The State of the Art
in Science Education:

Results of MA.R.CH. empirical studies

MAke science Real in sCHools (MA.R.CH.)

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PREFACE

The MAke science Real in sCHools (MARCH) network consists of 9 partners from 7 European countries and it brings together key players in the field of science education, science communication and relevant policies. The partners are uniquely placed in enhancing reflection and dissemination innovation in Science Education in secondary schools at a European level. The anticipated impact is an increased appreciation and application of the proposed methodologies amongst educators as well as an improved understanding of the career opportunities in science and research, leading to more young people choosing a career in science.

The network's objectives will be achieved through a highly innovative methodology including 'Innovation Swap Workshops' which will bring together teachers, pupils and scientists to focus on inquiry-based learning and interactive educational content that will make science teaching attractive to young people and present innovative international practices.

At the end of this 3-year project, the network aims to achieve the following:

- Improved perception of science in secondary schools
- Increased numbers of young people who chose a career in science
- Increased capacity/skills in teachers for engaging creatively with their students in scientific themes and for delivering inno vative methodologies in this field
- Improved policies for effective science education
- Establishment of sustainable links with key European players in Science Education.

As part of MARCH, an initial scoping exercise took place in 2014, consisting of a collection of best practices through desk research and interviews in partner countries, and through involving students in the procedure. Its objectives were to review the current state of Science Education across Europe and to map the state-of-the-art across Europe.

This work has been led by Forum Democrit and the author of the current report is Todor Galev, PhD, researcher at the Institute for the Study of Societies and Knowledge, Bulgarian Academy of Science. Contributions and revisions were made by Diana Popova, Forum Democrit, Bulgaria and Julia Karnahl, Jungvornweg, Germany.

The scoping analysis is based on both qualitative and quantitative research, including desk research on existing policies, practices and methodologies, in-depth interviews with relevant stakeholders (government officials, experts and practitioners from public, private and not-for-profit organisations, supporting science education in the schools), and online surveys among teachers and students from the seven participating countries.

Given the number of interviews conducted and the number of responses to the questionnaire, the results in this report do not necessarily provide an exact and complete picture of science education in each of the countries involved in the scoping study but it presents trends and highlights issues and challenges in the area of Science Education.

The results presented here will be tested and enhanced in the next stage of the MARCH project through the workshops that will be taking place in the seven countries involved in the project, and more significantly in the 'Innovation Swap Workshops' that will take place in three of those countries, all during 2015.

We hope the data collected here will be of use to the reader and that these results, together with the debates and ensuing conclusions coming out of the workshops, will in the end lead to a series of recommendations to policy makers that will result in changes and improvements in methodologies in Science Education and hence contribute to making science more attractive in schools.

Anastasia Andritsou
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INTRODUCTION

The current report presents the main findings from the initial scoping analysis, designed to fulfil two tasks through desk research, in-depth interviews with various stakeholders (government officials, consultants, education advisors, scientists, academics, scientific associations) and online surveys among students and teachers. The first task was to collect best practices from the seven participating countries with a focus on science teaching methodologies and every-day practices in secondary schools. The second task was to map the state-of-art of students' and teachers' perceptions and opinions of science teaching in the selected countries. The outcomes of this scoping analysis will ensure inputs for the planned project workshops, which aim to test and enhance the current science education methodologies and practices in the participating countries.

DESCRIPTION OF THE STUDY

The scoping analysis is based on both qualitative and quantitative research, including desk research on existing policies, practices and methodologies, in-depth interviews with relevant stakeholders (government officials, experts and practitioners from public, private and not-for-profit organisations that support science education in the schools), and online surveys among teachers and students from the seven participating countries. The fieldwork was conducted in the period May – October 2014 and the results are presented in the table below.

Table 1. MARCH Studies

	ONLINE SURVEYS		IN-DEPTH INTERVIEWS
	TEACHERS (Nº of responses)	STUDENTS (Nº of responses)	
Bulgaria	47	236	5
Germany	186	263	6
United Kingdom	46	173	3
Greece	36	114	4
Lithuania	37	188	3
Portugal	22	359	5
Serbia	15	94	4
TOTAL	**389**	**1427**	**30**

Source: MARCH project

In order to conduct statistical analyses of the data, two different approaches were implemented due to the differences between the planned and actual number of responses within the two groups – teachers and students.[1] Teachers' results were weighted statistically to allow inter-group analysis only, while the students' results were weighted against the total number of students in each country in order to allow both inter-group analysis and cross-country comparisons.

[1] Both surveys were designed not to be representative for the respective populations in the given country but rather to ensure the collection of information that can be used to grasp the existing trends, and to allow for collection of information about the science teaching methodologies and practices in secondary schools.

STUDENTS' AND TEACHERS' OPINIONS ON SCIENCE EDUCATION

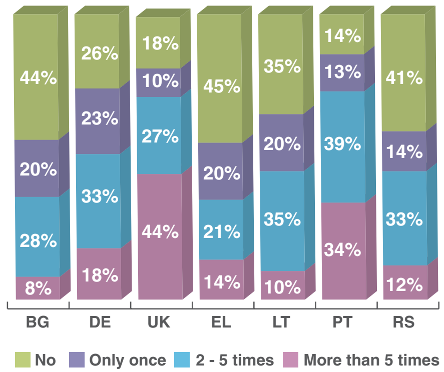
The distribution of students in the sample varies across the countries, fields of education, location of the school, age and sex as the survey has not been designed to be representative. (See Appendix 1, Figure 1. to Figure 3.) In most of the countries the schools from all types of locations are represented, except for Serbia where schools from rural areas are missing from the surveys of students. Similarly, in five of the countries, students from general schools dominate the sample, which mirrors the practical situation in these countries, while in Portugal and Serbia the students from schools that specialised in mathematics are overrepresented. However, neither the demographic characteristics of the students, nor the features of the schools allow for accurate extrapolation of survey results to the general population of students in each of the respective countries. The survey targeted at teachers was designed to be supportive of the results of the student' group and, due to the small number of planned responses, its results are analysed as responses of a single group without cross-country comparisons. The demography of the teachers and their schools mirrored the picture from the student survey with general schools dominating the group and the majority of them being located mainly in urban territories. (See Appendix 1, Figure 13 and Figure 14).

LEARNING STEM AT SCHOOL: FROM THEORY TO PRACTICE

STEM classes have been always an area where the theoretical and the practical side of the teaching have been heavily debated, as the practise is seen both as a way to better understand theoretical knowledge and as a means for increasing the interest of students in complex and hard-to-learn subjects. Since the late 1950s these challenges have been tackled through national policies for introducing specially-equipped laboratories in all schools across Europe. Despite the advances in science and technologies STEM teaching remains almost unchanged. The MARCH survey shows that in most of the countries the stages in STEM teaching follow the same sequence, starting with merely theoretical tasks and finishing with much more practical and, in many cases hands-on-science activities. In all of the studied countries, the proportion of students familiar with the theoretical stages is higher than the proportion of students in each country, engaged with the practical side of science. Initially, students are assigned with tasks that encourage review of material not included in their textbooks, in order to be prepared for a particular STEM topic. The next step requires students to elaborate and present a STEM topic to their classmates, encouraging the students to find ways of representing mostly theoretical knowledge in an engaging style. The final step is to assign students with tasks that require practical skills to be acquired and mastered and applied together with theoretical knowledge for solving real-life-problems in controlled experimental situation.

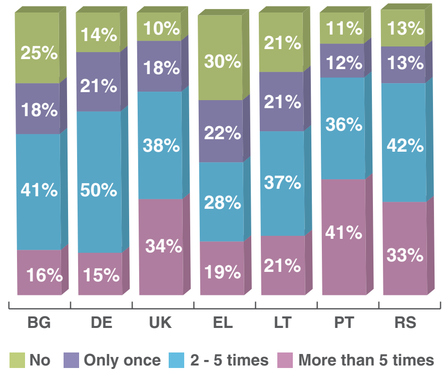
All of our surveyed countries, excepting Portugal and the United Kingdom, have a significantly larger proportion of surveyed students that have experience in presenting STEM topics without having any experience in hands-on-science activities compared with the share of students who had prepared their own scientific experiment and presented the results to their classmates.

Students experience in preparing a scientific experiment and presenting it to the class (%)



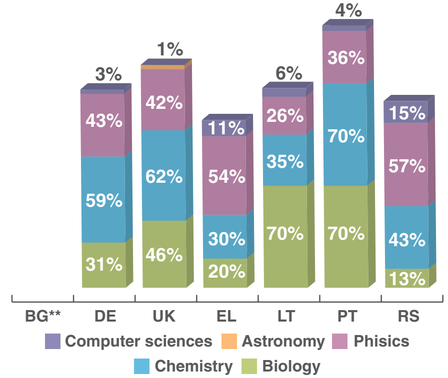
The biggest differences are observed in Greece, Bulgaria and Serbia, where the proportion of students that have never conducted a practical experiment during their whole stay in secondary school are largest. **The two exceptions, Portugal and the UK, demonstrate a quite different situation;** these are the countries with the smallest share of students that had never conducted a practical experiment (respectively 14% and 18%) and both countries are leaders in terms of frequency of experiments conducted by the students.

Students experience in preparing presentation on STEM and presenting it to the class (%)



Biology, chemistry and physics are the most popular fields for carrying out scientific experiments in the secondary schools in all the countries[2]. Even in the two countries, where mathematics dominates the main field of education of the surveyed students (Portugal and Serbia), the picture remains the same. On one hand, the results could be explained with the decade-long traditions in teaching these particular sciences in equipped school labs and/or using specifically designed experimental kits. On the other hand,

Scientific field of the last experiment run by the student (%)*



*Base: 994 cases (multiple choice question)
** Data not available

the relative lack of practical experience for students in the fields of computer sciences and astronomy demonstrate that ICT is still not successfully represented in STEM education. However, even amongst the most popular subjects, there are significant differences among the countries with biology and/or chemistry experiments being the most frequent choice in Portugal, Lithuania, the UK and Germany, while physics leads in Greece and Serbia.

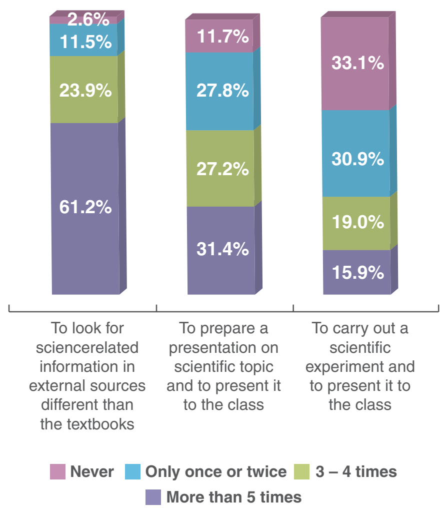
Partially, the lack of hands-on-science activities in the surveyed secondary schools is rooted in the curricula and existing teaching practices. According to the surveyed teachers, they tend to assign to their students mainly tasks related with the theoreti-

[2] Data for Bulgaria are not available.

cal side of the study.[3] Regardless of the non-comparable samples of teachers and students across the selected countries, the opinions of the both groups clearly show that teachers are more self-critical about their responsibilities in assigning practical tasks to the students, while the students think they need to do only what teachers asked them for. This shows that the majority of students are inclined mainly to deal with science-related topics, including practical tasks, only when they are required to do so by their teachers and not voluntarily.

However, the survey results demonstrate that science-related activities are attractive for more students when they are related to out-of-the-school activities, based on either entertainment or personal achievements. Almost half of the surveyed students (46%) have participated at least once in a national or international science Olympiads, contests or fairs. The leaders are Portugal (62%) and Bulgaria (59%), while the lowest shares are observed in Lithuania (32%) and the UK (37%). Serbia and Bulgaria are leading in terms of frequency of participation and, in both countries, the share of students who had more than five participations in such events are at least twice higher than in the other countries.

Teachers: frequency of assigning STEM related tasks to students during the last school-year (%)



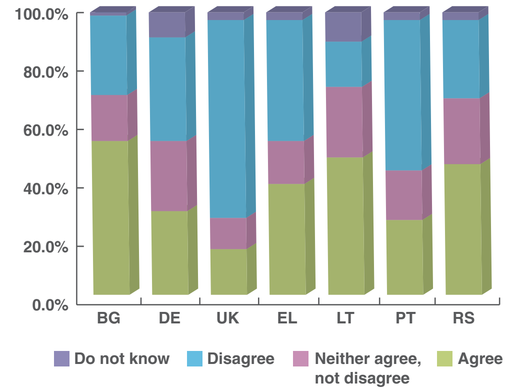
The survey results suggest two things: one, science is still not attractive enough for the majority of students and more and various external incentives for STEM enrichment need to be included in the curricula in order to get students closer to science topics; two, both incentives and training are needed for the teachers to facilitate the required shift of the teaching process towards larger involvement of STEM-related practical activities.[4]

[3] Results, based on the MARCH survey among teachers.
[4] The conclusion is based on both teachers' survey results and in-depth interviews with various stakeholders, supporting the science education in the secondary schools.

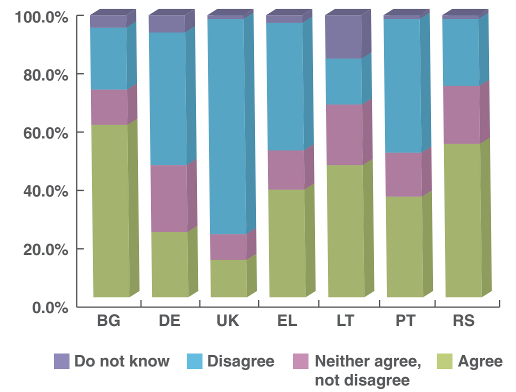
The policies and programs supporting STEM teaching in the secondary schools are developed mainly on a national level, but in single cases, the regional governments (e.g. of the federal states in Germany) are responsible for the school policies, including STEM teaching. Even in this case, there are nation-wide programs to support STEM that create incentives for reaching specific goals.[5] However, in most of the studied countries, the interviewed experts point out the differences regarding the curricula and the availability of resources for STEM teaching across the regions in terms of administrative and socio-economic divisions. Even in the UK and Germany, which are among the leaders regarding STEM teaching, the experts call for elaboration of unified educational standards (e.g. regardless of the type of the school – general or specialized one, or whether the school is located in rural or urban area or the school is small or large one). Beyond the formal education system, in all of the countries already exist a great variety of initiatives, led by various stakeholders that support STEM teaching, offering opportunities for both the students and the teachers.

The need for change in the curricula and the teachers' experience and capabilities is closely related in most of the countries to the need for improvement of the schools' resource base (equipped labs, experimental kits, better

There are not enough scientific laboratories in my school (%)



There is not enough laboratory equipment for demonstrations and experiments in my school (%)



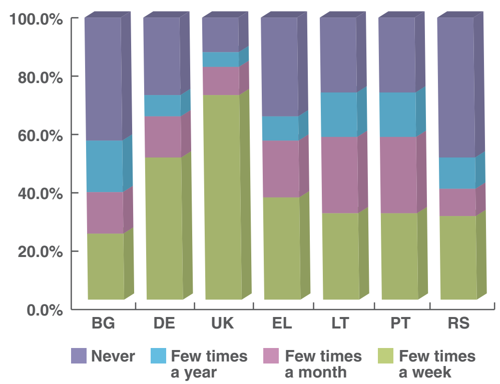
[5] E.g. "Go MINT" – The National Pact for Women in STEM Careers in Germany, which is promoted on national level, although the federal states are responsible for the secondary school policies in general.

utilisation of existing and introduction of new ICT, and even new techniques and methods of STEM teaching). The students' assessments of the availability of STEM equipment differ significantly among the countries, with the UK and Germany leading in the availability of scientific laboratories and related equipment, followed by Portugal. The countries with least access to equipment and resources are Bulgaria, Serbia, Lithuania and, to a lesser extent, Greece. In all the countries, including the leading ones, there is a strong correlation between the availability of scientific laboratories and laboratory equipment. This suggests that where laboratories exist they are sufficiently equipped. Further, it might be that a primary goal for improving the situation in certain countries is a policy for setting up new scientific laboratories in the secondary schools.

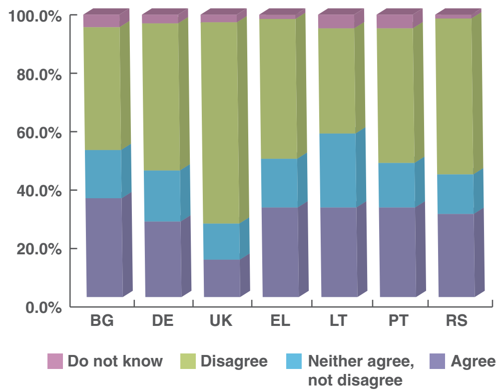
Conversely, the students' assessment of the availability of computer equipment in their schools does not differ among the countries with a single exception. Generally, one of every four students only assesses the availability of ICT equipment as insufficient but in the UK,only 14% think there is a shortage.

Regardless of the generally positive students' opinions about the availability of computer equipment in the schools in all countries, the students' assessment of the frequency of use of ICT by teachers for their science classes does differ significantly among the countries. (see Appendix 1, Figure 4 and Figure 5). The UK and Germany, followed by Portugal, are leading in both the frequency of use and the diversity of technologies (PC and/or notebook, projectors, smart board). However, **some countries have been catching up with the leaders.** Serbia has the same level of using PC / notebook as Portugal, while Lithuania and Greece lag behind UK and Germany with about 20 percentage points. In using projectors, Serbia and Lithuania are only 10 percentage points behind UK and Germany. Portugal sees most use (81%) of presentation technologies a few times a week, ahead of Germany (55%) and the UK (78%[6]). Smart boards are the least widespread technologies in the schools, except for the UK and Germany, and their frequency of use is significantly lower in the other countries than the rest of ICT. Among the surveyed seven countries, **Bulgaria has the lowest levels of both use and frequency of use of all the technologies** and only Serbia falls behind it regarding the use of one of the technologies, namely the smart boards.

Teachers use smart board in their science classes (%)



There is a shortage of computer equipment in my school (%)



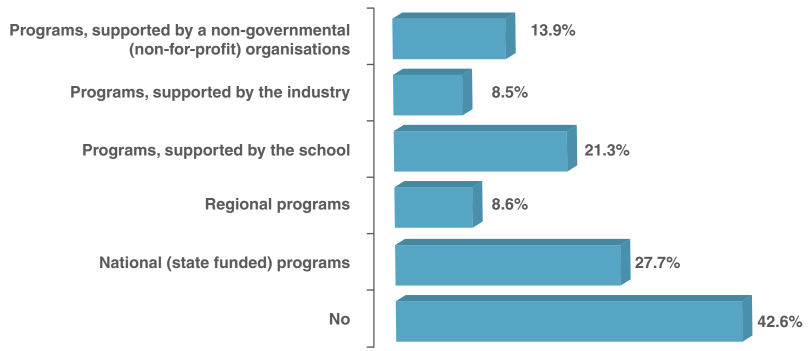
Despite the relatively high levels of use of ICT in all the countries, both the survey and qualitative data analyses show that ICT resources are still predominantly used in a traditional way – as a pure presentation technology or as a tool for searching for and organising the required information. The in-depth interviews confirmed this is particularly true for Serbia and Bulgaria but it is valid for other countries too. **The potential of ICT for online training, simulation of scientific phenomena, and for innovative methodologies involving students in practical scientific experiments through ICT,[7] is not being fully realized.** Partially, the problem is rooted in the **lack of information** about existing possibilities among the local teachers, especially in smaller secondary schools, and in the **lack of localized (translated in local languages) repositories** with ICT-enabled simulations, video clips, methodologies and practical guides. The other part of the

[6] The difference between Portugal and the UK is within the range of the statistical error.
[7] E.g. the so called Eratosthenes Project, firstly launched in 1997 but after that the project gained popularity across the globe and thousands of students from hundreds of schools join it every year. The project enables students to measure the radius of Earth, using both online and offline tools in taking data on the shadow of the Sun as it passes the local meridian and then collaborate one with another through a special web-sites. The project basically use the same way that Eratosthenes measured Earth's circumference over 2000 years ago. More information could be found at the initially original web-site of the project - http://www.eaae-astronomy.org/eratosthenes/. See also http://ciese.org/curriculum/noonday/, http://eratosthenes.ea.gr/, http://www.eratosthenes.eu/spip/, https://www.khanacademy.org/partner-content/big-history-project/solar-system-and-earth/knowing-solar-system-earth/a/eratosthenes-of-cyrene

problem is the **need for regular training of science teachers** in hands-on approaches. As the interviews show, except in the UK and (partially) in Germany and Portugal, such trainings exist only on a project-based principle and, in most of the cases, it is not provided as nation-wide programs, initiated by the respective state authorities.

Teachers' survey results also strengthen the above conclusions, as the majority of the teachers have never used any additional intra-school or external funding for improving their STEM teaching, including their own training and continuing professional development (CPD). The interviewed experts assess critically the existing government funding programs even in some of the leading countries, e.g. Germany, as not being effective enough regarding the specific needs of the beneficiaries mainly due to bureaucratic and administrative burdens.

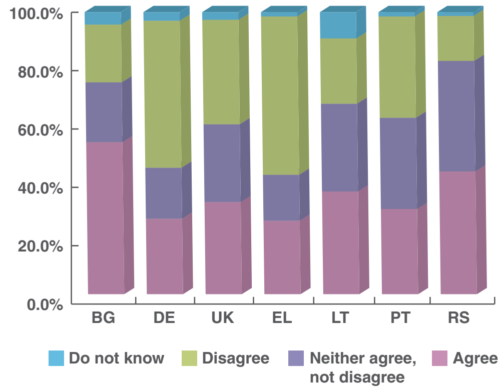
Teachers` usage of financial support for their STEM teaching (%)*



* Base: 840 responses (multiple choice question)

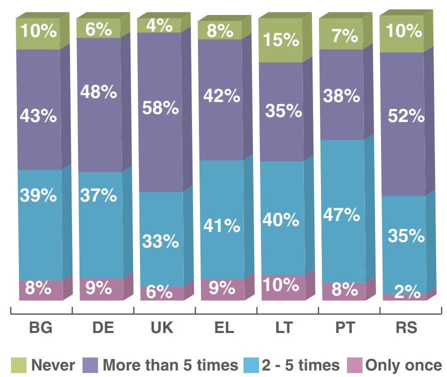
In general more than 1/3 of all surveyed students (37%) assess their science classes as predominantly theoretical and not helping them to gain necessary experience for solving practical problems in their life. The countries in which higher proportions of students describe their STEM lessons as overly theoretical are Bulgaria (55%) and Serbia (44%), which appears logical in the wider context of their survey results, but also Germany (41%) which is quite surprisingly as both the survey and qualitative data analyses portray it as one of the leaders in STEM education. Another surprising result is the lower share for Greece (28%)[8] as compared to the UK. The former is in fact, the country with the most clear-cut opinions of its students about the balance between theory and practice in their science education, irrespective of its overall survey results that rank it well beyond the leaders. The current study results do not allow an immediate explanation and call for future analysis of this contradiction.

Our STEM lessons are too theoretical and do not help to solve practical problems in my life (%)



Another aspect of the students' acquisition of practical experience in STEM is their ability to work with science related information from external sources, other than their textbooks. There are not significant differences among the countries with regard to the students experience in conducting such tasks assigned by their teachers in the last 12 months and the majority of the surveyed students (above 75%) declare as having done it regularly during this period. Having in mind the high degree of penetration of modern internet-based technologies and services in our society, it is not surprising that the online sources are preferred by students, irrespective of the country. Among them, Wikipedia is still the ultimate information source, used by 59% of the students. A significantly smaller proportion of students have used specialised web-pages, offering scientific information or learning materials (41%). The least used option is to look for help from family members

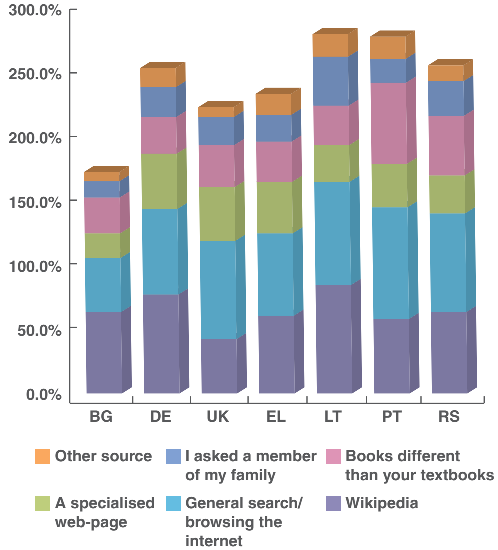
Students experience in tasks requiring to look for science-related information in external sources (%)



[8] The difference with the share in the UK (34%) is statistically significant

apart from in Lithuania where a significantly higher share of students, rely on support from their family (39%), as compared with the average of 23% for all the surveyed countries. The combination of internet as the most preferred information source and the rare use of specialised science-learning webpages clearly demonstrate that there is a room for development of STEM related e-learning resources, designed for both students and their teachers.

External information sources for STEM used by students (%)*



* Base: 1420 respondents; Multiple choice question; Percentages based on respondents

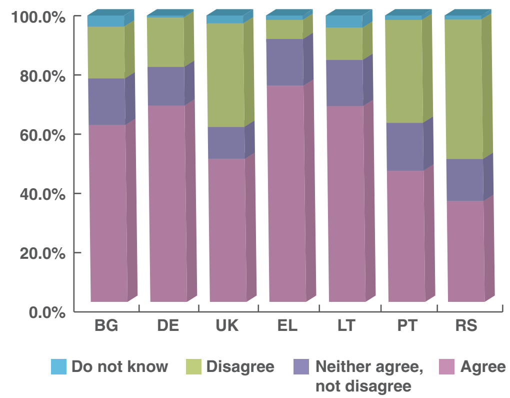
However, the qualitative data analysis reveals that the existing resources of this type appear to suffer from two main deficiencies. On one hand, they exist mainly in English language, while the availability of translated and/or specially localized[9] e-learning resources in local languages, especially for Bulgaria and Serbia, is highly limited. On the other hand, the use of e-learning resources is not a clear focus of many of the official curricula in the majority of the studied countries and in most of the cases, these types of resources are developed and promoted mainly ad-hoc (project-based) by various stakeholders that support/enrich science teaching but not by official state authorities.

An important issue for all countries, partially excepting Portugal and Serbia, is the lack of incentives in the official curricula and in the requirements, set up by the STEM teachers, for facilitating the interest of students in offline pure scientific publications. A concern, expressed by many of the stakeholders, is the need for particular attention in training students how to recognise "the real science" from the para-science, especially in the online environment. The library as a symbol of the learning process, regardless of the penetration of ICT into it, is still seen as an environment which has both educational and socialization functions, which are missing in the online world.

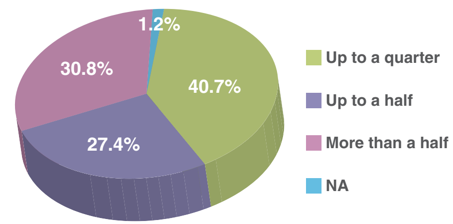
[9] The process of localization include not only pure language translation but in many cases it requires use of different examples, students are familiar with depending on their national, educational, cultural, etc. background, changes in the methodologies to fit better to specific every-day situations in the given country, etc.

Regardless of the considerably low share of students that have asked family members for information in order to fulfil their STEM tasks, more than half of the students (59%) are confident that their families could help them with explaining science-related issues, if they need it. The countries with significantly lower shares of students, relying on their families are Serbia (35%) and Portugal (46%), while the highest share is observed in Greece (75%). In addition, the analysis of qualitative data confirms that there are only a few good practices aiming at involving family members in science promoting activities together with their kids. The public policies need special focus in this regard, as they should offer incentives for both the kids and their families to deal with science. At the same time, the parents could initiate and develop respective activities, as their voluntary associations often play crucial role for the organisation of students' activities, additional to the official curricula.

If I need help with my STEM homework, I am able to get help from my family (%)



Teachers: part of information presented to students, based on additional sources and not the textbooks (%)



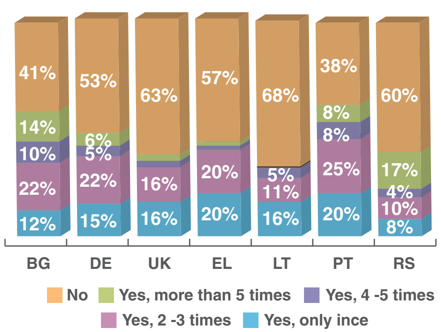
A positive feature of STEM teaching practices is the much broader use by the teachers of external sources for the preparation of their lessons. However, as both the survey results and the qualitative studies show, the sources and methods of teachers in looking for and using external information differ significantly; the majority rely mainly on “pure science” embodied in scientific literature for the preparation their own classes. A possible critique here is the minor use by teachers of recently available interactive and online based resources, mainly due to lack of information and skills among them.

Some characteristics of the education process contribute to the merely theoretical approach towards science in the schools. On one hand, due to the mass-nature of the secondary education, the evaluation of students is based mainly on written tests, which gives priority to theoretical knowledge. On the other hand, the curricula topics that are deemed necessary leave only limited opportunities for extra enrichment activities, both for the students and their teachers. The latter issue is clearly visible in some of the studied countries (Bulgaria and Greece). Suggested ways of addressing this include sharing of most promising practice amongst teachers, teachers’ evaluation to take account of STEM related extra-curricula activities, the number and type of the organized out-of-school activities could be increased and the, institutionalization of links between industry and secondary schools.

STEM STUDY - IN AND FOR SOCIETY

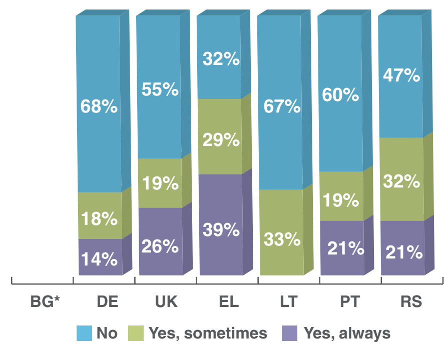
An important part of facilitating students’ STEM engagement is related to practices implemented outside the school – such as participating in science Olympiads or science fairs and contests, visiting a science museum or science centre, etc. Such practices could have high impact on the students and frame their attitudes and opinions as they offer them personalized practical experience and valuable social models to follow.

Participation in(inter)national science Olympiads contest or fairs (%)



The participation of students in national and international science Olympiads, contests or fairs provide a possibility to gain recognition in a broader social environment. Almost half of the surveyed students (46%) have been participated at least once in such a science-related event. Leaders are Portugal (62%) and Bulgaria (59%), while the lowest shares are observed in Lithuania (32%) and the UK (37%). Serbia, where a similarly low share of students had such an experience, is leading in terms of frequency of participation, followed by Bulgaria. In both countries, the shares of students who had more than five participations in such events are at least two times higher than in the other countries. The results are strengthened by the qualitative study, clearly demonstrating that even countries that lag behind others, in terms of factors that determine the state-of-the-art of science education, could still be considered as having an advantage in appreciating the wider applicability of theoretical knowledge. In both Serbia and Bulgaria, the results are due to the strong historically path-dependant tradition in STEM education, regardless of the shortcomings of the current situation. The engagement of school teachers in preparing their students for extracurricular science activities is of a great importance, notably for the international Olympiads and contests which require both self-motivation from students and additional long-term teaching practice. In some of the countries, the mentoring is more widespread than in others. The country with the highest share of students that have been mentored towards achievement in extra-curricular science activities is Greece, followed by the UK, and in last place is Lithuania.[10] The analysis of qualitative data shows that the role of stakeholders who are not part of the formal education system is also important, especially in countries such as Bulgaria, Greece, and Serbia, where they are responsible for fundraising and logistic support for both the students and their mentors. This

Students having mentors when prepared for science Olympiads, contests or fairs (%)



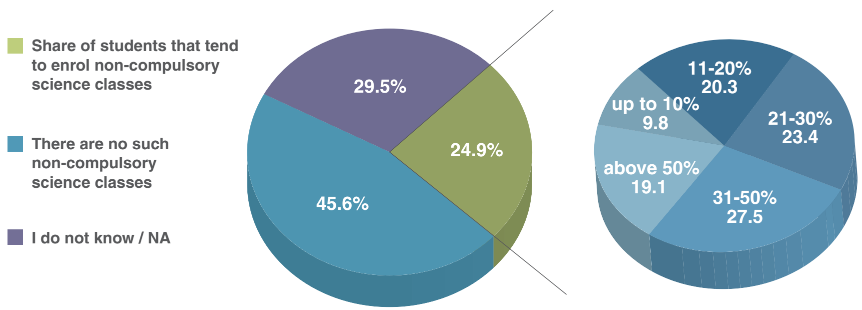
is particularly the case for international Olympiads. In these countries, the existing public

[10] Data for Bulgaria is not available.

policies and their financial instruments do not guarantee the required institutional support as is the case in the UK and Germany.

The involvement of teachers in offering more and diverse science and technology-related teaching is crucial, particularly when it is done as part of the school curricula, but the commitment of students to the opportunities they have been offered is also an important element for successful STEM education. Teachers tend to be critical especially in terms of students willingness to participate in non-compulsory science-related classes. Only a quarter of the schools offer such classes but, even when they are available, more than half of the teachers (54%) assess that less than one third of their students have enrolled in them. Only one of every five teachers (19%) have the chance to see the majority of the students (over 50% of them) to be enrolled to the non-compulsory science classes.

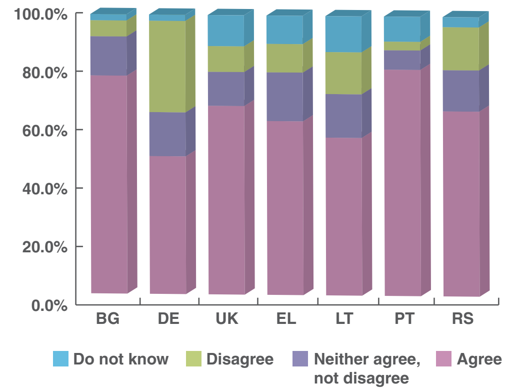
Teachers: shares of students that tend to enroll non-compulsory science classes (%)



SCIENCE SEEN AS A PATHWAY TO THE STUDENTS' CAREER

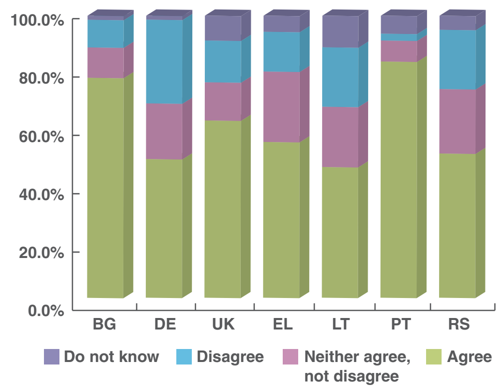
There are no significant variations in the opinions of students within any surveyed country regarding the importance of good science knowledge as a requirement for their higher education or career choice. If science could be of great importance for entering the university, in many of the cases, it has not the same value for getting the desired job.

I need to do well in science to get into the university of my choice (%)



There are indications that the students have at least partially speculative views on the value of science in the "real-world". These results suggest a need for specifically designed features of secondary school STEM education in order to facilitate better knowledge of the links between science and every-day life and careers.

I need to do well in science to get the job I want (%)



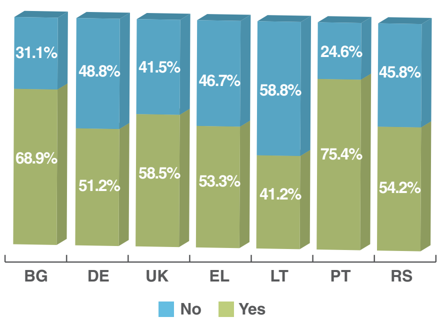
The students' views, mentioned above, could be an indication of wider public opinions of the value of STEM education and the image of science and scientists in society in general. Especially in Bulgaria and Serbia, those without a declared interest in science could consider STEM as an unimportant part of general education, due to the lower social status of scientists and science in general as compared to other spheres of the society.

The positive attitudes toward science among the majority of students in all surveyed countries are clearly visible in the expressed willingness for more STEM classes in the school, regardless of the main field of education and the school type. These attitudes suggest that the introduction of more science related topics would be welcomed by students if they are offered in an accessible and engaging way.

People outside of the formal education system, but engaged with education policy and related activities, recognise STEM teaching as a driver of innovation and professional career development, particularly in fields with a shortage of a highly qualified labour force such as engineering and IT. A common deficit, mentioned by several stakeholders from different countries, is the poor media and public representation of problems and needs regarding secondary schools STEM education. Another bottleneck, highlighted by many of the stakeholders, is the low level of willingness and practical engagement of businesses towards STEM education, especially in secondary schools. According to the stakeholders, the business enterprises in all of the countries prefer to be engaged with the universities.

The stakeholders' evaluation of the general public attitudes toward science is quite different. According to them, the majority

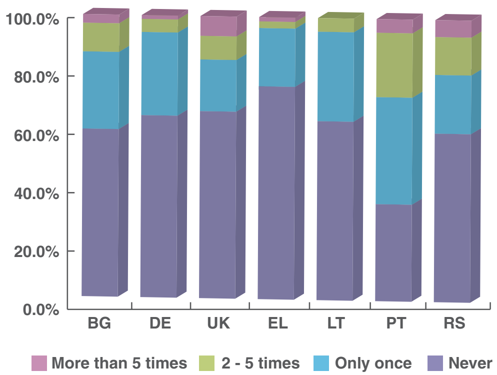
Would you like to take more science and technology related classes in school? (%)



of the people consider science an issue just for scientists, not accessible to the ordinary people. At the same time, the social and economic status of science and the scientists are considered as not being higher enough to be attractive as compared to many other social spheres. "Parents believe that enrolling their son a local football club might be a better bet. Who knows if they can't become another Ronaldo…" (an interview with coordinator of a science centre in Portugal).

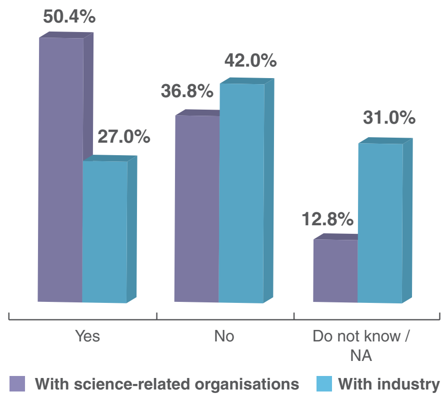
One of the important sources of both practice-based experience and theoretical knowledge is the personal encounter with science

Visiting a scientific organisation (%)



and technology in-the-making, which could include a visit to a science museum, science centre or scientific organisation, participation in science-related or science-promoting events or in specialised science-based training. The results of our survey suggest two main trends. (See Appendix 1, Figures 6 to Figure 12) Generally, a bigger proportion of students in every surveyed country has "passive" experiences through visits to the institutions, rather than personal participation in science-related events or training. Additionally, larger shares of students in every country surveyed have more experience with traditionally established approaches and

Teachers: schools` partnership with S&T (%)



institutions than with the newly emerging ones (e.g. museums vs science centres). In terms of visits to all type of science-related institutions, Portugal has notably better achievements than the others, particularly regarding the share of students who had visited a scientific organisation (65%), while countries that followed have lower results by more than 20 percentage points (41% for both Bulgaria and Serbia). Both of the above trends suggest a need for specific changes in public policies in terms of increased support for newly emerged practices and activities that relate to hands-on science experiences for students outside the school but as part of the official education curricula. The involvement of various stakeholders in the design and implementation of such policies is another strong advantage that could be turn into benefits for all the involved actors.

The teachers' survey results suggest that the schools' institutional partnerships remain in the field of science (public funded scientific organisations) but neglect industry. The qualitative study adds another critique to this picture; various stakeholders assess the existing cooperation between schools and science organisations as being predominantly weak, passive and formal in some of the countries (Lithuania, Serbia, Bulgaria, Greece).

In general, there is a need for revision of the main goals of science education in secondary schools, including revision of the curricula, in order to adopt science learning practices to the recent advances of science and technology, thus respecting the nature of science as part of everyday live. In this respect, the improvement of equipment available in schools is important but more crucial is the training of teachers and the broader involvement of scientists and engineers in the regular learning process.

CONCLUSIONS

Both our survey and qualitative analysis revealed that secondary education in the studied countries suffers from a few important deficiencies that pose serious challenges to public policies in short and medium term.

- Science education in secondary schools is related still more closely to education- and science-based organisations than to industry, including those countries with decades-long tradition of science and technology education;

- Science education in all the surveyed countries is still much more theoretically-based than focused on "hands-on" interactive practices.

- Even in leading countries, the respective policies are assessed by both the experts and teachers as having not provided the expected results. In other words, the policies are seen as being not sufficiently effective and the level of improvements is assessed as not what the stakeholders were expecting from.

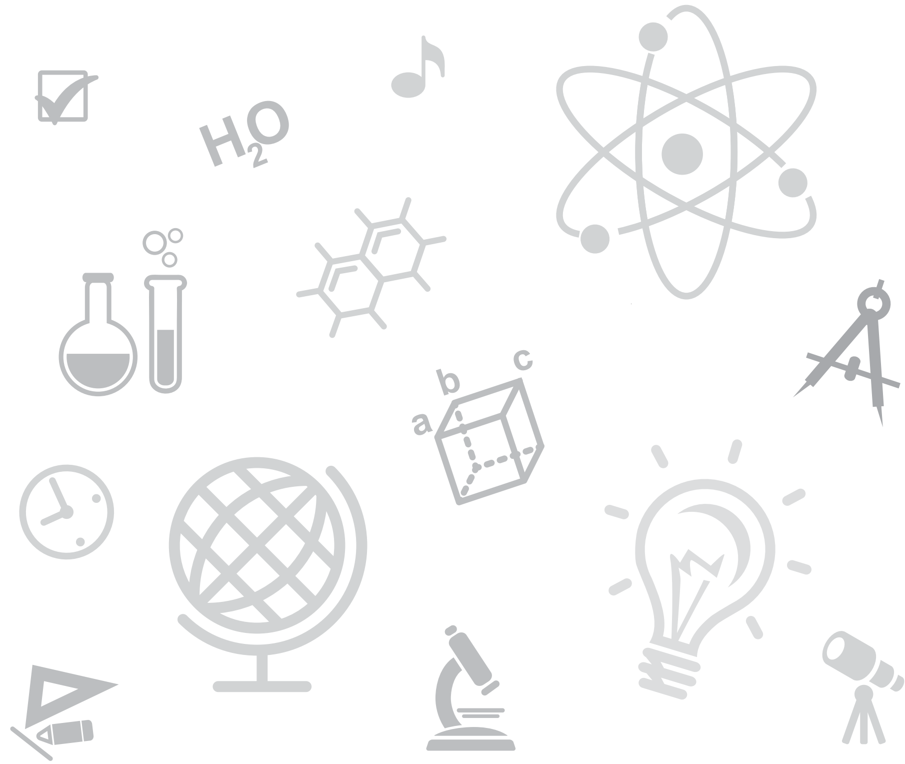
- Usually STEM education and all related activities are seen as the responsibility either of the official curricula, or of the students themselves. There are only small-scale good practices of STEM activities that could be defined as family learning. Public policies and public funded programs need special focus on creating incentives for common STEM related activities, for family members, students and their teachers;

- Particular attention is required in training students how to recognise accurate information, especially in the online environment, which is the primary source for the majority of students when they need science-related information.;

- The use of advanced and innovative methodologies (such as interactive, hands-on experiences and online resources) for attracting students to STEM is still limited in all the studied countries but most promising practice is observed in the UK, Germany and Portugal;

The use of specialised science-related online resources is limited mainly due to language barriers and sufficient teachers' training. The same applies to the possibilities offered by current ICT for simulation or practical implementation of scientific experiments;

- Even countries with relatively low achievements in secondary STEM education lead in specific, but important, characteristics. The participation and results of Bulgarian and Serbian students in international and national Olympiads are good examples;



APPENDIX 1
STUDENTS' SURVEY RESULTS

Figure 1

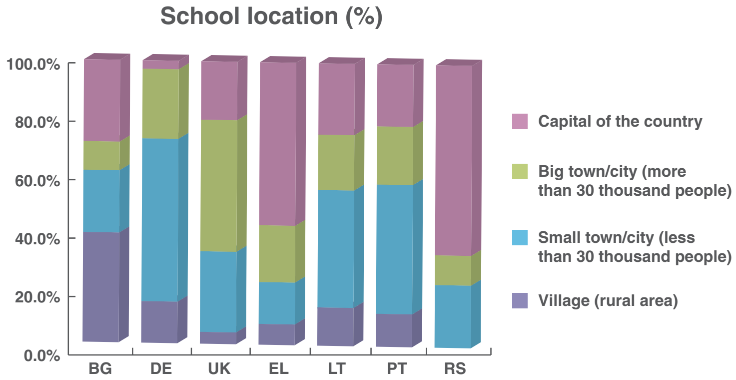


Figure 2

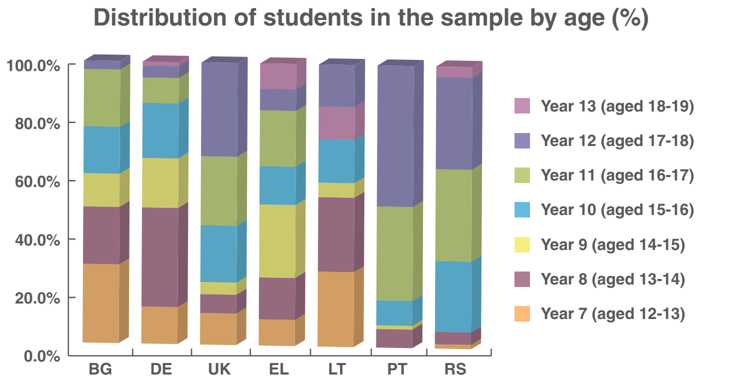


Figure 3

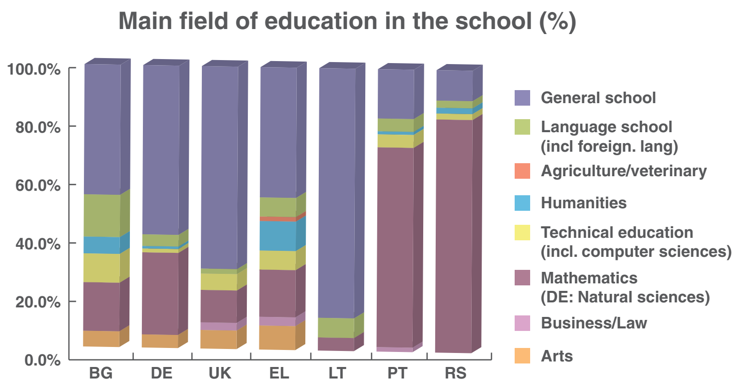


Figure 4

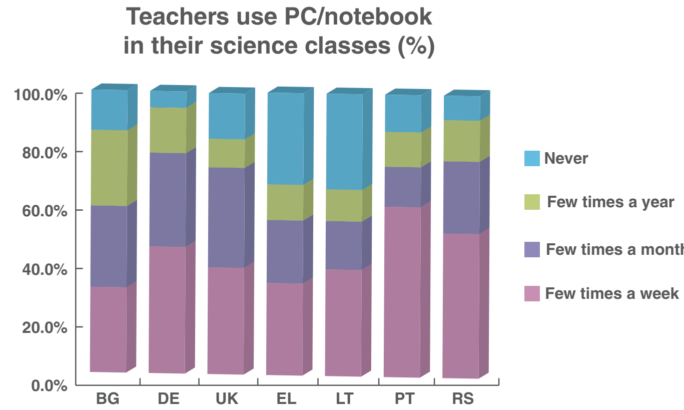


Figure 5

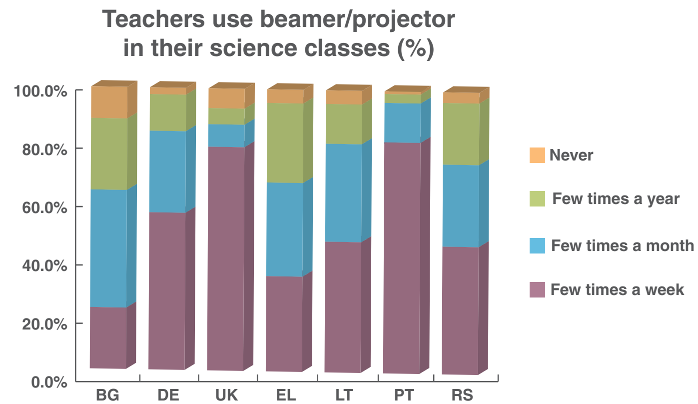
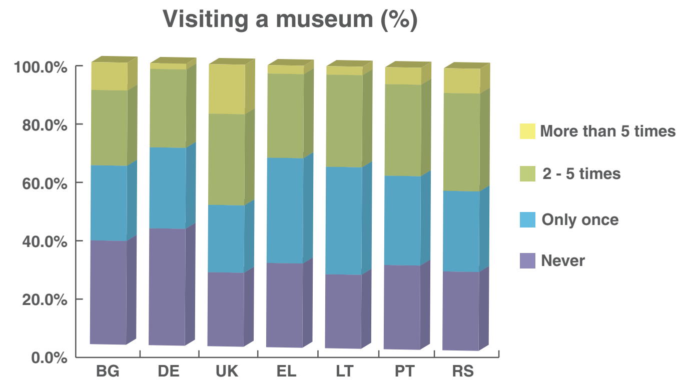


Figure 6



STUDENTS' SURVEY RESULTS

Figure 7

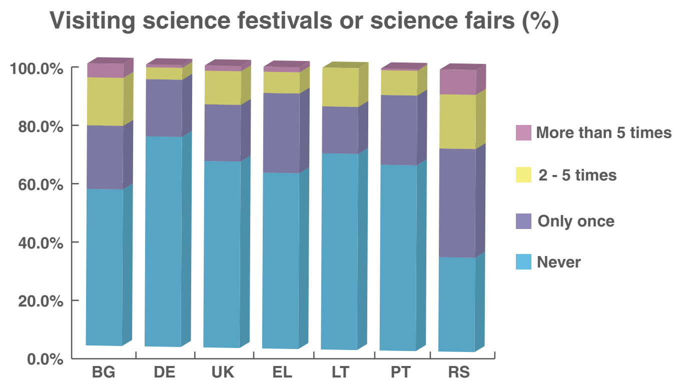


Figure 8

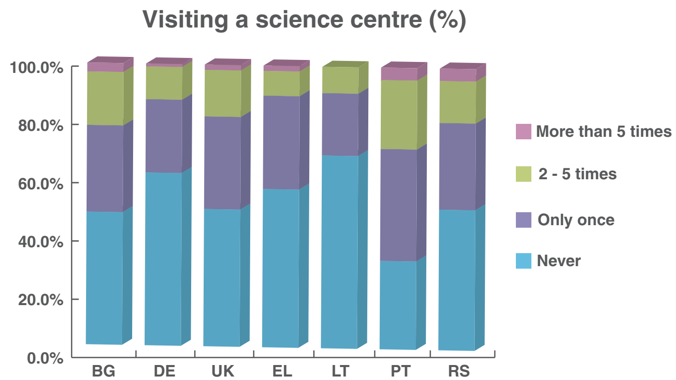


Figure 9

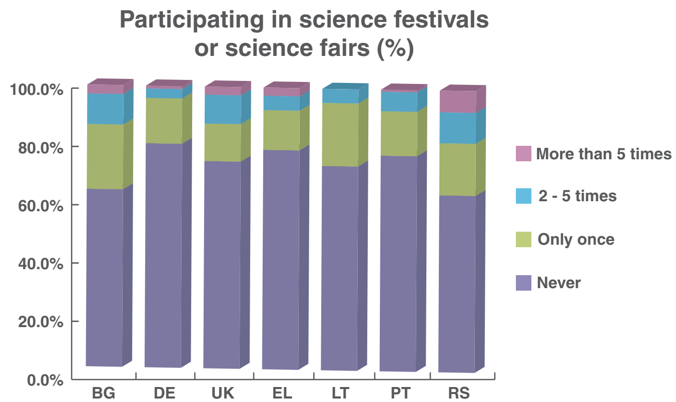


Figure 10

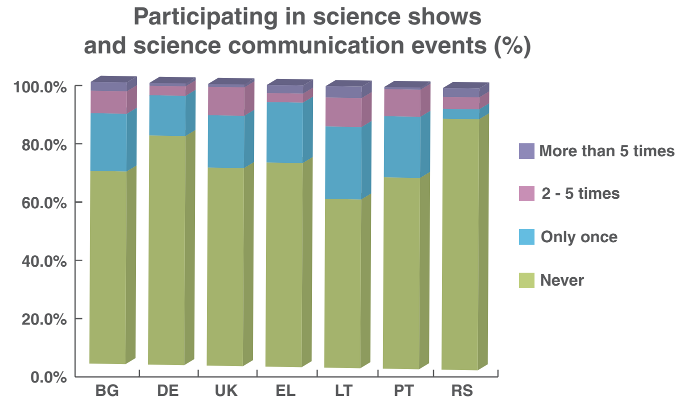


Figure 11

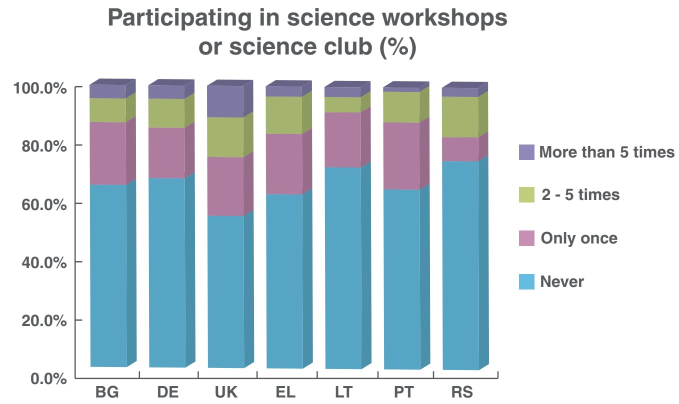
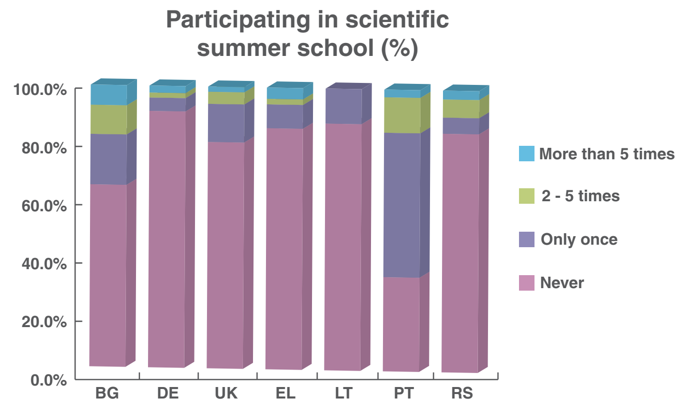


Figure 12



TEACHERS' SURVEY RESULTS

Figure 13

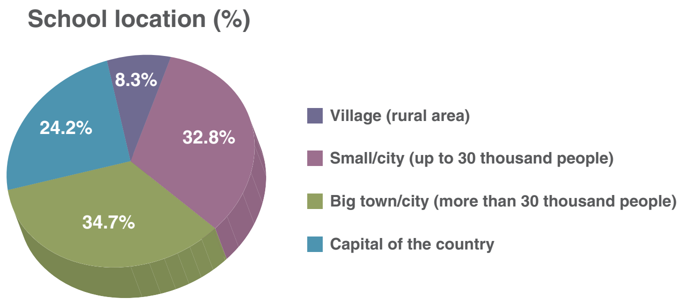


Figure 14

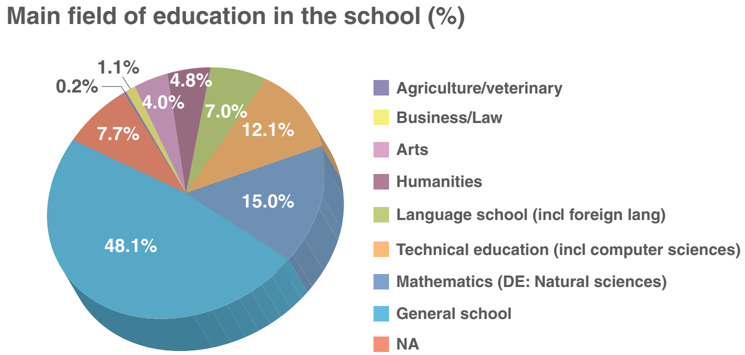


Figure 15

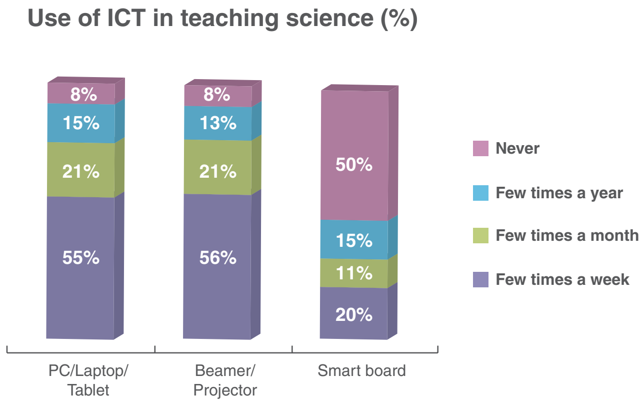


Figure 16

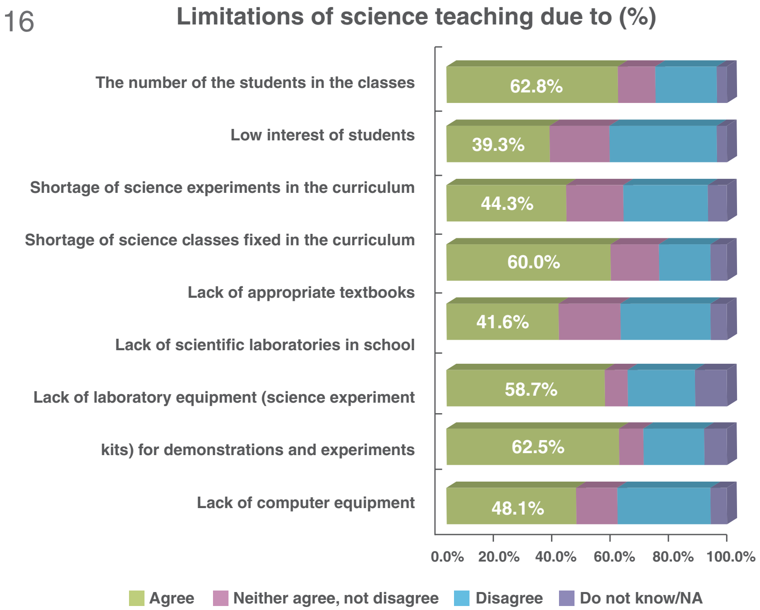
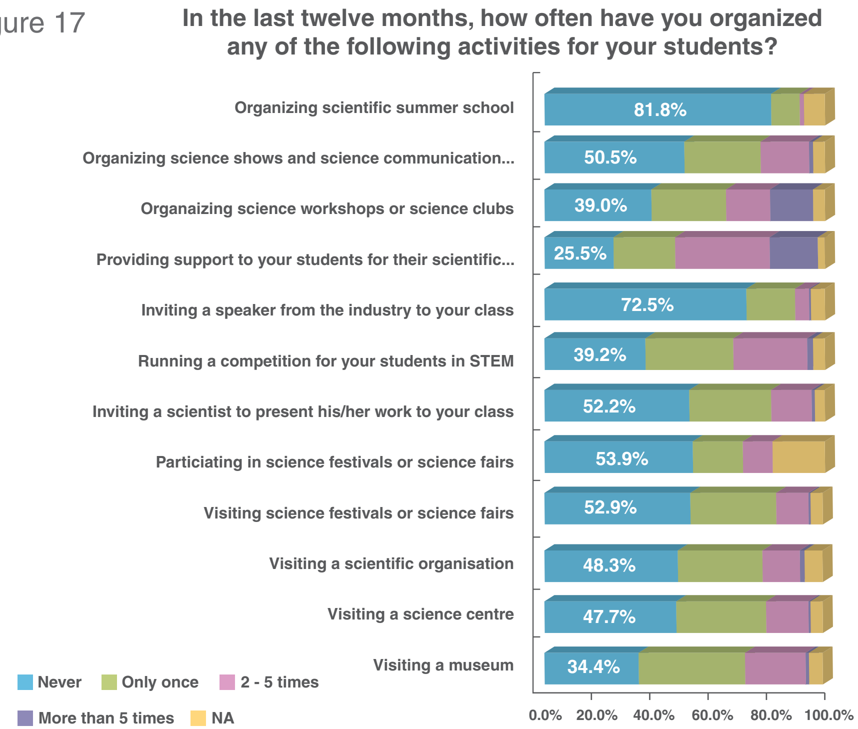


Figure 17



Lifelong Learning Programme

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