers	57%	72%
Insufficient Internet bandwidth or speed	61%	75%
Insufficient number of interactive whiteboards	45%	54%
Insufficient number of portable computers (laptops/notebooks)	60%	74%
School computers out of date and/or needing repair	59%	74%
Lack of adequate training of teachers	60%	75%
Insufficient technical support for teachers	69%	85%
Insufficient pedagogical support for teachers	57%	75%
Lack of content in national language	45%	60%
Lack of pedagogical models on how to teach STEM in an attractive way	63%	79%
School time organisation (fixed lesson time, etc.)	62%	76%
School space organisation (classroom size and furniture, etc.)	64%	80%
Pressure to prepare students for exams and tests	74%	86%
Lack of interest of teachers	45%	69%
Insufficient cross-curricular support from my school colleagues	44%	68%
No or unclear benefit from using ICT for STEM teaching	37%	52%
Using ICT in teaching and learning not a goal in our school	30%	59%
Administrative constraints in accessing adequate content/material for teaching	34%	56%
Budget constraints in accessing adequate content/material for teaching	64%	81%

For example, the lack of pedagogical models on how to teach STEM in an attractive way is mentioned by 63% of those who share their views with the school, while it goes up to 79% in the case of those who are more isolated.

In the case of "Insufficient cross-curricular support from my school colleagues", the proportion goes from 44% of the "shared-vision" respondents highlighting it as a factor, to 68% of the non-shared vision respondents. It is worth highlighting that implementing a STEM strategy in a school would require active collaboration among teachers of different disciplines, as well as the support of the school management (see Iglesias et al., 2018).

STEM teachers are highly interested in collaborating with STEM industries in various domains to enhance teaching and learning

In Figure 25 we show how over 80% of respondents would like to see more support from private companies operating in STEM fields, in every possible way, from offering financial support to more practical collaborations like having STEM professionals visiting the schools or facilitating school visits to their premises.

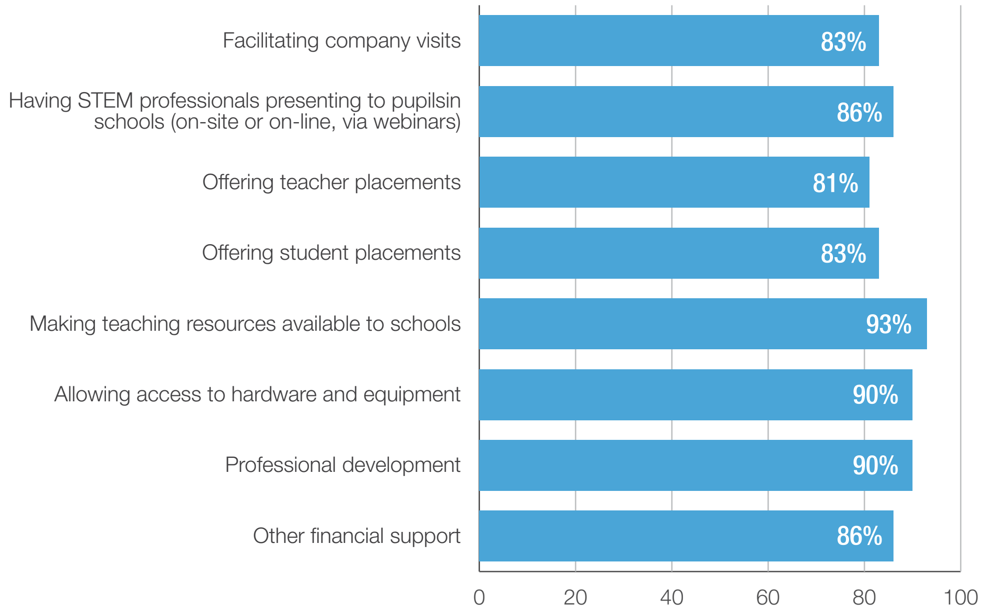


Figure 25: Percentage of respondents who would like to see a lot more additional support from companies [n= 3780]

It is particularly interesting that 93% of the respondents would really like companies to offer more teaching resources to schools. In contrast to this finding, in Figure 14 we saw that only 8 to 9% (when we control for the Mathematics bias) of the teachers surveyed are using resources coming from STEM industries in their classes, while, overall, just 8 to 9% show a clear resistance to implementing these resources in STEM teaching. With regard to the degree of commitment or need, across all subjects 44% of the respondents indicated a high need for resources from STEM industries and 40% said they "could use" such resources.

There appears to be a significant gap between the offer and/or visibility of teaching resources and materials coming from STEM industries and teachers' openness to trying them in schools. It is not yet clear whether this gap is due to a limited offer of pedagogical materials from STEM industries, or to an insufficient dissemination of private initiatives in the area of STEM education.

Conclusions

The STEM Education Practices teacher questionnaire provides a good insight into how teachers in Europe approach teaching. The results of the survey reflect a diverse landscape, with STEM teachers trying their hand at new pedagogies and diversifying the resources and materials they use in their practice.

However, these attempts are still in their early stages and need continuous support. Traditional teaching instruction, resources and materials still prevail in STEM classes. The case of Mathematics, a subject heavily represented across national curricula, is salient. In the STEM Education Policies report (European Schoolnet, 2018), Mathematics was identified as a "key lever to transforming STEM teaching and learning". The fact that Mathematics is being taught prevalently through traditional approaches, significantly more so than the other STE disciplines, indicates that the potential of this subject to transform STEM education is being limited in practice. Moreover, as national end-of-secondary-education exams approach, more diverse pedagogies increasingly give way to traditional teaching. Indeed, the pressure to prepare students for exams is the most frequently listed problem affecting STEM teaching. This situation calls for curriculum innovation, particularly in encouraging a more integrative approach to STEM teaching. These changes should be accompanied by assessment policies that give sufficient weight to formative evaluation methods, so as not to inhibit the use of innovative pedagogies in the final years of education. Evidence-based initiatives that develop and test new assessment methods compatible with innovative teaching practices should also receive appropriate support.

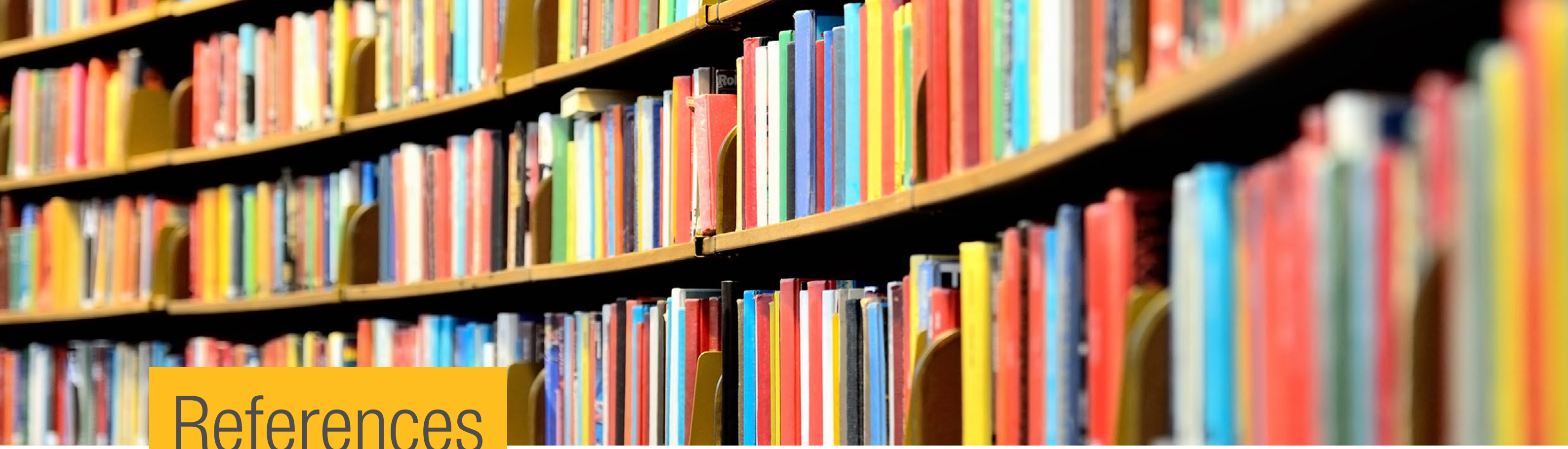
Teachers report needing more pedagogical models on how to teach STEM in an attractive way, and it is clear that initiatives in these areas should be supported, particular for less experienced teachers, who still appear to lack the confidence to include new pedagogies in their teaching. The STEM Education Policies report proposed the development of a common European framework of reference for STEM education, which could be a forward-looking opportunity to structure, inform and guide educational systems and teachers in the ways STEM teaching and practices could be approached. On a similar line, the results of the STEM Education Practices study call for actions in supporting European networks of exchange and assistance for STEM teachers to build confidence in approaching innovative teaching inside and outside the classroom. The fact that teachers turn primarily to their peers for professional support shows the important impact teacher networks can have.

Yet innovation can only happen with appropriate training and equipment. STEM teachers report carrying out most of their training in their personal time and, in some cases, science teachers report low access to experimental labs. These findings indicate possible deficits in fostering an educational culture which fosters innovation. There is also a clear need to support the development and dissemination of relevant STEM training programmes which encourage teachers to build up their subject and pedagogical knowledge, as well as their confidence in using new technologies in the classroom. Mechanisms to recognise and support teachers' efforts to improve their teaching should be put in place. Programmes should also address initial teacher education to ensure that new teachers are appropriately trained to approach innovation in their practice.

On the other hand, there is no evidence of resistance to positive change. Teachers generally show openness towards collaboration with STEM industries, and towards bringing more innovation into their classrooms, with three out of four of the teachers surveyed sharing a positive vision about innovative STEM teaching with their colleagues and heads of school. The report provides evidence to suggest that teachers appear more confident in approaching pedagogical innovation when they have the support of their peers and the school administration. Developing a clear STEM strategy at school level to promote and support innovative STEM teaching can play an essential role in improving the quality of STEM teaching and ensuring that STEM teachers benefit from the appropriate school-level support to improve their practice.

At all points in the survey, teachers report using, to different extents, various pedagogical approaches. Indeed, studies show that different teaching methods are more appropriate for achieving specific teaching goals, or for different types of classrooms. Future research could consider investigating further how the mix of different pedagogies in the teaching of STEM subjects contributes to achieving different learning outcomes, and what would be the optimal combination of pedagogies for an integrative STEM curriculum.

Lastly, it is important to reiterate that, regardless of the official curriculum, “the main impact that teachers have is through what is happening in the classroom” (UNESCO, 2004). The case studies included in the following section of this report are excellent examples of how teachers of Science, Technology, Engineering and Mathematics contribute to bringing innovation into their STEM teaching and help their students develop a better understanding of and motivation towards STEM studies and careers. These best practices in the field of STEM education should be clearly encouraged, promoted, recognized and shared between peers. Through presenting these exemplary case studies, the STEM Education Practics in Europe report aims to contribute towards this goal and to inspire other teachers to bring innovative approaches in their own STEM classes.



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APPENDIX 1: Innovative teaching practices in Europe

CASE STUDY 1: CLASSROOM BRIGHTNESS AND TWO VARIABLE STATISTICS

- **CONTRIBUTOR:** Alexandre TECHER, Mathematics and Sciences Teacher
- **WHERE:** France, Réunion, Le Tampon, Roland Garros High School
- **SUBJECT:** Mathematics/Science/Vocational
- **AGE RANGE:** 16-18

Overview

This project consisted in measuring the brightness inside a classroom, and it started from a very real problem: a high-school building composed of three classrooms whose electrical wires were removed following a storm. In order to use these classrooms again, it was necessary to focus on building renovation. Therefore, some light points had to be implemented in the rebuilding of the roof. The main objectives were:

- To conduct a study of the brightness inside the classroom to understand if the light points implementation was necessary or not.
- To perform related tasks, modifications to the electrical supply and distribution systems, rewiring buildings, replacing lamps/LEDs – tasks integrated into the students' curriculum.
- To teach about two variables – statistics and photometry & light measurement – through a project; both topics included in the students' Maths and Sciences curriculum.

The project was implemented with the aim of changing the teaching of classical subjects like statistics. Real-life problems show the need to have mathematical knowledge in order to devise solutions. The pedagogical aspect here is based on John Dewey's learning theory of "learning by doing". The project provided opportunities for cross-curricular teaching of Mathematics and Electro-Technics and implementing computational thinking in teaching practices, quite a new approach in the Mathematics curriculum.

Implementation

As the project was implemented in a vocational school, two types of activities were planned: vocational training activities and applied Mathematics activities using the STEM approach, pedagogy and materials.

The students involved in the activities were aged between 16 and 18. They were faced with a set of problems and were asked to come up with solutions and ideas and define an approach. Afterwards, they had to present their work in front of three other high schools.

The students had significant support from their Mathematics and Electro-Technics teachers who have always been there to guide them over the different hurdles.

One of the main activities they carried out, briefly mentioned before, presented students with the goal of measuring the mean brightness in a classroom and finding the less bright zones. The students found by themselves that they had to make a grid on the ground and had to find a way to evaluate the brightness level at each grid point. Once the method had been found and the tools to measure the brightness level had been provided, they had to find a correlation between the x-axis (y-axis constant) on the ground and the brightness level: this was done by a 2-variables statistics study and was later automated using a robot (TI ROVER). Through this activity, the students managed to compare the methods and tools used in their vocational courses with their Maths/Sciences courses: this is the point where interdisciplinarity made sense for them. This activity was implemented for three months with Maths and Electro- Technics teachers. Other partnerships were built up with the Regional Council, the Erasmus Agency and Texas Instruments.

Success stories

The project allowed for good cooperation among the different stakeholders – an essential condition for conducting cross-disciplinary teaching; most importantly, it gave the students challenges strongly linked to the real world.

Once the resources had been provided, students used them as their own, outside class hours in order to be more efficient during the class. They got involved in the activity without waiting for an explanation from the teacher. This was a good indicator of the effectiveness of the resources given.

Resources and materials

The materials used for this project include:

- Lux meters
- TI-Innovator Hub and TI-83 Premium CE graphing calculators and web resources to learn how to use them: https://education.ti.com/en/activities/ti-codes/84/10-minutes-innovator

CASE STUDY 2: MAKE TOMORROW FOR TURKEY

- **CONTRIBUTOR:** TTGV – Technology Development Foundation of Turkey
- **WHERE:** Turkey, 206 schools in Istanbul, Sakarya, Samsun, Izmit, Eskişehir, Ankara, Gaziantep, Şanlıurfa, Hatay, Mersin and Aydin
- **SUBJECT:** all STEM subjects
- **AGE RANGE:** >14
- **PROJECT WEBSITE:** https://ttgv.org.tr/en/programs/build-tomorrow

Overview

"Make Tomorrow for Turkey" is a project initiated by Intel and TTGV (Technology Development Foundation of Turkey) to introduce and teach 21st-century skills to secondary-school students in Turkey.

The project comprises different steps:

1. Teachers receive training and guidance on applied electronics and programming Ardunio Uno
2. Implementation of STEM projects by students under the guidance of trained teachers. The student teams are provided with technology kits and are required to work on projects defined as technology-based solutions to real-life problems/needs related to Health, Environment, Energy, and Smart Cities.
3. Evaluation and presentation of the projects implemented by students. The completed projects with their visual supplements are sent to TTGV for evaluation. Although the most successful three projects are chosen by the jury, all participants are awarded a certificate since the main objective of the project is the introduction of STEM skills.

Implementation

The main motivation behind the project was to introduce the basics of the Digital Transformation concept and mind-set to Turkish youth, particularly targeting lower- and upper-secondary school students. It aimed to create a community of practices involving teachers and students to develop STEM-related collaborative competencies. While seeking solutions to pre-defined problems, groups would learn about collaboration, innovation and entrepreneurship, as well as developing problem-solving, agile thinking and analytical skills and being able to start thinking like STEM professionals. In total, 206 schools, 537 teachers and 4270 students voluntarily participated in the “Make Tomorrow for Turkey” Programme.

According to the programme schedule, first the participating teachers received two days of applied electronics and programming training with the help of technology tool sets provided by TTGV. In every region/city a project coordinator teacher had been assigned by TTGV to follow the progress of the programme and coordinate the teacher groups.

After the teacher training programme had finished, every teacher formed the volunteer student teams of 4–5 students at their schools (the time spent on the project should not block the routine class programme of students and teachers).

Then, the volunteer student teams started working on project ideas, through team work with the guidance of teachers, providing solutions for problems they identified about the areas of “Health, Environment and Energy, and Smart Cities” by using the technology tool sets supplied by TTGV. Projects were expected to create effective solutions for everyday problems and would be evaluated by an independent jury in terms of creativity, technical infrastructure, and potential for commercialisation.

The student teams which had completed their demos described their project stories on project forms with visual supplements (video, photos, etc.) and submitted them electronically to TTGV.

An independent jury formed by TTGV chose the most successful finalist projects in each round of the programme in every region and the student teams were announced and awarded at a public event on a city basis. Every volunteer participant student and teacher was awarded the Programme Certificate and the first three groups were awarded commemorative medals and technology tool sets.

Success stories

The project reached 4,270 students and 537 teachers at 206 schools in 11 cities in Turkey, which shows its effectiveness. One significant result is that students understand that they should examine their surroundings more carefully to define the problems, evaluate the circumstances and find the corresponding solutions.

The technology kits were great materials for STEM teaching and for providing robotics lab infrastructures, especially in state schools. The items in the kits are used in projects for other national and international competitions or in elective or after-school courses.

Resources and materials

The toolsets used to construct different projects based on Ardunio Uno included: Ardunio Uno programming card; robot driving base; Hc06 Bluetooth module; LCD Screen; voice sensor Card; MPU6050 acceleration and gyro sensors; DC motor; servo motor; 250 rpm AC motor, wheel set and L298 driver card; DHT11 heat and moisture sensor; HC-SR04 ultrasonic sensor; HC-SR501 PIR motion detection sensor; LM35 temperature tensor; LDR light sensor; Wi-Fi module; supporting ICs, resistors, transistors; LEDs, buzzer; cables, jumpers; batteries. The “Make Tomorrow for Turkey” programme is supported by yearly donations from the private sector.

CASE STUDY 3: ASTROFINO IN SPACE

- **CONTRIBUTOR:** Emanuela Scaioli, Mathematics and Science Teacher
- **WHERE:** Italy, Istituto Comprensivo Statale di Fino Mornasco
- **SUBJECT:** Space education (out of school)
- **AGE RANGE:** >9
- **PROJECT WEBSITE:** http://finorobot.blogspot.it

Overview

Despite the growing demand for scientific professionals, there are still too few students, especially girls, who come into contact with science in an effective and stimulating way. One of the possible causes is represented by school pathways, which can also be correlated with the absence of a systematic and innovative training system.

"ASTROFINO IN SPACE" was implemented in the belief that it is possible to improve teaching practices, and that cooperative learning and problem-solving approaches are ideal for attracting more girls into STEM. The various activities allow everyone to get involved: even children with learning difficulties can complete tasks in an excellent way.

Implementation

ASTROFINO IN SPACE is a summer camp for girls aged 9 to 12, organised over five days. A simulated Columbus Lab of the International Space Station (ISS) was built in our school with the aim of involving astronaut girls in scientific experiments over the course of almost one week. Girl participants designed, constructed and launched rocket models in the school garden; they entered the simulated ISS through a tunnel and wore blue shirts and identification badges. An ASTRO PI kit was located in the Columbus Lab and supported the different types of space communication. Girls made robotic arms with Lego EV3 robotic kits to develop skills in space robotics and solved gravity questions through fun experiments such as egg drops.

The summer camp participants also met with the D-Orbit team to discuss D-Sat, a satellite that fell safely in a controlled way through the Earth's atmosphere, without leaving "waste".

At the end of the course we hope they will gain autonomy in constructing and programming robots and missions, and in the presentation of results, using various communication channels. The activities offer students opportunities to develop transversal skills such as time management, assignment of resources, teamwork, retrieving information, systems analysis, design and construction, logical thinking and problem solving.

Success stories

The girls were enthusiastic about the activities, appreciating in particular the construction and launch of model rockets, and the opportunities for team work. A great interest in ISS was demonstrated. They loved the rocket launches.

They declared that they had fun collaborating and listening and they had developed a new interest in space science.

Resources and materials

- EAS's AstroPi kit: https://astro-pi.org/
- n.6 Lego Mindstorm EV3 robot kits: https://www.lego.com/it-it/mindstorms
- IBSE resources from the ANISN group, such as "Voyager to Mars: egg drop experiment" or "Meringue crumbling": http://www.anisn.it/nuovosito
- Optical fibres come from our Photonic Explorer kit: http://www.eyest.eu/STEM-Programs/Photonics-Explorer
- Binary cards from Binary inventors: www.cartebinarie.it
- D-Sat news from D-Orbit team working in Fino Mornasco: http://www.deorbitaldevices.com/

CASE STUDY 4: OPEN MATCHBOX!

- **CONTRIBUTOR:** David Kusché, Computer science teacher
- **WHERE:** Austria, Schlierbach, Gymnasium der Abtei Schlierbach
- **SUBJECT:** Computer science
- **AGE RANGE:** 17-19

Overview

As a computer science teacher, the main goal of David's teaching is to arouse and increase students' interest in computer science. If they take a closer look at that subject, they will have a better basis for their later career choice.

The idea behind "Open matchbox!" came from collaborating with an Arts teacher, whose students furnished little rooms inside matchboxes: a project to automate the process of opening and closing of the boxes.

The students involved in the project had some experience with electronics and with the Arduino platform, both hardware and software. Our objective was to have an ultrasonic sensor that provides the distance to an obstacle in front of the box. If the distance remains correct for the required time, then a stepper motor opens the box with the aid of an appropriate mechanism.

The project involved a lot of skills in the participating students: developing an algorithm, implementing codes, construction with the help of a 3D CAD program and electronics, for example. Besides, working on such a project trains a lot of other skills, such as team work, seeing one's own limits and overcoming them, and problem solving.

Implementation

The project was implemented in the "computer science and natural science" class, an elective class which students can chose to do for three years at the beginning of grade 10, and it is carried out over 10 months (May to February). Students are required to go through a number of steps:

- Think out a plan for how to reach the goal.
- Make a project plan.
- Test the ultrasonic sensor with respect to the Arduino platform; do the same for the stepper motor.
- Develop the algorithm and implement it.
- Design an opening mechanism for the box.
- Get used to a 3D construction program.
- Construct needed parts.
- Print the parts with a 3D printer.
- Learn to solder, so that the electronic links are robust.
- Assemble all parts.
- Test the mechanism.
- Present the project and its development to an interested audience, consisting of other teachers, students and maybe parents.

David is the main contact person for the students, but the project involved collaboration with another teacher, who showed students the basics of the 3D construction program. Furthermore, they will learn soldering from a retiree who had always worked for a private company. And, of course, when they present their work, they will have to deal with an audience.

Success stories

The beginning of the project was a challenge: telling the students about the goal, telling them to develop a project plan and then letting them do things their own way, only giving them support if they asked for it. After a time (two weeks) they realised that they had too little knowledge about some critical points on the way to achieving the aim. Another challenge was to find relevant information about the ultrasonic sensor and the motor on the Internet. Here again, teamwork was the key to success.

Students came to the conclusion that working together on the algorithm was important, because everybody had a different perspective on the problem; and, by working together, they were successful in developing a robust algorithm. During this process, they understood the importance of developing an algorithm before implementing the code.

Resources and materials

- Arduino development environment (open source), language reference and examples can be found at: https://www.arduino.cc/
- Information about the ultrasonic sensor is available at: https://secure.reichelt.at/entwicklerboards-ultraschall-abstandssensor-debo-sen-ultra-p161487.html
- A description of the stepper motor can be found at: https://www.pollin.de/p/schrittmotor-set-daypower-s-spsm-5v-310543
- As a 3D CAD tool, Autodesk Fusion 360, which is free for three years for students/teachers, was used: https://www.autodesk.de/products/fusion-360/students-teachers-educators
- The school owns two RepRap xBots for 3D printing: http://www.reprap.cc/shop/de/content/xbot-155-ce-plug-print

CASE STUDY 5: ROOM AT THE BOTTOM: FROM THE SMALLEST, TO THE CONQUEST OF THE UNIVERSE.

- **CONTRIBUTOR:** Miguel Angel Queiruga Dios, secondary school teacher
- **WHERE:** Spain, Burgos, Jesús-María School
- **SUBJECT:** Physics, Chemistry, integrated STE(A)M
- **AGE RANGE:** > 14
- **PROJECT WEBSITE:** https://theroombottom.wordpress.com/

Overview

Plenty of Room at the Bottom is the title of the lecture given by Richard Feynman to the American Physical Society (Caltech, Pasadena, December 1959). At that meeting, Feynman explored the immense possibilities that miniaturisation and what is now called nanotechnology would offer. It has been more than five decades since Feynman told us for the first time that there is a place at the bottom, and, now that we are at the bottom, we see that the advances in research of the smallest have allowed the creation of new products applied to all fields: Medicine, Engineering, Mathematics, Computer Science, Chemistry, Physics, etc.

The main objective of the “Room at the bottom” activity is to allow students to carry out research activities using the methodology that the authors have defined as adaptive and creative Project-Based Learning (PBL): adapted to the student and looking for creative solutions to the problems and the approach. Throughout the project, students must carry out documentation activities, which, in addition to searching the Internet, includes reading books, interviewing scientists, carrying out specific experiments and research, and disseminating the results. The project must leave the classroom and seek contacts with scientific institutions, universities, artists, etc.

All this is done with nanotechnology as the central topic. To understand the relationship between science, technology, society and the environment, the topic was approached from the perspective of its contribution to space exploration, and from there, to understanding the benefits that the space industry brings to people’s daily lives.

Implementation

Nanotechnology appears in the contents of the subjects of Physics and Chemistry (students aged 14+). In fact, it is mentioned, although briefly, as a topic of great importance related to advances in all scientific and technological fields. Carbon allotropes are also studied in these subjects.

At the beginning of the course, student work teams are made and, after brainstorming, the topic on which they will develop their research is chosen. This project will be carried out throughout the year, from October to May, by dedicating some sessions in which the teacher meets with the teams to analyse the degree of progress, difficulties, possible ramifications of the project, new ideas, etc. Each team can comprise a variable number of students (between two and five, depending on the number of students in the class), although the optimum would be four. The bigger the group, the more development work is expected.

Once the team is formed, a project coordinator (the student responsible for organising the team and who will be a spokesperson in communication with the teacher) and a project secretary (student in charge of taking notes of the meetings, the agreements made, the tasks that arise and the students in charge of these tasks) are appointed.

After a documentation phase, students acquire the ability to seek contacts in the scientific community, make experiments, contact companies and institutions, etc. Students begin to become "experts" and can make an initial sketch of how the research will be conducted.

The teacher guides students, offers suggestions and contributes with new lines of development. Students and teachers seek information about institutions, universities, companies, European projects, etc., which they can contact in relation to the project.

The objective of the application of this project methodology is to develop high-school students' hard skills, but above all their soft skills, which very often fall into the background and are so important for their future work. It is about working on a project as openly as possible, without limits, so that students can develop their full potential.

Success stories

Success stories are best illustrated by the feedback from participating students:

[...] If you ask me why I studied a science degree, I will answer that these activities brought me closer to research, to want to know more about what surrounds us. And if you ask me why I want to be a teacher, I will answer that, thanks to my experience, I discovered a new way of learning, where the student moves away from the blackboard and the desk, to approach a more practical and self-taught learning, not only acquiring knowledge, but also the capacities to develop it. Beatriz Carnicero Rubio

Resources and materials

Materials used in this project:

For project design and management, information search:

- Project roadmap: notebook of the project to take notes of meetings, plan, share tasks, etc.
- PC with Internet connection
- Nanotechnology books (https://theroombottom.wordpress.com/category/lecturas/)
- Computer tools, including WordPress blog, YouTube channel, video editors, mobile phone, Tinkercad (https://www.tinkercad.com/), 3D printer

At the University (practices):

- General chemistry lab material
- Raman microscope
- Samples of nanomaterials
- Chloroauric acid, $HAuCl_4$
- Ascorbic acid

CASE STUDY 6: “WIL-DE STEM”: A NEW INITIATIVE BY WIL-DE WISKUNDE

- **CONTRIBUTOR:** Ludovic Wallaart and Frank van den Berg, Mathematics Teachers
- **WHERE:** The Netherlands and Belgium, as an online environment on YouTube
- **SUBJECT:** Mathematics from an integrative STEM approach
- **AGE RANGE:** >15
- **PROJECT WEBSITE:** https://www.youtube.com/channel/UCVh5oA0cGZgBhptlip19jmg

Overview

Students find collecting data on their own far more interesting than copying data from a book to their handhelds, and investigating the data in a dynamic way (sliders on the TI-Nspire CX, for example) far more satisfying.

Up until now, we made instructional videos on TI-technology concerning TI-84 Plus CE-T & TI-Nspire CX handhelds. With WIL-de STEM, still under the name of WIL-de Wiskunde (‘wiskunde’ in Dutch means Mathematics) we provide “Path to STEM projects”, enabling teachers and students to work with sensors, TI-Innovator HUB and TI-Innovator ROVER and more. These instructional videos on STEM-projects using TI-technology will help make more scientific sense of the world around us.

Implementation

The students involved in the initiative are aged between 15 and 18 and they already have their own TI-handhelds. We are focusing on students and teachers in the Netherlands (and Belgium), whom we encourage to start seeing the power of STEM, as an integrative approach to the teaching of Mathematics.

Different activities are organised to do this. On one occasion, we collected data from 110 students in our assembly hall and used CBR2-sensors together with TI-Nspire CX technology to measure the height of each student. The data was then transferred to their TI-Nspire-handhelds to start the dynamic exploration of its (in this case) normal distribution.

On several occasions, we presented the Path to STEM project at symposiums, mathematical meetings and events nationwide and we visited several schools. The objective is to persuade students and teachers to do more with the handhelds than the “regular” usage.

In addition, we presented the benefits of using TI-Nspire CX technology over the TI-84 Plus CE-T (still very much in used in the Netherlands).

Success stories

We are confident that WIL-de STEM with its Path to STEM project can play a major role in guiding teachers in the Netherlands to start looking at Mathematics in a different perspective. Students are very enthusiastic when working with STEM; in a world with screens all around them, working from a book is not always the best (or the only) way to learn.

Resources and materials

- TI-Nspire CX technology (in some cases TI-84 Plus CE-T technology)
- CBR2-ultrasonic sensors
- Force plate
- Dual range force sensor
- Easytemp
- Light sensor
- Voltage probe
- Gas pressure sensor
- TI-Innovator HUB
- TI-Innovator ROVER
- TI-Innovator Breadboards Pack.

CASE STUDY 7: THE EARTH'S CLIMATE AND GLOBAL WARMING

- **CONTRIBUTOR:** Maria Eleftheriou, Science Teacher
- **WHERE:** Greece, Crete, Heraklion, Experimental High School of Heraklion
- **SUBJECT:** Geology
- **AGE RANGE:** 13-15

Overview

Students in Greek schools learn in general about the climate in Europe but they are not informed about the climate of the globe and the causes of global warming of our planet. The "Earth's climate and global warming" project was carried out to educate and inspire students to be well-informed citizens and possibly the scientists of tomorrow. The project uses the Space Awareness Climate Box educational kit and its resources. Students learn about the climate and the global warming of the Earth through simple experiments and demonstrations. In the last part of the project, students perform simple experiments related to the global warming of our planet in a special event, with the participation of their parents, teachers and other students. This project gives students opportunities to interact with one another. Students learn to present their work, to think like scientists and to develop arguments about phenomena like global warming. Critical thinking is an essential skill that students acquire.

Implementation

The project starts by showing students what are the exoplanets, and discussions around the conditions that have to be fulfilled on Earth in order to have life, to encourage them to identify the vital conditions for life on another planet.

Then the different climates in the different regions of Earth are explored, with these main questions in mind: what are the main effects of climate change? Why is it occurring now? Students are encouraged to monitor these problems and to give possible solutions.

Activities and simple experiments are performed using the Space Awareness kit, which is related to the climate zones, winds, oceans and land of the Earth. In the process, students learn about satellites and how the data from satellites helps us understand complex phenomena that occur related to climate change.

Activities are carried out for two hours each week, over twenty weeks during the school year. Students work in teams of two or three.

In the last part of the project, students present their findings and demonstrate simple experiments they have learnt in a special event with their parents, other students and teachers.

Success stories

The project gives students opportunities to learn about the effects of climate change not only as individuals but also as citizens.

Students are more engaged when acting as researchers, and connecting science with real-life issues gives them the incentive to potentially follow a profession related to science.

Resources and materials

The project uses the Space Awareness Climate Box educational kit: http://www.space-awareness.org/en/activities/category/earth/#filters and its resources.

For practical work, students use: strong lamps, photovoltaic cell, electric motor, rulers, pocket calculators, balloons, candles, thermometers, watch, sand, transparent cups, transparent containers, pH indicator, boxes, pencils, markers and a computer.

CASE STUDY 8: APPLYING MATHEMATICS IN REAL-WORLD SITUATIONS

- **CONTRIBUTOR:** Rok Lipnik, Mathematics teacher
- **WHERE:** Slovenia, Celje, Gimnazija Celje – Centre
- **SUBJECT:** Mathematics
- **AGE RANGE:** 14-16

Overview

In traditional Mathematics teaching, students get a high level of theoretical knowledge, but the practical use of that knowledge is almost non-existent. This project tried to bring real-world applications into Maths classes.

The objective was to start adding practical activities to the existing teaching methods, and increase the practical use of Mathematics to increase student's interest in Mathematics. The activities developed were based on simple real-life applications of mathematical knowledge – passing volleyballs and shuttlecocks; lighting candles and predicting when they will burn out; logarithmic scales in sound volume, etc.

Implementation

Multiple activities were carried out in different classes:

- In the first-year class (14 and 15-year-old students) real life situations were modelled with linear functions – students were asked to bake muffins, and the teacher brought candles. The first objective was to try and estimate how long it takes for the candles to burn. Does it become easier to predict if one already knows what happens after 1 minute, after 5 minutes, …? When can one be certain? Students also made steaming hot tea and observed the temperature change. Can the tea cool down to zero degrees? Does it cool evenly?

Second-year students (15 and 16-year-olds) modelled the trajectories of the shuttlecock and the volleyball and the light reflection from a table, using the parabola. Students were asked to try and find other parabolas in real life (they noticed satellite dishes, and water coming out of a hose).

Third-year students tried their best at approximating the sound level of different devices (phones, our school bell, home alarm) and making a sound scale. Earthquakes were also investigated using data available on the Internet.

The activities lasted from 2 to 5 school hours (including preparation and analysis).

Other teachers were also involved – mostly as observers, but some also in the planning of future activities. Future collaborations with a Chemistry teacher for an idea around pH change are planned for the near future.

Success stories

A lot worked well in the project – mostly the fact that students had fun while doing Mathematics. That is something that changes their outlook – they become more motivated, better and faster learners, and more engaged. Students were also engaged in self- and peer evaluation – mostly by trying to come up with their own examples for real-world applications of Mathematics, which their deskmate then tried to solve. Then, they checked each other's progress and helped each other advance.

Resources and materials

The resources used in this project were usually simple materials such as candles and balls. The discussions were mostly directed by the teacher, who asked questions, requiring students to consider what they can predict and what would be interesting to know.

CASE STUDY 9: THE BIO-GO PROJECT

- **CONTRIBUTORS:** Rosa Soares, Biology teacher, and Ana Martins, English teacher
- **WHERE:** Portugal, Oporto, Escolas Garcia de Orta
- **SUBJECT:** Science, Technology, Biology, English
- **AGE RANGE:** 16-18

Overview

The Bio-Go Project has been developed in a secondary school, with students attending the Science and Technology courses, concerning the subjects Biology and English from the 12th grade. It has been implemented for 3 years.

The project aims to deepen students' knowledge about current science topics, positively inspire them to pursue careers in science, allow them to recognise the huge importance and impact of scientific breakthroughs and their applications, as well as the importance of using technology to promote and develop well-being in society and to underscore the importance of a foreign language – English – for their future lives.

During 2018-2019 the central theme is Biotechnology and its applications in different areas, mainly food production, biomedicine and environment.

Implementation

Students are from the 12th grade (aged between 16 and 18) and the activities are organised by two teachers (Biology and English).

Different topics from these two subjects are connected in activities covering different areas. Students are encouraged to research scientific articles, develop microscopy work and, whenever necessary, use virtual labs.

- Concerning Genetics, students use hands-on activities about the organisation and the regulating of genetic material (lac operon, PCR, DNA finger prints, etc.) and use virtual labs and among other more complex techniques such as the CRISPR-CAS 9 (https://international.neb.com/tools-and-resources/feature-articles/crispr-cas9-and-targeted-genome-editing-a-new-era-in-molecular-biology).
- Concerning Biotechnology in Food Production students carry out hands-on activities about lactase persistence, enzymatic immobilisation, fermentation, produced in ginger beer and some food conservation techniques such as pickles.
- Concerning Immunity, they work on the effects of phytoactive compounds, produced by onions (Allium cepa) and ginger (Zingiber officinale) on bacteria.
- Finally, related to the environment, the actions of micro-organisms in the biological treatment of waste waters will be investigated.

Besides the activities carried out in the context of the Biology and English curricula, students also participated in different projects, such as the "Brassica Growing Project" (John Innes Centre, Norwich Research Park) from October 2016 to April 2017, or the SciChallenge Contest for 2017.

In 2017-2018, students contributed to the second stage of the Plant Growth Project (from January to April 2018) among other activities. Students observed the growing of the plants, from the seed to flowering. They registered data related to the plants on a monthly basis including height and width, number of leaves, signs of disease parasites, slug/snail damage that affected the plants during the investigation process. Using a data recorder, they monitored temperature and moisture levels. In January 2017, students visited a research centre in Heidelberg (EMBL), one of the most privileged places for contact with researchers in different STEM areas. Activities were also developed in Escola Superior de Biotecnologia in Oporto, as a part of a project called ComCiência.

Success stories

The project plays an important role in helping students become aware of potential university courses, familiarising them with areas such as Science, Biology, Biochemistry, Bioengineering, Medicine and others.

Students have always shown enthusiasm and commitment in developing the activities, mainly the reports about their tasks. The study trip to EMBL was considered by all the participants involved an added value that allowed contact with the real research world.

Resources and materials

Scientific articles on Reproduction and Fertility Endurance, Genetics and Biotechnology in food production.

Biotechnology Virtual Lab: https://imagem.casadasciencias.org/online/36344278/36344278.php

CASE STUDY 10: HEMBIZIKA – A GAMIFICATION PROJECT

- **CONTRIBUTOR:** Mladen Sljivovic, Physics teacher
- **WHERE:** Serbia, Zajecar, Desanka Maksimovic
- **SUBJECT:** Physics
- **AGE RANGE:** >12

Overview

HEMBIZIKA was initially developed as a quiz game with questions on Chemistry, Biology and Physics (Serbian HEMija, BIologija fiZIKA).

The main improvement of the game was introduced when it was decided that students should be the ones creating their own questions, contrary to the usual practices in which teachers are the ones asking questions. The game was eventually used mainly in physics class, but the name remained the same.

Students are split into teams, playing against each other. In each round, the team gives one question from the subject's curriculum to the opposite team and gets one in return. The correct answer scores one point. The first team to have five points by the end of the round wins.

Implementation

HEMBIZIKA was introduced in 6th grade (students aged 12). Pupils were asked during class to create one question from a physics lesson taught that day and ask another student to solve it. The class was then divided in groups and HEMBIZIKA was introduced. For homework they were asked to create a list of questions for a next class during which HEMBIZIKA would be played. Rules when creating questions were that the student who asks the question must know how to solve it and that it has to be from the 6th grade physics curriculum.

Even though students enjoyed the game, it was noticed that they lacked sufficient skills to create questions corresponding to the lessons. Students would often show misconceptions and trouble with expressing ideas using scientific language. In the next few classes we checked student's question, analysed "good" and "bad" examples, and found a way to improve them. Students were shown examples of good questions from final exams at the end of elementary school, PISA testing and others.

The activity lasted through the whole year and was continued into the next one. The competition itself proved to be a highly motivating factor for most students, and at same time better results at exams were noticed.

The idea was to include other subjects present in final exams in Serbian education (biology and chemistry), but since this was the first time it had been applied in any class it was decided to stick with Physics.

The game was presented at the first national Scientix conference in Serbia in 2017, LUMAT Helsinki 201, and during a Scientix webinar.

Success stories

The game was not without its hurdles. For instance, problems occurred as most students were having a hard time formulating Physics questions. But analysing examples of good and bad questions in order to determine what was wrong and how we they could be improved showed great results.

A first objective of the game was to test students' knowledge in an imaginative and creative way, but later other results also came up. Students started to pay more attention to the context of the subject taught; they also started to use more resources when preparing for class.

There is also an added value from the teacher's perspective: instead of trying to motivate students to study for a better grade, a creative approach to testing was adopted. By listening to the questions that students prepare for the game, the teacher can better understand what lessons need to be explained better, what are students' common misconceptions, and how to better support them to improve their critical thinking and problem-solving skills.

Resources and materials

The game can be played as a board game, a card game, or as a live quiz run by the teacher. More information can be found at the following links:

- https://www.youtube.com/watch?v=haJaeNINWDs
- https://www.lumat.fi/index.php/lumat-b/article/download/305/290/
- https://www.luma.fi/en/files/2017/06/lumat-2017-sljivovic.pptx

CASE STUDY 11: BIOPLASTIC, BUILDING INNOVATIVE OPTIONS AGAINST POLLUTION AND LITTER

- **CONTRIBUTOR:** Nicolas Duquenne, Biology teacher
- **WHERE:** Belgium, Brussels, European School of Brussels 2
- **SUBJECT:** Biology
- **AGE RANGE:** >16

Overview

The Bioplastic project aims to develop STEM practices for high-school students, with all activities taking place during "mandatory" biology lessons, following the official pedagogical syllabus of European schools (level s6 and s7, two last years of high school). (https://www.eursc.eu/syllabuses/2002-d-66-fr-4.pdf).

The scope of the project ranges from developing students' scientific research skills and knowledge to raising their awareness of environmental issues.

Class activities will lead students to read scientific papers, face scientific issues, develop strategies to offer solutions, and, finally, to fulfil pedagogical expectations.

The project aims to increase students' interest in biology/science and their engagement in this subject, produce better academic results for students in this area and encourage them to pursue science careers.

Implementation

The different topics included in the syllabus lend themselves to being approached from the perspective of (bio)plastics, and hands-on activities are an important part of school learning. To enhance practical skills, students will be taught through the method of inquiry. The Bioplastic project builds new lab activities where students aged 16-17 will be asked to work on specific topics (e.g. catabolism of polysaccharides by chemical, physical or enzymatic actions, numeration under microscope of microplastics after extraction).

In European schools, some students have the opportunity to choose (1h30 a week) laboratory lessons in Biology. During this time, deeper practical skills can be implemented and more sophisticated equipment can be used. However, most of the activities take place within advanced Biology lessons.

Links to various initiatives and organisations are also sought to increase the contextualisation of teaching. "Bruxelles environnement" is the first stakeholder involved in this project, providing a series of training sessions on the “zero waste” goal. Links with Université de Bretagne (Earth sciences) were also sought, to facilitate access to information about oceanic microplastic sedimentation research.

Success stories

At the moment of writing, the project is still in its early stages, but positive signs are already apparent: students are happy to join such a project if they clearly understand the goal, and the school management is fully supportive if no negative impact is reported on students and colleagues’ timetables.

Resources and materials

Paper/web documentation:

- research.eu
- Science in School (European journal for science teachers)
- Plos-one : open access scientific papers
- Institut français de l’education: IFE

All laboratory devices are used during the project:

- microscopes
- micropipettes
- centrifuge
- sieves for granulometry
- spectrometers for colorimetry
- chemicals

CASE STUDY 12: DOING MATHS AS RESEARCHERS DO IT

- **CONTRIBUTOR:** Ariana-Stanca Văcărețu, Mathematics teacher
- **WHERE:** Romania, Cluj-Napoca, Colegiul National Emil Racovita
- **SUBJECT:** Mathematics
- **AGE RANGE:** 15-18

Overview

The “Doing Maths as Researchers Do It” elective course is a scientific and technical workshop for high-school students. The course allows students to meet researchers and experience an authentic Maths research process in school, with both a theoretical and an applied dimension.

The course aims to introduce students to a different way of doing Mathematics, develop their curiosity and enjoyment in doing Mathematics through a method which fosters autonomy and imagination, create links with academics to foster student understanding of Maths research careers, and increase student engagement in and intrinsic motivation towards Mathematics.

Implementation

In this course, Mathematics research topics are launched by professional researchers after being discussed with the teachers. The way in which research topics are presented is essential: they should require investigation, the topic text should be easy to read, formulated in everyday language and the investigation should be focused on only one question, allowing multiple approaches, and describe an open problem with more than one solution.

Small groups of two to three students choose one of the proposed problems and do research work to solve it. The students organise their work, identify the resources (strategies, knowledge, experience, equipment, software, materials), and decide how the resources will be used for building and maintaining a shared understanding of the task and its solutions. The students’ activity is facilitated by the teacher. A researcher from Babes-Bolyai University in Cluj participates in the course and periodically meets with the students to discuss their research and general Maths/ scientific research methodology.

Then, students share their research results at different scientific events, and write and publish a scientific article about their research findings.

The Inquiry-Based Learning (IBL) approach is fundamental to this course. IBL is used in a collaborative and interactive context. It is not the solution which is the most important in the context of this elective course, but the process.

There is no special requirement related to the students' Maths knowledge or skills, and all high-school students who want to take the course are welcome. Yearly, around 30 high-school students (aged 15–18) enrol in this course.

Students in my class work together with students from Lycée d'Altitude de Briançon (France) to search for solutions to the same research topic. In this way, this elective course is a replica of scientific research – researchers from different countries collaborate and communicate in English to find solutions to different problems and share their findings.

Success stories

The project evaluation highlighted a number of important achievements, including:

- Higher student levels of collaborative problem solving, of competences related to making use of aids and tools, and increased oral presentation and writing skills (related to the presentation of the research results).
- Low and average achievers in Maths were very interested in participating in the elective course, and there was evidence of increased student motivation for improving their Maths academic performance while / after taking the elective course.
- Three of our students stated that they intend to work in scientific research after graduating from university.

Resources and materials

- The curriculum of the elective course was developed after the MATh.en.JEANS (MeJ) (Méthode d'Apprentissage des Théories mathématiques en Jumelant des Etablissements pour une Approche Nouvelle du Savoir) workshops: http://www.mathenjeans.fr/
- The research topics of the elective course are provided by the researcher. However, a list of research topics is available on the MATh.en.JEANS website: http://www.mathenjeans.fr/sujets
- During the Learning Maths and languages through research and cooperation – MatLan (Erasmus+ KA2) project, the "Syllabus of the elective course Doing Maths As Researchers Do It" and the "Guidelines for assessing students' skills developed through Maths research" were developed and can be accessed: http://matlanproject.weebly.com/intelectual-outputs-and-multiplier-events.html
- Financial resources for students' participation in different scientific events were provided by various sponsors or by including the implementation of the elective course in various Erasmus+ projects: "Learning Maths and languages through research and cooperation – MatLan" (2014-2016): http://matlanproject.weebly.com/ and "Maths&Languages" (2017-2020): http://mathsandlanguages.mathenjeans.eu/)

APPENDIX 2: Teacher questionnaire – Science, Technology, Engineering and Mathematics Education Practices

The questionnaire is addressed to Science, Technology, Engineering and Mathematics (STEM) teachers in secondary education (lower secondary and upper secondary – students aged 10 to over 19), and it aims to collect information about teaching practices in STEM education. The results of the study will be made freely available online before the end of 2018 and included in the Scientix Observatory.

As a STEM teacher, you are invited to complete the questionnaire and provide feedback for at least one of the STEM classes you teach. If you teach more than one STEM class, at the end of the survey you will have the option to provide information about up to three additional STEM classes you teach, by revisiting just the class-specific questions of the survey (Questions 1 to 4). By class, we mean the specific group of students who attend a specific lesson. The objective of this questionnaire is to assess the current practices of STEM teachers regarding the way they organise their teaching. More particularly, the questionnaire will investigate areas such as: pedagogical approaches, the type of resources used by teachers and students to facilitate STEM teaching and learning, the use of Information and Communications Technology (ICT) in the teaching process and the need for specific teacher training. You can also contribute further to this study by opting to be contacted to provide a case study. Answering this questionnaire should require no more than 20 minutes.

Data collection and processing

The data collected through this survey will be used strictly in line with the objectives defined above. This questionnaire is supported by Scientix, the community for science education in Europe, and Texas Instruments Education Technology GmbH, and has been developed by EUN Partnership AISBL in collaboration with Deloitte SAS. All anonymous data collected via this survey will be made freely available online (open access).

If they wish, participants can provide their name and email at the end of the survey, only if they are interested in providing follow-up information which would lead to a case study. EUN Partnership AISBL is the controller of this personal data. This information will not be shared outside EUN Partnership AISBL (for example, your name and e-mail address will not be shared with Texas Instruments), will be used only according to the purposes declared and will be deleted at the end of 2018. If you have any questions regarding this survey, please contact Adina Nistor (adina.nistor@eun.org).

CLASS-SPECIFIC INFORMATION

1. Please provide information about one STEM class you teach.

If your subject is not listed, please choose the closest option, or in the case of combined subjects, the option which is dominant in the subject taught.

CLASS 1

Subject taught	Age of the students	How many boys per class?	How many girls per class?	How many lessons/ sessions a week do you teach this class?

1.1. Subject taught

- ☐ Biology
- ☐ Chemistry
- ☐ Physics
- ☐ Earth sciences
- ☐ Combined Biology and Chemistry
- ☐ Combined Physics and Chemistry
- ☐ Combined Biology and Geology
- ☐ Mathematics
- ☐ Technology
- ☐ ICT (computer use only)
- ☐ ICT (database & network design and administration)
- ☐ ICT (software, applications development & analysis)
- ☐ Engineering (chemical engineering and processes)
- ☐ Engineering (environmental protection technology)
- ☐ Engineering (electricity and energy)
- ☐ Engineering (electronics and automation)
- ☐ Engineering (mechanics and metal trades)
- ☐ Engineering (motor vehicles, ships and aircraft)
- ☐ Engineering (nanotechnology, biotechnology, etc.)
- ☐ Architecture and town planning
- ☐ Building and civil engineering
- ☐ Agriculture, Forestry, Fisheries and Veterinary
- ☐ Medicine
- ☐ Medical diagnostic and treatment technology
- ☐ Integrated STEM

1.2. Age of the students

- ☐ 10 – 11
- ☐ 11 – 12
- ☐ 12 – 13
- ☐ 13 – 14
- ☐ 14 – 15
- ☐ 15 – 16
- ☐ 16 – 17
- ☐ 17 – 18
- ☐ 18 – 19
- ☐ Over 19

1.3. How many boys per class?

- ☐ 0-5
- ☐ 6-10
- ☐ 11-15
- ☐ 16-20
- ☐ 21-25
- ☐ >25

1.4. How many girls per class?

- ☐ 0-5
- ☐ 6-10
- ☐ 11-15
- ☐ 16-20
- ☐ 21-25
- ☐ >25

1.5. How many lessons/sessions a week do you teach this class?

- ☐ 1 session
- ☐ 2 sessions
- ☐ 3 sessions
- ☐ 4 sessions
- ☐ 5 or more sessions

2. Which pedagogical approaches are you using in your STEM teaching for this class and how much?

	CLASS 1
Traditional direct instruction (lessons are focused on the delivery of content by the teacher and the acquisition of content knowledge by the students).	
Teaching with experiments (experiments are used in the classroom to explain the subject matter).	
Project-/Problem-based approach (students are engaged in learning through the investigation of real-world challenges and problems).	
Inquiry-Based Science Education (students design and conduct their own scientific investigations).	
Collaborative learning (students are involved in joint intellectual efforts with their peers or with their teachers and peers).	
Peer teaching (students are provided with opportunities to teach other students).	
Flipped classroom (students gain the first exposure to new material outside of class, and then use classroom time to discuss, challenge and apply ideas or knowledge).	
Personalised learning (teaching and learning are tailored to meet students' individual interests and aspirations as well as their learning needs).	
Integrated learning (learning brings together content and skills from more than one subject area).	
Differentiated instruction (classroom activities are designed to address a range of learning styles, abilities and readiness).	
Summative assessment (student learning is evaluated at the end of an instructional unit and compared against a benchmark or standard).	
Formative assessment, including self-assessment (student learning is constantly monitored and ongoing feedback is provided; students are provided with opportunities to reflect on their own learning).	

Answer choices:

- Not at all
- Very little
- To some extent
- A lot

3. To what extent do you use the following aspects of teaching and learning (with or without ICT) when teaching this class?

	CLASS 1
I present and explain scientific ideas to the whole class	
Students work alone at their own pace	
Students work on exercises or tasks individually at the same time	
I demonstrate a scientific idea to the whole class	
Students conduct experiments	
Students discuss ideas with other students and the teacher	
Student make decisions about how they learn	
Students conduct their own scientific study and research activities	
Students work in groups, with well-defined tasks	
Students work collaboratively, working together to find solutions to problems	
Students reflect on their learning	
I support and explain things to individual students	
I use different types of materials (visual, audio, written) in my classes	
I use content from different subjects to explain scientific concepts	
I invite other STEM teachers of different disciplines to coordinate our teaching of certain common topics	
I organise field trips/visits to museums/company visits to contextualise scientific concepts	
Students take tests and assessments	
I give feedback to my students during a learning activity	
Students participate in assessing their own work and the work of their peers	
Students give presentations to the whole class	
I integrate Arts into my STEM teaching to increase student engagement	

Answer choices

- Not at all
- Very little
- To some extent
- A lot

4. Which learning resources / materials are you currently using when teaching this class?

	CLASS 1
Paper-based materials	
Audio/video materials	
Presentations (MS Power Point, Libre Office Impress, Sway…)	
Robots	
Sensors, data loggers	
Calculators	
Graphing calculators	
Manipulation in an experimental lab	
Web-based or computer-based simulations	
STEM-specific software (e.g. Geogebra, Function Plotter…)	
Data sets / Spreadsheets (MS Excel, Libre Office Calc,…)	
Word processors (e.g. MS Word, LibreOffice Write, OneNote, Notepad…)	
Online collaborative tools (Padlet, Mentimeter, Tricider, Kahoot…)	
Resources published by private companies operating in STEM fields	
Resources for special needs learners	
Resources for personalised learning	

Answer choices

- Not at all
- Very little
- To some extent
- A lot

YOUR STEM TEACHING IN GENERAL

5. How do you usually learn about the teaching resources you are using in class?

You can choose more than one answer

- ☐ They are shared by the educational authorities in my country
- ☐ They are shared by my network of peers
- ☐ I actively search for resources in repositories of educational resources (e.g. Scientix)
- ☐ I actively search the Web for relevant teaching resources
- ☐ I subscribe to the information channels of national and international STEM education projects, which are publicly funded (social media, newsletters…)
- ☐ I subscribe to the information channels of private companies who publish STEM education resources (social media, newsletters…)

6. Which learning resources / materials would you like to use, but do not have at your disposal?

	I WILL NOT USE	I COULD USE	I NEED	I ABSOLUTELY NEED	NOT APPLICABLE (I ALREADY HAVE)
Robots	○	○	○	○	○
Sensors, data loggers	○	○	○	○	○
Calculators	○	○	○	○	○
Graphing calculators	○	○	○	○	○
Experimental lab	○	○	○	○	○
Web-based or computer-based simulations	○	○	○	○	○
STEM-specific software (e.g. GeoGebra, Function Plotter, Remote Labs,.)	○	○	○	○	○
Augmented reality/Virtual reality tools (including for example Virtual Labs)	○	○	○	○	○
Resources for personalised learning	○	○	○	○	○
Resources for special needs learners	○	○	○	○	○
Resources published by private companies operating in STEM fields	○	○	○	○	○

7. You would like to see more support for schools from private companies operating in STEM fields in:

	NOT AT ALL	VERY LITTLE	TO SOME EXTENT	A LOT
Facilitating company visits	○	○	○	○
Having STEM professionals presenting to pupils in schools (on-site or on- line, via webinars)	○	○	○	○
Offering teacher placements	○	○	○	○
Offering student placements	○	○	○	○
Making teaching resources available to schools	○	○	○	○
Allowing access to hardware and equipment	○	○	○	○
Professional development	○	○	○	○
Other financial support	○	○	○	○

OBSTACLES TO IMPLEMENTING EFFECTIVE STEM TEACHING

8. Is your use of STEM teaching affected by the following?

	NOT AT ALL	VERY LITTLE	TO SOME EXTENT	A LOT
Insufficient number of computers	○	○	○	○
Insufficient number of Internet-connected computers	○	○	○	○
Insufficient Internet bandwidth or speed	○	○	○	○
Insufficient number of interactive whiteboards	○	○	○	○
Insufficient number of portable computers (laptops/notebooks)	○	○	○	○
School computers out of date and/or needing repair	○	○	○	○
Lack of adequate training of teachers	○	○	○	○
Insufficient technical support for teachers	○	○	○	○
Insufficient pedagogical support for teachers	○	○	○	○
Lack of content in national language	○	○	○	○

	NOT AT ALL	VERY LITTLE	TO SOME EXTENT	A LOT
Lack of pedagogical models on how to teach STEM in an attractive way	◯	◯	◯	◯
School time organisation (fixed lesson time, etc.)	◯	◯	◯	◯
School space organisation (classroom size and furniture, etc)	◯	◯	◯	◯
Pressure to prepare students for exams and tests	◯	◯	◯	◯
Lack of interest of teachers	◯	◯	◯	◯
Insufficient cross-curricular support from my school colleagues	◯	◯	◯	◯
No or unclear benefit from using ICT for STEM teaching	◯	◯	◯	◯
Using ICT in teaching and learning not a goal in our school	◯	◯	◯	◯
Administrative constraints in accessing adequate content/material for teaching	◯	◯	◯	◯
Budget constraints in accessing adequate content/material for teaching	◯	◯	◯	◯

SUPPORT FOR STEM TEACHING

9. In your country / region, STEM teacher training for teachers in your subject(s) is:

- ☐ Compulsory
- ☐ Not compulsory, but recommended
- ☐ At my own discretion

10. In the past two school years, have you undertaken professional development of the following type and for how long?

	LENGTH	TYPE
Introductory courses on Internet use and general applications (basic word- processing, spreadsheets, presentations, databases, etc.)		
Advanced courses on applications (advanced word-processing, complex relational databases, Virtual Learning Environments, etc.)		
Advanced courses on Internet use (creating websites/homepage, video conferencing, etc.)		
Equipment-specific training (interactive whiteboard, laptop, etc.)		
Courses on the pedagogical use of ICT in teaching and learning		

	LENGTH	TYPE
Subject-specific training on learning applications (tutorials, simulations, etc.)		
Course on multimedia (using digital video, audio equipment, etc.)		
Participate in communities (e.g. online: mailing lists, Twitter, blogs; or face to face: working groups, associations…) for professional discussions with other teachers		
Personal learning about innovative STEM teaching in your own time		
Cooperation with industry for the contextualisation of STEM teaching (joint development of learning resources, placement in industry...)		
Other professional development opportunities related to innovative STEM teaching		

LENGTH

- No time at all
- Less than 1 day
- 1-3 days
- 4-6 days
- More than 6 days

TYPE

- Online
- Face to face
- Both
- Not applicable

11. Do you use a computer / tablet / smartphone and the Internet to update your subject knowledge or undertake personal or professional development in any subject (i.e. whether or not related to the subject you teach)?

	NOT AT ALL	VERY LITTLE	TO SOME EXTENT	A LOT
To actively search for information and update your knowledge (teaching resources, news articles, etc.)	○	○	○	○
To undertake professional development courses	○	○	○	○
To participate in online communities (mailing lists, Twitter, Facebook, blogs…)	○	○	○	○
To create new materials either for personal use (e.g. calendar, personal website, own blog) or for my lessons (e.g. I create my own digital learning materials for students).	○	○	○	○

12. To what extent do you receive the support of the following groups to improve your STEM teaching?

	LITTLE/NO SUPPORT	MOSTLY TECHNICAL SUPPORT	MOSTLY PEDAGOGICAL SUPPORT	BOTH TECHNICAL AND PEDAGOGICAL SUPPORT
Other teacher(s) of the same subject	◯	◯	◯	◯
Other teacher(s) of a different STEM subject	◯	◯	◯	◯
Other teacher(s) of other, non-STEM subjects	◯	◯	◯	◯
School ICT / technology coordinator	◯	◯	◯	◯
Experts from outside the school (industry…)	◯	◯	◯	◯
An online helpdesk, community or website	◯	◯	◯	◯
Other school staff	◯	◯	◯	◯

13. Do your colleagues and head of school share a positive vision about innovative STEM teaching at your school?

Examples of innovative STEM teaching include: Inquiry-Based Science Education, Project-Based Learning, Flipped Classrooms, the use of ICT tools in STEM education, etc.

☐ Yes ☐ No

TEACHER OPINIONS AND ATTITUDES

14. In your opinion, does innovative STEM teaching (using ICT, and innovative pedagogical approaches) have a positive impact on the following?

	NOT AT ALL	VERY LITTLE	TO SOME EXTENT	A LOT
Students concentrate more on their learning	◯	◯	◯	◯
Students try harder in what they are learning	◯	◯	◯	◯
Students feel more autonomous in their learning (they can repeat exercises	◯	◯	◯	◯
Students understand more easily what they learn	◯	◯	◯	◯
Students remember more easily what they've learnt	◯	◯	◯	◯
Students develop their critical thinking	◯	◯	◯	◯

	NOT AT ALL	VERY LITTLE	TO SOME EXTENT	A LOT
Students become more interested in STEM careers	◯	◯	◯	◯
ICT facilitates collaborative work among students	◯	◯	◯	◯
ICT improves the class climate (students are more engaged, lessdisturbing)	◯	◯	◯	◯

15. To what extent do you disagree or agree with each of the following statements about the use of ICT for STEM teaching at school?

	STRONGLY DISAGREE	DISAGREE	AGREE	STRONGLY AGREE
ICT SHOULD BE USED FOR STUDENTS TO: ...do exercises and practise	◯	◯	◯	◯
...retrieve information	◯	◯	◯	◯
...work in a collaborative way	◯	◯	◯	◯
...learn in an autonomous way	◯	◯	◯	◯
ICT USE IN TEACHING AND LEARNING POSITIVELY IMPACTS ON STUDENTS': ...motivation	◯	◯	◯	◯
...achievement	◯	◯	◯	◯
...higher level skills (deep understanding)	◯	◯	◯	◯
...competence in transversal skills (learning to learn, social competences, etc.)	◯	◯	◯	◯
ICT USE IN TEACHING AND LEARNING IS ESSENTIAL: ...to prepare students to live and work	◯	◯	◯	◯
...in the 21st century	◯	◯	◯	◯

PERSONAL BACKGROUND INFORMATION

16. Country in which you teach

- Albania
- Andorra
- Armenia
- Austria
- Azerbaijan
- Belarus
- Belgium
- Bosnia and Herzegovina
- Bulgaria
- Croatia
- Cyprus
- Czech Republic
- Denmark
- Estonia
- Finland
- France
- Georgia
- Germany
- Greece
- Hungary
- Iceland
- Ireland
- Italy
- Kosovo
- Latvia
- Liechtenstein
- Lithuania
- Luxembourg
- Macedonia (FYROM)
- Malta
- Moldova
- Monaco
- Montenegro
- Netherlands
- Norway
- Poland
- Portugal
- Romania
- San Marino
- Serbia
- Slovakia
- Slovenia
- Spain
- Sweden
- Switzerland
- Turkey
- Ukraine
- United Kingdom (UK)
- Other (please specify)

17. Are you

- Female
- Male
- Other

18. Including this school year, how long have you been teaching (at any school)?

- Less than 1 year
- 1-3 years
- 4-10 years
- 11-20 years
- 21-30 years
- 31-40 years
- More than 40 years

19. Age

- 30 or under
- 31-35
- 36-45
- 46-55
- Over 55

20. How often do you use a computer, a tablet or a smartphone for activities other than work (e.g. shopping, organising photos, socialising, entertainment, booking a hotel, contacting family and friends)?

- Never
- A few times a year
- Almost monthly
- Weekly
- Daily

21. How many lessons / sessions do you teach in total each week?

- Fewer than 10 sessions per week
- 10-20 sessions
- 20-38 sessions
- 38 or more sessions

22. What is the duration of one lesson/session in your country?

- 35 minutes
- 40 minutes
- 45 minutes
- 50 minutes
- 55 minutes
- 60 minutes
- Other (please specify)…

23. Would you like to provide class-specific information about between one and three additional classes you teach?

○ Yes ○ No

[OPTIONAL] INFORMATION ABOUT THE ADDITIONAL CLASSES YOU TEACH

24. Please provide information about between one and three additional classes you teach. [Answer per class]

If your subject is not listed, please choose the closest option, or in the case of combined subjects, the option which is dominant in the subject taught.

CLASS 2*

Subject taught	Age of the students	How many boys per class?	How many girls per class?	How many lessons/ sessions a week do you teach this class?

CLASS 3*

Subject taught	Age of the students	How many boys per class?	How many girls per class?	How many lessons/ sessions a week do you teach this class?

CLASS 4*

Subject taught	Age of the students	How many boys per class?	How many girls per class?	How many lessons/ sessions a week do you teach this class?

*Answer choices detailed in Q1

25. Which pedagogical approaches are you using in your STEM teaching and how much? [Answer per class]

	CLASS 2*	CLASS 3*	CLASS 4*
Traditional direct instruction (lessons are focused on the delivery of content by the teacher and the acquisition of content knowledge by the students).			
Teaching with experiments (experiments are used in the classroom to explain the subject matter).			
Project-/Problem-based approach (students are engaged in learning through the investigation of real-world challenges and problems).			

	CLASS 2*	CLASS 3*	CLASS 4*
Inquiry-Based Science Education (students design and conduct their own scientific investigations).			
Collaborative learning (students are involved in joint intellectual efforts with their peers or with their teachers and peers).			
Peer teaching (students are provided with opportunities to teach other students).			
Flipped classroom (students gain the first exposure to new material outside of class, and then use classroom time to discuss, challenge and apply ideas or knowledge).			
Personalised learning (teaching and learning are tailored to meet students' individual interests and aspirations as well as their learning needs).			
Integrated learning (learning brings together content and skills from more than one subject area).			
Differentiated instruction (classroom activities are designed to address a range of learning styles, abilities and readiness).			
Summative assessment (student learning is evaluated at the end of an instructional unit and compared against a benchmark or standard).			
Formative assessment, including self-assessment (student learning is constantly monitored and ongoing feedback is provided; students are provided with opportunities to reflect on their own learning).			

*Answer choices detailed in Q2.

26. To what extent do you use the following aspects of teaching and learning (with or without ICT) when teaching your classes? [Answer per class]

	CLASS 2*	CLASS 3*	CLASS 4*
I present and explain scientific ideas to the whole class			
Students work alone at their own pace			
Students work on exercises or tasks individually at the same time			
I demonstrate a scientific idea to the whole class			
Students conduct experiments			
Students discuss ideas with other students and the teacher			
Student make decisions about how they learn			
Students conduct their own scientific study and research activities			
Students work in groups, with well-defined tasks			
Students work collaboratively, working together to find solutions to problems			
Students reflect on their learning			
I support and explain things to individual students			

	CLASS 2*	CLASS 3*	CLASS 4*
I use different types of materials (visual, audio, written) in my classes			
I use content from different subjects to explain scientific concepts			
I invite other STEM teachers of different disciplines to coordinate our teaching of certain common topics			
I organise field trips/visits to museums/company visits to contextualise scientific concepts			
Students take tests and assessments			
I give feedback to my students during a learning activity			
Students participate in assessing their own work and the work of their peers			
Students give presentations to the whole class			
I integrate Arts into my STEM teaching to increase student engagement			

*Answer choices detailed in Q3.

27. Which learning resources / materials are you currently using when teaching each class? [Answer per class]

	CLASS 2*	CLASS 3*	CLASS 4*
Paper-based materials			
Audio/video materials			
Presentations (MS Power Point, Libre Office Impress, Sway…)			
Robots			
Sensors, data loggers			
Calculators			
Graphing calculators			
Manipulation in an experimental lab			
Web-based or computer-based simulations			
STEM-specific software (e.g. Geogebra, Function Plotter…)			
Data sets / Spreadsheets (MS Excel, Libre Office Calc,…)			
Word processors (e.g. MS Word, LibreOffice Write, OneNote, Notepad…)			
Online collaborative tools (Padlet, Mentimeter, Tricider, Kahoot…)			
Resources published by private companies operating in STEM fields			
Resources for special needs learners			
Resources for personalised learning			

*Answer choices detailed in Q4.

APPENDIX 3: Science, Technology, Engineering and Mathematics Education Policies in Europe – Executive Summary

Studies funded by the European Commission or conducted by Science, Technology, Engineering and Mathematics (STEM) communities such as the STEM Alliance have highlighted major issues regarding the situation of STEM in European education systems: the low attractiveness of STEM studies and careers, or the unmet labour-market needs in STEM-related sectors that are expected to grow in the future.

To address these problems, many initiatives and programmes have been pursued, such as "The New Skills Agenda" initiative from the European Commission to focus on improving the quality and relevance of STEM skills development, to promote STEM studies and careers and to support teachers' professional development. They are supplemented in some countries by national approaches to deal with STEM issues.

In this context, Texas Instruments and European Schoolnet, with the support of Scientix, joined forces to conduct a study on STEM education policies and STEM teachers' practices, with a focus on 14 European countries[18]. The study aims to nourish the European public debate on STEM education by providing information on STEM policies and STEM teachers' practices. The first part of the study, which consists of this report, highlights the main trends of public education policies carried out in Europe in favour of STEM and proposes general observations and synthetic recommendations. Industry and university stakeholders took part in the study by providing their insights. STEM representatives from 14 European Ministries of Education answered a comprehensive survey documenting their actions and ambitions for developing STEM education.

Through this study, the actors consulted for this work outlined potential solutions to STEM challenges:

1. Attracting more students and teachers to STEM education through a global approach from primary to adult education that will better anticipate the skills needed for the society of the future;
2. Breaking down the barriers between subjects with pragmatic initiatives (teacher training sessions, publishing contents, sharing best practices, etc.) to improve the quality of STEM education by building on each country's strengths;
3. Evaluating and integrating curriculum and pedagogical innovations: all energies must be oriented in the right direction with value added purpose-built technologies and services that need to be provided; positive experimentations need to be rolled out across the entire education system and disseminated among European countries (sharing of best practices, ideally in line with a common European framework);
4. Developing a common European framework of reference for STEM education and coordinating national STEM initiatives related to publishing pedagogical content to ensure teachers' needs are being met;
5. Fostering deeper collaboration with universities and industry to develop STEM teachers' skills.

These five points reveal a major strategic issue. While European countries participating in the study described their ambitions and actions regarding STEM education, it is difficult to observe at present the implementation of an integrated strategy involving all the domains and actors concerned on a national or European scale.

To cope with the fast pace of technological innovation, European education systems need a better vertical integration of their STEM policies with better relations between schools, universities and companies in STEM fields. They need a better horizontal integration too for developing a balanced approach between the different parts of the STEM block of subjects.

18 Austria, Belgium (Flanders), Denmark, France, Greece, Hungary, Italy, Lithuania, Malta, Portugal, Romania, Slovakia, Spain and Turkey.

SCIENTIX

The community for science education in Europe

This "Science, Technology, Engineering and Mathematics Education Practices report" is a Scientix Observatory publication from Scientix, the community for science education in Europe with the support of Texas Instruments. The present report is the second in a series of investigations into STEM education policies and practices in Europe. Its aim is to provide information on how educators throughout Europe are organising their STEM teaching. The first publication of the series – the STEM Education Policies report, published in October 2018 - highlighted the main trends of public education policies carried out in Europe in favour of STEM and proposed general observations and a set of recommendations for future actions.

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