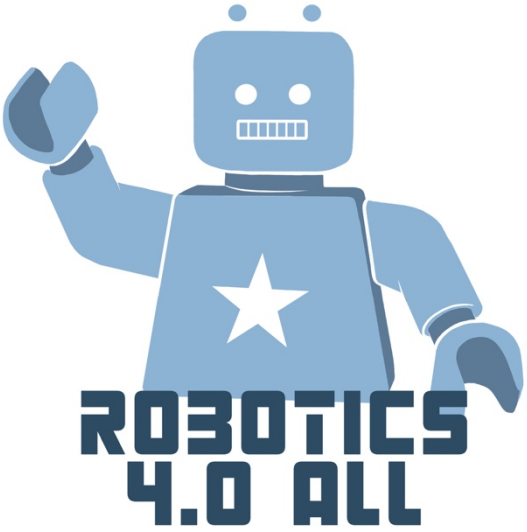
Integrated Report
Output 1



Developing STEM competences with Robotics
ROBOTICS 4.0 ALL

2018-1-NO01-KA202-038813

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Introduction

According to recent estimates (Shift Happens Educational, 2010), around 65% of children entering primary school today will ultimately end up working in completely new job types that do not yet exist. 21st century skills such as STEM (Science, Technology, Engineering and Mathematics) and digital competencies, analytical and critical thinking, team spirit and cooperation are deemed necessary to enhance one's educational capacity and to increase future employability opportunities, while adapting and keeping up-to-date with modern technology. "Robotics 4.0 All" aim is to better prepare kids, youngsters and teachers to this change.

"Robotics 4.0 All" has four key objectives that are interconnected with each other:

1. Conduct a European research and needs analysis over the current state of STEM education, and identify gaps and best practices.
2. Create new innovative curricula in order to combine best practices and fill the identified gaps.
3. Train the trainers and experts of the consortium based on LEGO Mindstorms.
4. Train and educate children up to 17 years old who will then participate as teams in a Transnational Robotics Tournament with their peers.

This integrated report is the result of the work the seven partner countries has done in researching and analyzing the current state of STEM in relation to robotics in their respective countries. The countries involved with the project are: Norway, Greece, Croatia, Spain, Cyprus, Bulgaria and Estonia. All partners submitted an initial individual country report, and this integrated report combines the results found.

This report will focus on the common gaps found in the partner countries that "Robotics 4.0 All" should aim to fill with their curriculum, and the best practices that the "Robotics 4.0 All" should use in order to maximise the output of said curriculum.

Each country`s individual report is attached as an appendix.

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1.0 Status and challenges in STEM and robotics in Europe

Each partner was asked if the STEM offers in their country were sufficient to increase kids` STEM education. They were also asked to explain their answer so that “Robotics 4.0 All” can aim to better the situation in each country, as well as in other countries interested in increasing kids´competencies in STEM and robotics.

Based on the feedback from the all the project partners it is possible to comment on the status of STEM and robotics education in all of the countries combined. In the following paragraphs the status and common challenges for all partners are described.

The research carried out by the project partners concludes that the majority of the “Robotics 4.0 All” partner countries have a big variety of STEM and robotics offers available. Unfortunately, they are mostly available in urban communities, where funding for these kind of offers is more easily accessible. The geography of a country, and it´s division into municipalities and regions is shown to affect the availability of STEM offers.

The abundance of offers can also be a root of confusion, as it is difficult for teachers and school leaders to decide which one to offer to their students. It is also hard to evaluate the quality of each offer as there does not exist any official evaluation criteria to evaluate them by. The quality of the STEM offers is not controlled in any way in either of the participating, consequently some teachers and schools may end up using their funds on offers that do not give them the learning outcome desired.

All partner countries agree that funding and financial situation of national of regional authorities make a big impact on the STEM offers available. Even if an offer is granted funding one year, it can be impossible to get the funding needed for the following year. This issue makes the offers unreliable for students and schools, and challenging for the providers as they need to be able to plan their futures. In addition, seeing that most initiatives are run

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by one or two enthusiastic teachers, and highly dependent on them to take responsibility and initiative, the initiative is in turn very fragile. If the enthusiastic person is unable to run the initiative, it will most likely disappear.

When asked to use a few sentences to answer if the offers in their country are perceived to be sufficient in order to increase kids´ STEM education, the countries stated the following:

Bulgaria: sufficient offers, but mostly located in the capital, and for a fee, so kids and youngsters in rural areas, or in low income families, are excluded.
Cyprus: many offers but they are not good enough, and it is difficult to know which one to choose.
Croatia: A wide set of offers, but it is concentrated in urban areas, and there is no way to control the quality of the offered programs. There is also a great challenge of securing long time funding for successful initiatives.
Greece: wide selection of initiatives, which seems sufficient, but no official programs, and no quality control.
Spain: STEM-related subjects in studies previous to VET and Higher Education is scarce, and is highly dependent on the region of study, as education is a competence of the autonomous areas of Spain. As such, no current regulations comes from the central government in the matter of robotics, programming or any other computational field.
Norway: varied initiatives of high quality that are sufficient. However, geography and the municipalities´economy affects whether the initiatives are available to users. Initiatives are also greatly dependent on a dedicated enthusiastic person who takes responsibility to start and operate it.
Estonia:When asked, teachers do not find activities to be enough for increasing level of STEM in Estonia.

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2.0 Gaps

2.1 Identified gaps and improvement recommendations

The research carried out by each partner country identified a large number of gaps, and many of them were common for two or more countries in the project. Therefore, the gaps are structured in a table where the countries that identified them are mentioned first, then the identified gap, and lastly suggested improvements made by the partners.

Country	Gaps	Recommendation for improvement
Cyprus, Croatia, Bulgaria, Greece, Spain, Norway, Estonia	Lack of qualified teachers and/or teacher development education	• new STEM strategy • new curriculum • teacher training programmes
Cyprus, Croatia, Bulgaria, Greece, Spain, Norway, Estonia	STEM initiatives are not available for everyone financially	• add STEM education to the formal curriculum of public schools
Cyprus, Greece, Norway, Estonia, Spain, Bulgaria	Lack of equipment	• national and regional funding schemes
Croatia, Greece, Estonia, Spain, Cyprus, Norway	Robotics education is dependant on an eager robotics teacher who takes personal responsibility	• make robotics a part of the compulsory curriculum, and make school management more involved and the subject less dependent on that one teacher

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		• Some school leaders do not facilitate STEM activities. By disseminating the Erasmus+ project widely amongst the school communities, we can inform and evoke awareness of the importance of facilitating STEM activities in schools.
Bulgaria, Norway, Spain, Estonia, Cyprus	STEM initiatives are not available for everyone geographically	• e-learning platforms
Croatia, Greece, Estonia, Spain, Cyprus,	Robotics is only available as an elective subject	• make robotics a part of the compulsory curriculum, and make school management more involved and the subject less dependent on that one teacher
Croatia, Estonia, Cyprus, Greece, Norway	Lack of teacher educational material	• accessible national data-base with material available • New fresh material needs to be produces
Norway, Cyprus, Bulgaria, Greece, Spain	No customized STEM curriculum	• Make a curriculum that provides a complete package: teaching plan,

		mission/challenge, expected learning outcomes, teacher´s guide etc.
Norway, Spain, Greece, Bulgaria	STEM initiatives exist, but they are not available for everyone because of policies.	• national or regional government could choose to make a selection of STEM initiatives available for all municipalities.
Croatia, Norway, Greece	Lack of evaluation criteria	• a peer and self evaluation scheme
Estonia, Norway, Bulgaria	Older teachers won´t adapt to robotics	• motivational seminars
Estonia, Norway, Greece	Competition based learning is not financially supported and competition days are not working days	• funding • compensation for teachers working weekend days for competition
Norway, Estonia, Greece	Municipalities are dependent on the one enthusiast to take initiative and responsibility for it voluntarily.	• make two or more employees in the municipality responsible for managing and organizing STEM related activities and offers in the region.

Norway, Cyprus, Estonia	Too much information and too many competitive offers are available. It is difficult for teachers and schools to choose which one serves their needs.	• gather all the initiatives in a national online database.
Greece, Spain	Too little time in school, little flexible school system	• more time, would help teachers to offer STEM programs of better quality
Greece	Governmental financial crisis	• more governmental funds are critical to the development of STEM education
Cyprus	Judges in robot competitions favor students from their own school, using victories as a recruitment strategy for their school (conflict of interest issues)	• new STEM education reform • new curriculum • initiatives needs to be certified

As described above, there are seventeen gaps detected in the partner countries. Unfortunately, the project can not aim to improve all of them, so this report will be focused on the eight gaps that is in “Robotics 4.0 All” power to improve. The chosen gaps represent the characteristic STEM and robotics education gaps from all seven participating countries, and it is therefore recommended that “Robotics 4.0 All” focus on closing them when developing the curriculum.

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2.2 Closing the gaps through “Robotics 4.0 All”

The eight chosen gaps are the characteristic STEM and robotics education gaps collected from all seven participating countries. The gaps were chosen on the basis on two criterias:

1. A majority of the partner countries identified this gap in their research.
2. “Robotics 4.0 All” is able to close the gap within the scope of the project.

In the following table each gap is described shortly, followed by curricula recommendations made by the partners and FIRST Scandinavia. The recommandations suggests what the project should focus on to be able to close the gaps identified in the individual reports.

Gap	Erasmus+ curriculum recommendations
Lack of qualified teachers and/or teacher development education	• Make sure the coaches and teachers involved with Erasmus+ programme receives sufficient training. Create the the teacher training like a learning trail where even inexperienced teachers can learn and become confident in teaching the curriculum • Make material available for free and online after the project is tested and quality is assured
STEM initiatives are not available for everyone financially	• Make the Erasmus+ materials available for free
No customized STEM curriculum	• Make an Erasmus+ curriculum that provides a complete package: teaching plan, mission/challenge, expected learning outcomes, teacher´s guide etc.
Lack of equipment	• The Erasmus+ programme cannot

	assist municipalities in seven countries with equipment, but through making the materials available for free, perhaps the cost for equipment can be easier to bear
Robotics education is dependant on an eager robotics teacher who takes personal responsibility	• Create the teacher training like a learning trail so it can make all teachers excited about STEM, and make them feel confident enough to implement it in their teaching. • Some school leaders do not facilitate STEM activities. By disseminating the Erasmus+ project widely amongst the school communities, we can inform and evoke awareness of the importance of facilitating STEM activities in schools.
STEM initiatives are not available for everyone geographically	• Make the Erasmus+ materials available for free online, so that it is accessible for everyone everywhere.
Robotics is only available as an elective subject	• We can not change the curriculum in our participating countries, but we can point out the learning outcome in our curriculum, so that teachers see that they can use robotics to teach mandatory subjects like math and more.
Lack of teacher educational material	• Ensure that the Erasmus+ teacher training materials are available for all teachers. • Create the the teacher training like a learning trail where even inexperienced teachers can learn and become confident in teaching the

	curriculum.

In addition to the eight chosen gaps, it is suggested that the “Robotics 4.0 All” project also focuses on improving the reputation of programming, gaming and technology among kids and youngsters. By creating awareness of the positive sides and learning opportunities in gaming and programming, for both teachers, parents and students, the project may contribute to inspire more young people to choose programming and technology as their future career path.

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3.0 Best practices

Each partner was asked to list and describe the best practices within STEM education and robotics in their country. As the offers in each country varies greatly, they are listed underneath its representative country together with a short explanation. The project will use these best practices as inspiration in the creation of the "Robotics 4.0 All" curricula.

3.1 Partner countries` best practices

Below is the listing of the top STEM offers each partner country has to offer their kids and youngsters.

- **Cyprus**
  - Cyprus Science and Research Centre - CSRC: CSRC is a product of collaboration of all major universities and stakeholders of the island of Cyprus.
  - Robotics Academy by the Grammar School Nicosia: The Grammar School Nicosia was the first private school to consider alternative teaching methods.
  - *FIRST*Ⓡ LEGOⓇ League is a technology and knowledge competition with a global reach aimed at children aged 10 to 16 years. Teams are annually given a new challenge based on a real world issue, where they need work as engineers, scientists and programmers.
- **Croatia**
  - Croatian Makers League - part of the Croatian Makers project of the IRIM. The goal of the league is to include robotics, automatics and programming in the primary schools in Croatia.
  - Robocup Junior Croatia - is part of international organization. In Croatia it is run by Croatian Robotics Association.
  - *FIRST*Ⓡ LEGOⓇ League is a technology and knowledge competition with a global reach aimed at children aged 10 to 16 years. Teams are annually given

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a new challenge based on a real world issue, where they need work as engineers, scientists and programmers.

- **Bulgaria**
  - *FIRST*Ⓡ LEGOⓇ League is a technology and knowledge competition with a global reach aimed at children aged 10 to 16 years. Teams are annually given a new challenge based on a real world issue, where they need work as engineers, scientists and programmers.
  - Electronic Platform for Science Education in Secondary Schools - The electronic system for science education is based on the open-source Moodle learning platform. The platform provides many different functionalities, easy to be used by both teachers and students. It contains learning materials (presentations, movies, tests, statistics of the performance etc.).
  - Learning by Doing in Science Education Using ICT - Students are required to prepare interactive presentations on preset scientific topics by themselves. In order to complete the task, students learn how to use different software programs and how to prepare presentations, movies etc.
  - Use of Online Virtual and Remote Labs in Science Education - Online laboratories are aimed at supporting education based on research and provide opportunity to conduct scientific experiments in virtual environments.
  - MARCH project - aims to address a number of educational challenges that are linked to perceptions on science and existing science education methods and practices in secondary schools across Europe
- **Estonia**
  - *FIRST*Ⓡ LEGOⓇ League is a technology and knowledge competition with a global reach aimed at children aged 10 to 16 years. Teams are annually given a new challenge based on a real world issue, where they need work as engineers, scientists and programmers.
  - Robotex and Robomiku battle – multidiscipline competitions (line following, folk race, sumo, taxi drive, pulling the rope etc)

- HITSA – Information Technology Foundation for Education (HITSA 2019). Governmental institution that supports schools with funding, offers trainings, network and materials.
- Rocket 69 TV show (Rocket 69). It is a TV show where high school students compete in science challenges. In each show, one participant is excluded, leaving in the end the winner – who gets 10 000 EUR for studies. This show has been running in Estonia for more than six years and is extremely popular among young kids.

- **Greece**
  - The National Educational Program "Daidalos" - The programme aims to bring the special skills and talents of pupils in the field of science, technology and the arts to the surface
  - WRO-Hellas - The World Robot Olympiad (WRO) is a global robotics competition for young people
  - Science debate - Students become parliamentarians and discover the links between science and politics through Dialog in the European Student Parliaments
  - *FIRST*Ⓡ LEGOⓇ League is a technology and knowledge competition with a global reach aimed at children aged 10 to 16 years. Teams are annually given a new challenge based on a real world issue, where they need work as engineers, scientists and programmers.
- **Spain**
  - STEM Madrid - STEMadrid is a plan designed by the Autonomous Community of Madrid to boost education in STEM subjects among students in Madrid's schools at pre-school level, primary school level, secondary school level, VET and adult education
  - RoboTech - Founded and sponsored by Fundacion Endesa, this nationwide tournament seeks to promote the creation of projects that transform the education of youngsters through programming and robotics.
  - Scratch challenge - this initiative allows students to work on their computational thinking in the classroom of a variety of schools at various levels

- ARDUINO CTC 101 - CTC Arduino is part of a national movement called “Creative Technology Lessons” (Clases de Tecnologías Creativas)
- TIC Steam - TIC-STEAM project seeks to boost STEM competences among school teachers through the use of programming techniques and robotics to solve small learning challenges
- FLL - *FIRST*Ⓡ LEGOⓇ League is a technology and knowledge competition with a global reach aimed at children aged 10 to 16 years. Teams are annually given a new challenge based on a real world issue, where they need work as engineers, scientists and programmers.

- **Norway**
  - *FIRST*Ⓡ LEGOⓇ League is a technology and knowledge competition with a global reach aimed at children aged 10 to 16 years. Teams are annually given a new challenge based on a real world issue, where they need work as engineers, scientists and programmers.
  - Newton - A science room owned by a municipality or county, where kids and youngsters find top quality equipment, an knowledgeable and engaged teacher and age and topic specific learning resources.
  - Teach the kids coding! - a non-profit volunteer-based organisation. Their aim is to teach kids and youngsters to understand their role in the digital community, and to help them become creators of technology, not only users.
  - The technological backpack - a commitment made by the The Norwegian Directorate for Education and Training, which enables schools to apply for grants for equipment for teaching programming, and digital teaching resources.

3.2 Best practices for “Robotics 4.0 All”

"Robotics 4.0 All" aims to make a teacher training program and a curricula for kids and youngsters to learn about practical STEM and robotics. A part of the project is to create a camp where the teacher training and student curricula is implemented, and form and content will be inspired by the best practices that are identified in all participating countries. More specifically, 48 youngsters and 12 adults from 6 countries around Europe will participate directly into our project's scheduled transnational activities, while even more will have the opportunity to be benefited through the partners' local training classes and get to know the exciting new world of robotics. The acquired and newly developed skills and competencies will help our target groups and beneficiaries be better prepared and equipped for future educational and professional chances, while the liaison, the exchange of best practices and the establishment of synergies among the participating organizations and relevant stakeholders will help maximize the impact in the present and in the future.

To be able to fulfill the set goals for "Robotics 4.0 All" we will use the identified best practices from the partner countries as inspiration on how to structure the new curricula. Based on the identified gaps and recommendations for improvement, a list of criteria for the project curricula is suggested to best accommodate the purpose of "Robotics 4.0 All".

Criteria:

- Totally runs over a longer period of time (more than a week)
- Enables in-depth learning
- Focuses on cross-curricula work
- Has challenge based, open ended tasks
- Creates awareness of STEM in everyday life
- Uses a set curriculum and teaching plan ("plug and play") to make it easily accessible

Partner countries have mentioned a wide variety of best practices from their area. Some are government policies and national educational programs, while others are private initiatives. While the project can not implement policies, it can be inspired by the form and means of the selection of best practices, and sifted through the criteria above. When that is done, we find the common denominator to be *FIRST*Ⓡ LEGOⓇ League, which is suggested by all participating partners.

FIRSTⓇ LEGOⓇ League is a challenge based knowledge and technology competition that runs for several weeks and in that way enables in-depth learning. The program stimulates to cross-curricula work as students need to do research and testing on a wide selection of themes, as well as to build and programme a robot. By launching a new real life themed challenge each year, it also makes students aware of STEM in several fields in everyday life. *FIRST*Ⓡ LEGOⓇ League is launched each year with a detailed teacher manual as well as instructions for students, similar to what is suggested in our *gaps-section. FIRST*Ⓡ LEGOⓇ League has proven to be a good example of a best practice, as it is inspiring for kids and youth, who often enrolls in the program year after year.

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4.0 Conclusion

In the table on page 8, each identified gap is described shortly, followed by curricula recommendations made by the partners and FIRST Scandinavia. The recommandations suggests what the “Robotics 4.0 All” project should focus on to be able to close the gaps identified in the individual reports.

“Robotics 4.0 All” aims to make a teacher training program and a curricula for kids and youngsters to learn about practical STEM and robotics. Partner countries have mentioned a wide variety of best practices from their area. We found the common denominator to be *FIRST*Ⓡ LEGOⓇ League, which is suggested by all participating partners.

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5.0 Recommended further research

It is evident that our “Robotics 4.0 All” project can contribute significantly to the challenges of STEM education offers in relation to robotics. As the scope of our research and project is small, below is a listing of the further research opportunities that exist and should be look into by other projects.

- The training of Teachers in STEM and Robotics.
- The lack of a curriculum for the teachers for STEM and Robotics.
- The access to proper equipment.
- Larger financial allocations on national/regional/local levels for the improvement of the schools equipment
- Inclusion of robotics as elective subject in primary and some secondary schools
- More local support for community technology clubs
- Development of teachers/trainers materials, curricula etc.
- Improvement of teachers/trainers professional development in the field of STEM and robotics.
- Making the participation affordable for students
- Access to high quality STEM education
- Establish fair and wide distribution methods of government funds and grants.
- Establish a national online database of educational resources for STEM, where teaching resources, teaching plans and teacher´s guide are available.
- Establish a geographic plan for integration of STEM activities in relation to robotics. Norway is long, with great distances between cities and villages, which in turn means that kids and youngsters are dependent on having offers located in their village, city or municipality.

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6.0 References

Shift Happens Educational, 2010, Karl Fisch and Scott McLeod: Shift Happens, YouTube video, n.d. Available from: https://youtu.be/SBwT_09boxE. (n.d.).

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7.0 Appendix

Appendix 1: Individual report Norway

Appendix 2: Individual report Greece

Appendix 3: Individual report Croatia

Appendix 4: Individual report Spain

Appendix 5: Individual report Cyprus

Appendix 6: Individual report Bulgaria

Appendix 7: Individual report Estonia

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FIRST Scandinavia

ROBOTICS 4.0 ALL

NORWAY

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1.0 Current level of STEM in Norway

1.1. Meaning/definition and difference of STEM in Norway

STEM is still a somewhat new term in Norway, and most teachers will not be able to tell you what the acronym stands for. However, the term is becoming more popular and it is spreading rapidly. Especially the new focus on programming and 21st century skills in the upcoming national curriculum has helped it become better known among teachers who teach science and programming (Utdanningsdirektoratet n.d). The STEM term is not commonly used, but the term “realfag” (math, biology, chemistry, physics) is used extensively, as is technology and digital competence. The latter has been a part of the national curriculum since 2006. These terms describes much of the content of STEM, but we believe that STEM will soon become a commonly used and known term in Norway as the focus on programming and technology increases.

STEM education is a popular topic in Norway, and many municipalities are currently offering it to its young inhabitants. It takes the form of voluntary classes in school, mandatory school activities, after school activities, courses and competitions. The number of offers are increasing, but the quality and availability differs strongly. It is often dependent on geography and an enthusiast who takes initiative, which makes the offer in each municipality variable, both in quantity and quality. The only national initiative that is currently active is *Vitensenteret´s* (Science Centers) country initiative mission to give all 5th graders a day long lesson in programming (Vitensenteret n.d.).

However, next year, the new curriculum will take effect and the content of the STEM term will become a part of the national curriculum, even though the term is not used.
In sum, the term STEM is not commonly known or used among teachers in Norway, it is mostly a term used by teachers who already hold a special interest for programming and technology. The new national curriculum will include STEM education, but not the term STEM itself.

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The current level of STEM education in Norway is high in some areas, and low in others, because of it dependency on location, and a local enthusiast who takes initiative and responsibility for the offers. In the future we believe that the term will be popularly used, and that the availability of offers in STEM education will be improved massively.

1.2. Publications aimed at analysing the development and implementation of STEM in education

1.2.1. Norwegian publications

Nordic Journal of STEM education
The Nordic Journal of STEM education is a scholarly peer-reviewed, open-access journal publishing in the broad field of educational development in Science, Technology, Engineering, and Mathematics (STEM) (Higher Education Nordic Journal of STEM education n.d.).

***Tett på realfag* (Close up on science)**
A government strategy developed to increase the science competency for kids in kindergarten and students up to the age of 16. The project takes place between 2015 and 2019. The main goal of the strategy is to increase kids´ and students´ competencies in sciences through better learning methods and increased motivation (Realfagsstrategien 2018).

Nordic Institute for Studies in innovation, research and education (NIFU)
NIFU evaluated the *Tett på realfag* (Close up on science)-strategy in March 2019 (Evaluering av realfagsstrategien 2019).

Norwegian Directorate for Education and Training (UDIR)
Offers a variety of statistics, research, in-depth publications, user evaluations and analysis on the current level of STEM (Utdanningsdirektoratet n.d.).

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1.2.2. EU publications

Education Policies in Europe
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 (Scientix 2018).

Labour Market Situation and Comparison of Practices Targeted at Young People in Different Member States
The report intends to provide an up-to-date overview of the labour market situation in STEM occupations, and to analyse European and national approaches to encourage STEM uptake in relation to these labour market needs. The aim is to identify practices which help to increase the supply of STEM skilled labour (European Parliament 2015).

1.3. Types of STEM methodologies applied

1.3.1 National/regional/local policies	
New National Curriculum	Is there to ensure that every school in the country is bound by law to teach students the same skills. The main changes from the previous curricula are that programming, innovation, in-depth learning, cross-curriculum teaching are now a part of the national curriculum.
Voluntary subjects in school (programming/technology)	The two elective courses were added to the country curriculum to give students the opportunity to learn more about programming and technology. It is a national curriculum, but schools are not forced to offer them to their students.

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Municipalities can apply to become a *Realfagskommune* (Science Municipality)	Stimulates municipalities to want to increase their educational focus on, and competency in, the sciences. The municipality can apply nationally to become a Science Municipality. This means they receive funding for equipment and help from leading professionals to improve their educational offer within sciences and STEM.
Realfagsløype (Science trail)	A tool for local competency development for teachers within the natural sciences. Online resources are free of charge for teachers to help them to further develop their competence. The resource is developed by *Matematikksenteret* (The Norwegian Centre for Mathematics Education) and *Naturfagssenteret* (The Norwegian Centre for Science Education) to make sure that all teachers, no matter location or economy, can get continuing education.
Lektor 2	National science initiative funded by the Ministry of Education and Research (Kunnskapsdepartementet) and led by the Center of Natural Sciences at the University of Oslo (UiO). The program offers competency development for teachers and funding to encourage them to invite experts from science businesses to create curricula based teaching resources for science subjects. It aims to stimulate kids and youngsters´ interest and motivation for the sciences, increase their learning outcomes, increase recruitment to the sciences and to increase teachers´ knowledge and competence about how to cooperate with the world of business.
ENT3R	National initiative funded by The Norwegian department of Knowledge and led and run by the National Center of Science Recruitment. It is a recruitment initiative to stimulate more kids

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	to choose an education within the sciences. It aims to give kids a positive impression of science and math. ENT3R arranges afternoon activities run by students at the local university or college. Here the kids and youngsters can attend and learn more about the sciences, do experiments, meet role models, and get help with their homework from science students. It is arranged in 18 universities and colleges all over the country, and for those who live too far from one of these locations, they also offer online help with math homework.
Continuing education for math teachers	The Norwegian Directorate for Education has invested greatly in the continuing education of Norwegian teachers, especially in maths to improve the educational offer in the subject. Teachers from all over the country can apply each year to enter a study program where the teacher workload is decreased for a period of time while they study. They are paid their normal salary while studying. Many teachers apply to these program each year, but it is up to each school to map what needs they have and to decide which teacher who gets to enter the programs (Utdanningsdirektoratet n.d.)

1.3.2 National centers that work for recruitment and further engagement among kids and youth	
The Norwegian Centre for Mathematics Education	Funded by Norwegian Directorate for Education and run by Norwegian University of Science and Technology. The creation was done to make the centre contribute to raising the quality in the mathematics education in kindergartens and schools through the development of teaching

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	resources, competency development among teachers, and research on the field of mathematics in kindergarten and schools.
Norwegian Centre for Science Education	Funded by the Norwegian Directorate for Education and Training and run by the University of Oslo. With its function as a national resource centre, the Norwegian Centre for Science Education was created to contribute towards improvements in the quality of science education. The centre shall help increase motivation and interest for the sciences at kindergarten and at all compulsory school levels.
National Center for Science Recruitment	Funded by Norwegian Directorate for Education and Training and run by Norwegian University of Science and Technology. It was created for the purpose of increasing recruitment to math, natural science and technology-education, to secure a competitive, sustainable and equal society.
Talentsenter (Talent center)	Initiative by the Government to better the educational offer to high achieving kids in math, natural science and technology, to give those who excel an opportunity to go further in-depth in their subject of choice. It is a part of the *Tett på realfag* initiative which aims to help low achieving kids get better learning outcomes, and give high achieving kids new and positive challenges.

1.3.3. CSO´s

and others that work to engage kids and youth in STEM,
and to give them good experiences with science and technology

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NHO Jenter og Teknologi (NHO Girls and Technology)	Through the use inspiring female role models, NHO Girls and Technology are able to get the message across; that there are endless possibilities out the for girls choosing to start an education and career in technology. The overall goal is to increase the number of girls in technology related studies. (NHO n.d.)
Vitensenter (Science Centers)	Science Centres are a collection of popular science experience and educational centers throughout the country. It is partly funded by the Norwegian Government, local and national sponsorships in addition to regional government and municipality. They teach kids, youngsters and visitors about nature, environment, health and technology through their own initiatives and collaboration with others.

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2.0 STEM education in Norway

The below answers are based on information gathered in the EU Survey and interview of key stakeholders.

2.1. The following offer STEM education in relation to robotics in Norway	2.2. Type education offered
FIRST Scandinavia	*FIRST*® LEGO® League (FLL): FLL is an international knowledge and technology competition/program for kids between 4 and 16 years. Each year the competition releases 3 challenges; one for 4-6 year olds, one for 6-9 year olds, and one for 10-16 year olds. In the competition, which has a focus on engineering, programming and 21st century skills, kids participate as a team to solve a challenge with a specific topic.
FIRST Scandinavia	Newton Room: Is science room owned by a municipality or county, where kids and youngsters have access to top quality equipment, a knowledgeable and engaged teacher, and age and topic specific learning resources connected to the national curriculum. The goal is to give kids engaging lessons with high learning outcomes. The teaching modules available are created by the network which is run by FIRST Scandinavia, the creator of Newton Room.
Makerspace	Makerspace is a collaborative work space inside a school, library or public/private facility for making, learning, exploring and sharing. These makerspaces offer a variety of activities, some

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	of them are STEM related, but not all.
Valgfag teknologi i praksis Valgfag forskning i praksis	Subjects in the national curriculum that are voluntary to choose. It is both voluntary for the schools to offer them to students, and voluntary for the students to choose them as a part of their schedule. The challenge for schools is to find teachers with the right competence who are able and willing to teach the subjects.
Forskerfabrikken	A social entrepreneur that works to engage more kids and youth in science, and to help them understand the processes they learn about on a deeper level. They do this through courses, activities and summer camps.
Den teknologiske skolesekken	A 5-year long state initiative, with a NOK 450 million financial framework, that aims to give kids knowledge and understanding of technology, programming and algorithmic thinking. It also aims to give teachers access to quality digital educational resources. The goals are reached through economic funds and other measures aimed at school owners, school leaders and teachers.
http://www.vitensenter.no/	Regional science centers where visitors learn through experimenting. The topics to be explored are nature, environment, health and technology. Their target groups are kindergartens, schools and the public at large.
Kodeklubber	Private local coding-clubs throughout Norway, often started by local enthusiasts to facilitate kids´ and youngsters´ interest in coding and programming. There are about 160 registered clubs, which throughout the year have the opportunity to participate in over 12,000 activities.
Teknolab	A TeknoLab consists of teaching equipment that enables the students to try out principles and

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	ideas in technology, mathematics, mechanics, design, data and electronics etc.. TeknoLab provides an increased degree of so-called individually adapted teaching. Each student is inspired to explore issues within science and technology, based on their own resources and knowledge.
Lær Kidsa Koding	Learn Kids Coding! is a voluntary movement that works to help kids and youngsters learn to understand and control their own role in the digital community. We want to help young people to not only be users, but also creators of technology. One of the events they organize is *Code-hour*. Code-hour is a programming lesson, ready to use for students of all ages. Programming is part of the Code-hour which is a worldwide voluntary digital initiative for children to learn programming in school.
Jenter Koder	"Girls Codes" wants to inspire girls of all ages to explore unparalleled opportunities using technology. Girls Codes is a voluntary initiative with the goal of increasing the proportion of girls taking computer technology and science after completing upper secondary school. One of the events they organize is "Girls Tech Fest" - where 400 girls under the age of 10 meet for a full day of programming.
Kodegenet	"The code-genom" offers programming resources in Norwegian, and is an offer to everyone who is interested in computers, programming and electronics.
Skaperskolen	The "Innovation and creator-school" aims to inspire kids and youngsters to create and explore activities using technology. It also gives support to teachers so they can facilitate these activities at their schools.

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Utenriksdirektoratet (Udir)	The Norwegian Directorate for Education and Training is responsible for the development of kindergarten and primary and secondary education. The objective of the Directorate is to ensure that all children, pupils and apprentices receive the high quality education they are entitled to.
SFO/AKS	Collaboration between the municipality of Oslo and some schools in Oslo. Students in secondary schools go through training to provide peer-training in programming to kids in daycare facilities for school children. The students are offered a salary for their effort, and kids are given an opportunity to learn programming at an early age.
Vitenfabrikken	Offers exhibitions and interactive installations. Facilitates a variety of STEM related activities, such as *FIRST*® LEGO® League, code cracker competitions, mathematics room, makerspace and more.

2.3. Are offers sufficient in order to increase kid´s STEM education in your country?

The Norwegian responses to the questionnaire and the interviews of key stakeholders, show us that there is a wide selection of offers that are sufficient to increase kids´ STEM education in Norway. The range and quality of the offers are exceptionally good, but unfortunately not everyone is able to take advantage of them.

Norway is long, with great distances between cities and villages, which in turn means that kids and youngsters are dependent on the offers offered in their municipality. Unfortunately the economy and resources in the municipalities differs greatly, which effects the range of

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STEM offers available to its inhabitants. Some kids and youngster will therefore have a great range of offers to choose from, while other will have few or none.

Furthermore, the offers that are available are not put in a system, subsequently schools and the public can not get an systemized oversight. They all exist in different places and contexts, and it seems like the key stakeholders and respondents of the survey do not know about all the offers, neither where they are to be found. Several teachers we have spoken to have confirmed our impression, as they have explained that they did not know about the national initiatives and resources for the subjects they teach.

Luckily, more resources are becoming available online for free, which means that the municipalities with poor economy are able to implement them if they make the time and effort. Although, municipalities and cities with a strong economy will always have more resources in the form of competent employees, equipment and time to give their kids and youngsters a broad range of offers to choose from, especially being able to offer practical activities, not only theoretical ones. Consequently, the latter group will have better experiences with STEM, and may have a greater chance of mastering these skills as they grow older.

2.4. Identified gaps and recommended improvements

Gaps and improvements identified through the EU Survey and the interview of key stakeholders are as follows:

- **Good STEM initiatives exist, but they are not available for everyone.**
    - *Improvement potential*: National or regional government could choose to make a selection of STEM initiatives available for all municipalities. That would ensure that all children got the same basic STEM knowledge no matter where they grew up. A Newton Room would be an good example of initiative, as one room can serve several schools and municipalities.
- **Even though good STEM initiatives exist, municipalities are dependent on the one enthusiast to take initiative and responsibility for it voluntarily.**

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- *Improvement potential*: Make two or more employees in the municipality responsible for managing and organizing STEM related activities and offers in the region. They should also be given funds to keep themselves updated on the development in the field of STEM.

- **Too much information and too many competitive offers are available. It is difficult for teachers and schools to choose which one serves their needs. A national online database of educational resources for STEM activities should be established.**
  - *Improvement potential*: Gather all the initiatives in a national online database. Divide between the different kind of resources: funds available for continued education for teachers, funds for municipalities and schools to develop STEM activities, centers that schools can contact for competency development, online competence development programs, programs for high achieving students, local homework help and inspirational activities like ENT3R and so on. An national online database like this would gather the resources, systematize them, and make them widely available for everyone.
- **Financial issues: many schools lack equipment because of poor economy.**
  - *Improvement potential*: This issue is hard to tackle because of the complex financial situation of each municipality. One solution would be that the Government funds all municipalities with a minimum of equipment, based on counselling from the STEM resource organizer we suggested above. Alternatively, municipalities can use more resources to review the already existing offers (mentioned above), and to implement those which are free of charge.
- **No standardised STEM training for teachers. There are only a few additional training programs accessible, and some are not affordable for school owners, school leaders and teacher.**
  - *Improvement potential*: The new curriculum includes programming and other STEM based activities in several subjects, but a majority of teachers have never had any training in STEM related activities. When making the new curriculum, the Government could develop a national class or workshop for all teachers to participate in, to ensure a minimum STEM skill level amongst educated teachers. Teacher education institutions should also create similar offers for students training to become teachers, so that they are prepared for the new shift in the Norwegian school system. See also our description of what the teacher students in Stavanger have done to prepare themselves on

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their own initiative (se bullet-point regarding “teacher education does not prepare future teachers for providing STEM activities” below).

- **No customized examples of the STEM curriculum. There is:**
  - a lack of “plug and play” activities that are ready to be used in the classroom with specified competency aims to be targeted.
  - no concrete examples of how teacher can make the connection between programming and mathematics, English, natural science, social studies and the other subjects on the curriculum.
  - no focus on creating awareness of what robotics is being used for in today's society.
  - *Improvement potential*: The designated centers for mathematics, natural sciences, culture and so on can be tasked with creating teaching resources for these purposes. A clear overview of competency aims, teaching methods, examples of solutions (but with open ended tasks) and thorough instructions for teachers would secure that all teacher have the ability to give their students good learning experiences with STEM and robotics.
- **Teacher education does not prepare future teachers for providing STEM education.**
  - *Improvement potential*: Make digital competence, STEM didactics and robotics a part of the teacher training programmes. At the University of Stavanger, the students themselves have created a club named DDV (Digital Didactic Workshop) to increase their own knowledge on the topic. The club´s motivation is to let students reflect on processes of learning, competences, and pedagogic, and in that manner develop and increase their professional didactic competence. This initiative should be copied by the other teacher trainer institutions. (Universitetet i Stavanger 2018).
- **Some school leaders do not facilitate for STEM activities.**
  - They focus exclusively on other existing activities such as sports, fundraising etcetera. They need to be more engaged in facilitating for STEM activities to make them more interesting and popular and available for all student. They need to give teachers more time and resources to learn how to implement STEM education in their teaching, and make STEM activities for the whole school just like they would with in example a sports day.
  - *Improvement potential*: Knowledge and awareness are often the reasons why school leaders do not facilitate STEM activities more. They do not know enough about what is is, and how to implement it. If the central government

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made a basic “how to” for school leaders, and gave them funds and time to learn more about the possibilities, more leaders would probably facilitate STEM related activities in their schools. A basic minimum activity that all schools had to implement in their schedule would ensure a minimum of STEM based activities in all schools.

- **Create awareness of the positive sides and learning opportunities with gaming and programming, for both teachers, parents and students.**
    - The negative attitudes towards these fields have a great affect on young people and their parents, which can lead to fewer choosing programming and technology as their future occupation.
    - *Improvement potential*: Knowledge about the positive sides of gaming and programming is key to affect negative attitudes, both among school leaders, teachers and parents. This can be helped through contact with role models like in example NHO Girls and Technology and ENT3R.
- **Some of the available teaching resources for STEM education exist without context.**
    - Improvement potential: Challenged based and open-ended questions will engage a wider group of kids and increase their interest and persistence, but many of the teaching resources on STEM activities are made to last for 1-2 hours and lack context. Lack of context may lead to less motivation and persistence, thus lowering the learning outcome. Teaching resources should be made to last for more than an hour as it does not facilitate in-depth learning. If teaching resources are challenge-based it will enable students to put the new information into a context and help them keep focus and hopefully have persistence to complete the challenge. This method is similar to *FIRST*® LEGO® League.

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3.0 Best practices

3.1. Best practices

Below is a listing of the top four practices identified in our research based on results of the EU Survey and interview of key stakeholders. They are chosen based on the practices criteria listed under section 3.2.

3.1.1. *FIRST®* LEGO® League

FIRST® LEGO® League is a technology and knowledge competition with a global reach aimed at children aged 10 to 16 years. Teams are annually given a new challenge based on a real world issue. With the issue in mind, teams have to find a problem, and subsequently do the research needed to find a solution to this problem. After 8 weeks the team participates in a tournament, where they present and market their solution. In addition, the teams have to design and build a LEGO Education MINDSTORM EV3 robot to complete missions on a robotfield. It all takes place on a competition day where all the teams in the region attend. The teams have 8 weeks to prepare for the competition. (*FIRST®* LEGO® League n.d.)

3.1.2. Newton Room

A science room owned by a municipality or county, where kids and youngsters find top quality equipment, an knowledgeable and engaged teacher and age and topic specific learning resources. The goal is to give kids engaging lessons with high learning outcomes. The teaching modules available are created by the network which is run by FIRST Scandinavia, the creator of Newton Room. (Newton Room 2019).

3.1.3. Lær kidsa koding (Teach the kids coding)

Teach the kids coding! is a non-profit volunteer-based organisation. Their aim is to teach kids and youngsters to understand their role in the digital community, and to help them become creators of technology, not only users. The organisation has a valuable network, and provides teaching resources and teaching methods for everyone to use through their web page, and the facilitation of local activities and events. (Lær kidsa koding 2019).

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3.1.4. Den teknologiske skolesekken (The technological backpack)

The technological backpack is a commitment made by the The Norwegian Directorate for Education and Training, which enables schools to apply for grants for equipment for teaching programming, and digital teaching resources. Only schools that are already committing and investing in *Lærerspesialist* (Teacher spesialist) in programming are eligible to apply, leaving many schools ineligible. Its main goal is to make sure kids and youngsters have access to, and knowledge about, technology, algorithmic thinking, programming and digital teaching tools. (Utdanningsdirektoratet 2019).

3.2. Practices criteria

The practices fulfill the following criteria, which the respondents of the EU Survey and interview objects believe to be important factors of a successful STEM initiative. They:

- engage kids and youth.
- facilitate in-depth learning.
- last for longer period of time.
- provide opportunities for progression in complexity.
- have the potential to reach kids and youngsters from all across the country, including all age groups and social background.
- are cross-curriculum based, enabling kids and youngsters to use a lot of their own knowledge and experience, and make sure that all participants feel like they have something to offer.
- come at no cost for the end user (kids and youngsters).

3.3. Are practices adaptable into the Erasmus+ program?

Based on the finding in this report, the practices are adaptable into the Erasmus+ program.

In addition to the criteria above in section section 3.2, the Erasmus+ program should also:

- Runs over a certain period of time
- Enables in-depth learning
- Focuses on cross-curricula work

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- Is challenge based
- Creates awareness of STEM in our everyday life
- Uses a set curriculum and teaching plan (“plug and play”)

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4.0. Policy initiatives

4.1 Central government initiatives

Central government have implemented the following policies to increase the competencies of both children and adults in STEM education and/or robotics:

- The creation of Norwegian Centre for Mathematics Education
- The creation of Norwegian Centre for Natural Science Education
- Tett på realfag - (Close up on science). A National strategy for increased competency in natural sciences and technology
- Den teknologiske skolesekken - The Technological Backpack
- Lærerspesialist - Teacher Specialist (teachers can apply to become a specialist in their field at their school, and subsequently have access to further training and invitation to courses).

4.2. Regional government initiatives

Does regional government have any policies implemented to increase the competencies of both children and adults in STEM education and/or robotics?

Regional governments have the power to make choices that affect STEM education and/or robotics. Examples can be:

- Establishing a Newton Room
- Fund youngsters´ participation in *FIRST*® LEGO® League
- Arrange SFO/AKS like the city of Oslo (read more under section 2.1, p.12)
- Vitensenter (Science Centers)
- Establish a Makerspace
- Offer elective courses in secondary school (Technology and programming)
- Apply to become a Science municipality

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4.3. Upcoming policy initiatives

The following policy initiatives are being implemented in the next few years, that aims to increase the competencies of both children and adults in STEM education and/or robotics:

A upcoming and very important policy is the new National Curriculum in Norway. In the fall of 2020 it will be launched in all Norwegian schools. The general part of the curricula has been totally renewed, so have all of the subject curriculas. Several of them do now involve programming and robotics. It is believed to be the the most important policy that have/will be implemented in Norway regarding STEM education and robotics (Utdanningsdirektoratet n.d.).

4.4. Identified gaps recommended to Erasmus+

The research identified the following gaps, which can be implemented into the Erasmus+ program:

- **Good STEM initiatives exist, but they are not available for everyone.**
    - Erasmus+ needs to make sure the curriculum we make is accessible for everyone.
- **No standardised STEM training for teachers.**
    - If possible, Erasmus+ can make a teacher trainer training for our robotics camps that can be shared together with the curricula.
- **No customized STEM curriculum.**
    - Erasmus+ can contribute to this, by making a curriculum that provides a complete package: teaching plan, mission/challenge, expected learning outcomes, teacher´s guide etc.
- **Some school leaders do not facilitate STEM activities.**
    - By disseminating the Erasmus+ project widely amongst the school communities, we can inform and evoke awareness of the importance of facilitating STEM activities in schools.
- **Create awareness of the positive sides and learning opportunities in gaming and programming, for both teachers, parents and students.**
    - Erasmus+ can contribute in changing negative attitudes towards these fields, and have a great affect on young people, which can lead to more youngsters choosing programming and technology as their future career path.

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- **Some of the available teaching resources for STEM education exist without context.**
    - Erasmus+ should make a challenged based and open-ended challenge to engage more kids and increase interest and persistence.

5.0. Conclusion and further research

One can make the conclusion that Norway has many STEM activities in relation to robotics available. Research done for this report shows that there are too many activities and types of programming tools to choose from, rendering school owners, school leaders and teachers to not know which one to choose. In addition, the activities available might not be accessible to all schools due to geography and economic situation of the municipality.

In order to solve these issues, more research is needed to:

- Establish fair and wide distribution methods of government funds and grants.
- Establish a national online database of educational resources for STEM, where teaching resources, teaching plans and teacher´s guide are available.
- Establish a geographic plan for integration of STEM activities in relation to robotics. Norway is long, with great distances between cities and villages, which in turn means that kids and youngsters are dependent on having offers located in their village, city or municipality.

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6.0. Reference guide

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Table of contents

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1.0 Current level of STEM

1.1. Meaning/definition and difference of STEM in Greece

In Greece, STEM stands for Science, Technology, Engineering and Mathematics. STEM education is effective in the holistic understanding of concepts, since the basic qualities of knowledge favor the associated concepts more than the independent ones (Νικολόπουλος 2019).

According to EU Skills Panorama Glossary, STEM skills are defined as those skills "expected to be held by people with a tertiary-education level degree in the subjects of science, technology, engineering and maths" (European Commission 2015).

The focus on STEM education increases obviously in Greece, and many different types of organizations offer such activities. Still, there is not an official definition for STEM. However there are many initiatives in this attempt to promote STEM Education.

In 2015 Scientific Association for the Promotion of Educational Innovation was established and since 2015 is organizing workshops, conferences, seminars, trainings, competitions - festivals and European programs. The main purpose of E.E.P.E.K is to promote innovative actions in the educational community and the development of appropriate support structures that can be applied to the wider Greek educational system. Among the various objectives is the development and promotion of technological and educational services for finding and implementing the most appropriate educational activities (Scientific Association for the Promotion of Educational Innovation n.d.).

A few year later, in 2017 the Hellenic Education Society of STEM, (ΕΕ3 STEM), was formed in attempt all the Professionals dealing with STEM in Education to stand together and try to define the qualifications of a program, to be considered as STEM program. Hellenic Education Society of STEM is a registered, independent, nonprofit professional body and its

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members work for STEM education at primary, secondary and tertiary level (Hellenic Education Society of STEM n.d.).

A national initiative under the Horizon 2020 framework is The European project H2020: « Open Schools for Open Societies – OSOS». Its purpose is to prepare the introduction of the "Open School" innovation structured around natural sciences and STEM focusing on thematic areas linked to modern social challenges, in all education levels. 21 agencies (ministries, universities, research centres, museums, schools etc.) from Europe, the USA and Australia participate in the project. I.E.P. is the national coordinator for Greece (Institute of Educational Policy n.d.).

1.2. Publications aimed at analysing the development and implementation of STEM in education

1.2.1. Greek publications

Publications found through the desk research come basically from Conference Proceedings and there are a few Conferences dealing with relevant to STEM Education issues. Yet to mention that in Greece Educational Robotics is basically positioned in IT subjects and operated by Computer Science Teachers, as a result most of the publications are drawn upon this field of teaching.

Science View

Science View, the Hellenic Association of Science Journalists, Communicators and Writers is based in Athens, Greece and is a member of the European Union of Science Journalists' Associations, EUSJA. Science View aims to sustain science journalism in Greece and promotes science communication activities. These activities include video productions and scientific documentaries, science journalism and communication training workshops, online seminars via SV's training web platform and e-learning courses.

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Furthermore, Science View organizes conferences and events, and creates printed and electronic publications, newsletters, online magazines, websites, information portals and brochures. (science view n.d.).

9th Pan Hellenic Conference "Computer Science Education" 2018
Several aspects of the integration of Robotics in teaching at all the school grades were introduced are available in the Proceedings of the conference and published at the National Documentation Center's official website (9th Pan Hellenic Conference "Computer Science Education" 2018).

Scientific Association for the Promotion of Educational Innovation Annual Conference 2018
As mentioned already above, among the various objectives of the Association is the development and promotion of technological and educational services for finding and implementing the most appropriate educational activities. In the 4th annual Conference there is a section devoted to research and articles in Educational Robotics and Technology available in the Association's website. (Scientific Association for the Promotion of Educational Innovation 2018).

ICL2018 – The Challenges of the Digital Transformation in Education
This interdisciplinary conference aims to focus on the exchange of relevant trends and research results as well as the presentation of practical experiences in Interactive Collaborative Learning and Engineering Pedagogy. In Greece it was organized in cooperation with International Society for Engineering Pedagogy, the International Association of Online Engineering and Aristotle University of Thessaloniki (International Conference on Interactive Collaborative Learning n.d.).

It is also worth mentioning some personal thesis and Articles from Greek Researchers in the field of STEM and Robotics Education free to access on Google Scholar and with many references to their researches:

A learning environment for geography and history using mixed reality, tangible interfaces and educational robotics

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Authors: Stefanos Xefteris, George Palaigeorgiou, Areti Tsorbari
Published in: International Conference on Interactive Collaborative Learning (ICL)

Integrating ICT technologies in history and geography teaching may promote critical thinking and bridge the gap between unconstructive information accumulation and an explorative and critical learning approach. The aim of this study was to design, deploy and evaluate a low cost and easy-to-use mixed reality learning environment for interdisciplinary and embodied learning of geography, history and computational thinking. The proposed learning environment is comprised of an augmented 3D-tangible model of southern Europe where students interacted using their fingers, and a second treasure hunt augmented interactive floor depicting historical sites, where students performed tasks with Mindstorms EV3 robots.

Educational robotics: Open questions and new challenges
Author: Dimitris Alimisis
Published in: Themes in Science and Technology Education

This paper investigates the current situation in the field of educational robotics and identifies new challenges and trends focusing on the use of robotic technologies as a tool that will support creativity and other 21st-century learning skills. Finally, conclusions and proposals are presented for promoting cooperation and networking of researchers and teachers in Europe that might support the further development of the robotics movement in education.

Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences
Authors: Soumela Atmatzidou, Stavros Demetriadis
Published in: Robotics and Autonomous Systems

This work investigates the development of students' computational thinking (CT) skills in the context of educational robotics (ER) learning activity. The study employs an appropriate CT model for operationalising and exploring students' CT skills development in two different age groups (15 and 18 years old) and across gender. 164 students of different education levels (Junior high: 89; High vocational: 75) engaged in ER learning activities (2 hours per

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week, 11 weeks totally) and their CT skills were evaluated at different phases during the activity, using different modality (written and oral) assessment tools. The results suggest that: (a) students reach eventually the same level of CT skills development independent of their age and gender, (b) CT skills in most cases need time to fully develop (students' scores improve significantly towards the end of the activity), (c) age and gender relevant differences.

The use of LEGO Mindstorms in elementary and secondary education: game as a way of triggering learning

Authors: Soumela Atmatzidou, Iraklis Markelis, Stavros Demetriadis
Published in: International Conference of Simulation, Modeling and Programming for

Autonomous Robots (SIMPAR), Venice, Italy
In this work we present a didactic approach that investigates the effectiveness of using the Lego Mindstorms robots as tools for introducing students to basic concepts of programming through game play activity. Our approach comprises collaborative and entertaining features and emphasizes the element of competition between student groups in elementary and secondary education. Overall, the paper provides research evidence that approaching learning as an entertaining activity, through the use of LM robots and the spirit of team competition, offers a pleasant, creative and effective method of instruction for the acquisition of introductory programming knowledge.

All these publication create a strong theoretical basis and indicate a rapidly growing interest in the fields of STEM related to robotics. However, the desk research shows that there are a lot of gaps and of course a complete curriculum for STEM and Robotics does not exist.

1.2.2. EU publications

ANALYTICAL HIGHLIGHT FOCUS ON Science, technology, engineering and mathematics (STEM) skills

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STEM - related jobs are expected to grow faster than average over the next decade, but there are various challenges for business and policy makers in ensuring appropriate supply of these skills. STEM skills are critical to innovation and in creating a competitive edge in knowledge-intensive economies. From 2003 to 2013, the number of people working in STEM occupations grew by 12%, three times as much as total EU-28 employment. STEM occupations now account for 7% of all jobs. Much of this growth occurred from 2003 to 2008. However, there are signs of a recent upturn, which is creating recruitment difficulties in most EU-28 countries. Demand for STEM skills is anticipated to increase in the short and medium term. Whilst the numbers of STEM students and graduates are both increasing, some employers report that they are not 'job ready' and do not possess the 'right' skills, especially Soft skills (EU skills panorama 2015).

STEM EDUCATION POLICIES IN EUROPE

This report is based on data gathered from sector experts. A survey was sent to STEM representatives from 14 European countries (including Greece) with questions on the place of STEM in the education system, the reform projects linked to STEM education, the situation regarding the professional capacity-building of STEM teachers and the development of specific pedagogical and learning resources (Scientix 2018).

1.3. Types of STEM methodologies applied

1. **Constructivism approach**

This methodology views robotic technologies not as mere tools, but rather as potential vehicles of new ways of thinking about teaching, learning and education at large. We appreciate the importance of learners' existing knowledge, conceptions and culture, as well as of their interests and varied learning styles. Our approach encourages learners to participate actively in the learning process. Through robotics learners build something on their own, preferably a tangible object, that they can both touch and find meaningful. In robotics learners are invited to work on experiments or problem-solving with selective use of available resources, according to their own interests, search and learning strategies. They seek solutions to real world problems, based on a technological framework meant to engage

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students' curiosity and initiate motivation. The robotics industry so far mainly aims at humans using pre-programmed prefabricated robots. The ways in which the robots are made and programmed is a black box for their users. It is a paradigm compatible with the traditional educational paradigm of the teacher or the curriculum book revealing and explaining ready-made, ratified and thus unquestioned information. Very differently from this approach, our methodology suggests the transition from "traditional" black-box technologies to the design of transparent (white-box) digital artefacts where users can construct and deconstruct objects and have a deep structural access to the artefacts themselves. The white-box metaphor for construction and programming might generate a lot of creative thinking and involvement in learners. When students can have control of specific robots in a rich learning environment embedding the construction of robots and programs to control them the emphasis might move on interesting learning activities in the frame of specific learning areas such as science and technology. The design of robotic construction activities is associated with the fulfilment of a project aimed at solving a problem. In such a learning environment, learning is driven by the problem to be solved. To engage students in activities requiring to design and manufacture real objects, ie robotic structures that make sense for themselves and those around them, should devise activities that will encourage students to construct but also to encourage them and give them appropriate support in order to experiment and explore ideas that govern construction. Activities may take the form of research posing problems that are authentic, multidimensional and can have more than one solution. It is particularly important that the problems are proposed to be open and allow students to work with their own unique style and the way they wish. The work will actively involve students in learning opportunities by giving them control and ownership of their learning, encouraging creative problem solving and combining interdisciplinary concepts from different knowledge areas (science, mathematics, technology, etc.). The learning activities are as open as possible so that students have opportunities to participate in the final configuration of them and ultimately provide opportunities for reflection and collaboration within the team. (Alimisis 2012)

2. A Scenario-Based Approach for Designing ER Activities

Educational scenarios aim to design a learning situation composed by different activities in order to achieve certain learning objectives through different learning strategies. Pernin and Lejeune describe the learning scenario as “a description, made a priori or a posteriori, of the progress of a learning situation at a given level, or a learning unit, whose goal is to ensure the appropriation of a precise set of knowledge. A scenario describes roles, activities and also knowledge resources, tools and services

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necessary to the implementation of each activity". Learning scenarios include instructions for teachers, a theoretical framework for each addressed problem, the materials required for implementation, activity sheets for students, and possibly other materials (e.g., software, robotic tools, lesson plans). The learning scenario is therefore implemented as a series of teaching and learning activities. In this context, the scenario is a complete instructional intervention: it encompasses specific objectives, goals, the consideration of potential learning problems, and the implementation process, including appropriate activities and teaching strategies, assessment procedures, and so forth. In Komis et al., a framework for designing educational scenarios that incorporate digital technologies as a guide for prospective and practicing teachers was proposed. The design and implementation framework for educational scenarios integrates digital technologies into the pedagogical approach according to contemporary learning theories. It is also based on principles of science teaching, according to the main components of the TPACK (Technological Pedagogical Content Knowledge) model. An educational scenario that integrates digital technologies (in our case, robotics) as an educational and cognitive tool, describes the teaching and learning activities and the tools used (abstract tools such as schemata or software and/or physical tools such as special artifacts), which constitute both the starting point for teachers and learners' activities and the framework within which they will take place. It involves the application of effective teaching and learning strategies as a means of achieving learning objectives through the use of an appropriate digital environment (educational software, robotics tools or other materials). In most cases, the scenario targets the teaching and learning of one or more main concepts in a curriculum subject area (for example programming or robotics or 160 V. Komis et al. both). The scenario may also address concepts that belong to different subject areas, in an interdisciplinary perspective, or it may target concepts beyond the curriculum. This is the case when the use of robotics enhances concepts from STEM education in fostering art or social skills. The educational scenario was modified to create an appropriate conceptual model for teaching, especially programming concepts through the integration of robotics. This conceptual model aims to minimize methodological faults in order to maximize the validity of research findings developing a knowledge construction and competencies adopted in the learning process. Therefore, five different types of educational activities are proposed Here are the descriptions for the activities within the ER scenario: a. Preparatory activities. These activities aim to prepare the learners for the ER activity. The preparatory activities often include a teacher introduction to the scenario objectives in whole of the class, small groups or individual organization, without manipulating a robotic tool. The teacher attempts to trace the children's prior knowledge of programming and robotics and at the same time introduces the robotic tool. A Scenario-Based Approach for Designing ER Activities 161 b. Activities for the initial knowledge construction. In this second type of activities, the teacher guides the children in the use of ER for manipulation (inquiring, exploring, discovering and cognitive conflict) through peer-group (collaborative) interaction and involvement. In some cases these activities are strongly guided in terms of construction and/or programming depending on the learner's initial knowledge of ER. c.

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Activities for the knowledge construction consolidation. In these activities, the children have more responsibilities as they get to design, manipulate (inquiring, exploring, discovering and cognitive conflict) and interact with peers. These activities imply more co-creative problem solving opportunities because of the larger opportunities to design, construct and/or program the robot. These activities lead the children through manipulation, to a more reflective process for testing and access either on a robotic construction and its programming or only on programming of a pre-constructed robot. d. Evaluation activities can be embedded through the prior knowledge construction activities or can be carried on in a separate way. Evaluation could focus on learning objectives aligned with the curriculum (e.g. force transmission) or skills such as the 21st century skills related to ER, problem solving, collaboration, creativity, critical thinking and computational thinking. e. Metacognitive activities consider robotics as a potential cognitive or metacognitive tool that can bring the children to better understand and control their cognitive processes such as how to use particular strategies for problem solving. Meta- cognitive activities can also be embedded through the prior knowledge construction activities or can be carried on in a separate way. We suggest considering the five activities of this scenario for planning and organizing educational robotics (ER) activities that aim to achieve a curricular integration and ensure a progressive level of guidance towards the consolidation of the knowledge building process. The guidance is based on the scaffolding strategies of the Zone of Proximal Development (ZDP). The scaffolding is partly defined in the initial planning by the teacher but could be adapted according to the prior knowledge identification from the first activity. (Komis, Romero & Misirli 2017)

1.3.1 National/regional/local policies

National Curriculum	Science, Technology, Mathematics and Informatics are school subjects from Primary School to High School for all schools in Greece.
Flexible Hours are part of the National Curriculum for Primary Schools every week.	Teachers in Primary School have the flexibility to implement new Projects during these hours feeling free to choose subjects of the class's interest.
Municipalities can offer Educational Programs	There few examples of Municipalities supporting STEM Programs. All the Municipalities though have a department dealing with Education and supporting schools

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	of their region.
« O pen Schools for Open Societies – O SOS»	A H2020 program structured around natural sciences and STEM focusing on thematic areas linked to modern social challenges, in all education levels (Institute of Education Policy n.d.).
STEM Discovery Week 2019	International initiative that invites projects, organisations and schools across Europe and around the world, to celebrate careers and studies in the fields of Science, Technology, Engineering and Mathematics (STEM). The tagline for this year's campaign is "best practices in using innovative STEM resources" (Scientix 2019).

1.3.2 National centers that work for the Research in the fields of Science, Technology & Informatics offering educational programs and content	
General Secretariat for Research and Technology	The General Secretariat for Research and Technology (GSRT) is a modern public service assigned with the task of defining, as well as coordinating the implementation of, the national policy for Research, Technological Development and Innovation. It supports the activities of research and industry bodies through competitive research programmes highlighting economic performance and a socially fair allocation of outcomes. Furthermore, it supervises research and technology bodies, which provide local communities with the skills necessary for producing knowledge and boosting innovation. GSRT actively follows EU and international

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	developments in the field of RDI and represents the country to the EU and International Organisations within its competence (General Secretariat for Research and Technology n.d.).
Athena Research & Innovation Center in Information, Communication and Science Technologies	The mission of Athena RC is to conduct outstanding research in Informatics and Computational Sciences, tackling global challenges, addressing local needs, and producing novel and deep technological results with a broad impact on other sciences, industry, and society at large (General Secretariat for Research and Technology n.d.).
NOESIS – Thessaloniki Science Center and Technology Museum	NOESIS – Thessaloniki Science Center and Technology Museum is a non-profit cultural and educational foundation that promotes the public understanding of Science and Technology, in a way that is both educational and recreational. The main objective of the Center is the popularization of modern scientific and technological knowledge and its dissemination to the public through exhibitions, movies, educational programs, seminars and lectures (General Secretariat for Research and Technology n.d.).

1.3.3. CSO´s

and others that work to engage kids and youth in STEM,
and to give them good experiences with science and technology

HELLENIC PHYSICS SOCIETY FOR SCIENCE AND EDUCATION	A Non Profit Association for the Promotion of Physics through lectures, publications, student competitions (Hellenic physics society for science and education n.d.).

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HELLENIC MATHEMATICS SOCIETY	An Association for the Promotion of Mathematics through lectures, publications, student competitions (Hellenic mathematics society n.d.).
HELLENIC EDUCATION SOCIETY OF STEM	An independent, non-profit professional body and its members work for STEM education at primary, secondary and tertiary level (Hellenic Education Society of STEM n.d.).
eduACT – THE ORGANIZATION FOR FUTURE EDUCATION	A non-profit organization with the vision to offer quality education and innovation. Yet on the basis of its mission is to inspire students and learners of all ages to discover knowledge with the use of technology, robotics and science (eduact n.d.).

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2.0 STEM education in Norway

The below answers are based on information gathered in the EU Survey and interview of key stakeholders.

2.1. The following offer STEM education in relation to robotics in Norway	2.2. Type education offered
eduACT	*FIRST*® LEGO® League (FLL): FLL is an international knowledge and technology competition/program for kids between 4 and 16 years. Each year the competition releases 3 challenges; one for 4-6 year olds, one for 6-9 year olds, and one for 10-16 year olds. In the competition, which has a focus on engineering, programming and 21st century skills, kids participate as a team to solve a challenge with a specific topic.
eduACT	Workshops in Robotics and Coding for ages 5 – 16 in a pedagogical framework cultivating co-operation and teambuilding through STEM and Robotics
eduACT	International Robotics Camp: Kids and teens from different countries are gathering together doing robotics in their summer vacation in Greece. STEM activities are held during sport and art activities allowing learners to have a holistic STEM experience.
CSO – NGO – VET	Workshops in robotics & Coding, participation

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	in Robotics Championships
Private primary or secondary schools	In-classs practical activities, in-class theoretical activites, robotics and stem after school clubs, attending robotics Competitions, F1 for schools, physics and maths projects
Public primary or secondary schools	In-classs practical activities, in-class theoretical activites, workshops, attending robotics Competitions
HEI (Higher education institution)	Computational STEM activities, Educational Robotics, attending robotics Competition

2.3. Are offers sufficient in order to increase kid´s STEM education in your country?

Through the data analysis we can assume that there are many offers for STEM education in Greece. However, as was also noticed through the desk research there are very few official initiatives in this field and as a result there are not specific guidelines or indicators for measuring the quality of the programs. Consequently, this also makes it difficult to define whether these offers are sufficient and can lead to the increase of STEM education in Greece.
The only reliable measurement system, measuring the quality of STEM education in relation to robotics existing, are the Robotics Championships. Robotics Competitions, are private initiatives and it is not obligatory for every organisation offering STEM Education to attend. Yet they are not part of the formal Education in Greece either. However, as it is a reliable measurement, the answers are indicating that all types of organizations offering STEM Education in Greece attend these championships.

Based again on the responses of the questionnaires, an unofficial indicator could might be the career choices related to STEM professions that students make and how much the STEM

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education they have acquired helped them to their career, but this is something really difficult to measure and even if we had this option there are many aspects affecting their STEM carriers during their adult lives.

Some further suggestions of the participants are the assessment through practical tests including real-world problem solving in a 360 evaluation basis (before, during and after the learning procedures).

Last but not least, many of the participants find it important in order to suggest a system, firstly the teachers to have better training on robotics and LEGO Education robotics equipment.

Considering all the above, it is obvious that teachers need support and a complete manual, with educational tasks and guiding content in order all the STEM educators to work in the same basis and with the same quality standards for their programs. This would also give the opportunity to measure STEM education in our country.

2.4. Identified gaps and recommended improvements

Despite the wide offer of STEM Programs, the answers given to our research are indicating some barriers in the implementation of the programs and also improvement potentials. Gaps and improvements identified through the EU Survey and the interview of key stakeholders are as follows:

The STEM science is being used by non-scientific teachers without a certain purpose or goal.

69,2% of the survey participants, answered that teacher training is necessary for a better quality in STEM Programs and 19,2% consider the support from school leaders crucial to achieve these standards.

Financial Barriers and the Economic Crisis in Greece

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STEM initiatives are private. There are very few public initiatives, which are not massive. 15,3% of the survey participants consider it important more funds to be given from the state for this scope, Furthermore 53,8% of them believe that programs would meet a better quality if teachers could get sufficient equipment.

Inflexible Curriculum in the Greek Schools

Time seems also an important aspect, with 30,7% of the participants mentioning that more time, would help them to offer STEM programs of better quality. Now STEM programs are in a volunteer basis and mostly after the official school hours. It is rather difficult to be implemented in the heavy school program.

3.0 Best Practices

Regarding the best practices we set as a basic criterion the four projects to be well known to the academic world and mentioned to the literature review. Moreover, to be adjustable in several learning environments and not only in the school classes and giving focus in the skills acquired by the participant students. Two of them (FIRST LEGO League and WRO) were also mentioned as best practises from the participants of our research.

The National Educational Program "Daidalos"

One of the firsts programs in this field. The programme aims to bring the special skills and talents of pupils in the field of science, technology and the arts to the surface. Moreover, it offers an opportunity for the practical application of knowledge acquired through the development of creativity and ingenuity by both pupils and educators (Karatrantou, Tachos & Alimisis 2005).

WRO-Hellas

The World Robot Olympiad (WRO) is a global robotics competition for young people. The World Robot Olympiad competition uses Lego Mindstorms manufactured by LEGO Education. The Hellenic Educational Robotic Contest is such a practise in Greece and mentioned in related articles. (Fessakis, Kladogenis & Markouzis 2012).

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Science debate! European Student Parliaments Project in Greece
Students become parliamentarians and discover the links between science and politics through Dialog in the European Student Parliaments (science view 2015). The academic research made for the projects indicates that argumentation is situated in science education and its beneficial contribution in advancing students' understandings of the epistemology of science (Smyrnaiou, Petropoulou & Sotiriou 2015).

***FIRST* LEGO League (FLL)**
FIRST LEGO League teams research a real-world problem such as food safety, recycling, energy, etc., and are challenged to develop a solution. They also must design, build, program a robot using LEGO MINDSTORMS® technology, then compete on a table-top playing field. It all adds up to tons of fun while they learn to apply science, technology, engineering, and math concepts (STEM), plus a big dose of imagination, to solve a problem. Along their discovery journey, they develop critical thinking and team-building skills, basic STEM applications, and even presentation skills, as they must present their solutions with a dash of creativity to judges. They also practice the Program's signature Core Values (FIRST LEGO League n.d.). The program is offered in Greece and mentioned in the related to STEM Education literature as a STEM offer in the country (Theodoropoulos, Antoniou & Lepouras 2016).

Taking into consideration the best practises and the barriers and with a holistic perspective of the literature review and the questionnaires' answers, we can have a quite clear view of the gaps and needs in STEM Education for Greece. This knowledge can lead to meaningful activities adaptable in an Erasmus+ Program.

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4.0. Policy initiatives

4.1 Central government initiatives

As described in the Greek Curriculum, the aim of the IT (Information Technology) course for introduction in programming is: acquiring knowledge and skills in understanding a problem, planning algorithms, learning programming techniques, implementation, and control of the program (Κ Υ Ρ Ι Α Κ Ο Υ and Φ Α Χ Α Ν Τ Ι Δ Η Σ 2012). Concerning the Educational Robotics, nowadays it is not included in the official curriculum of Greek school education (Alimisis, Karatrantou & Tachos 2005).

Central government in Greece have only implemented desultory initiatives, especially in the basis of EU projects. These initiatives are not massive and have a restricted duration and of a short perspective.

4.2. Regional government initiatives

There very few initiatives and the basic characteristic of all, is the short duration and the occasional perspective. A new promising initiative started through the collaboration between the Municipality of Pilea – Hortiatis and eduACT. The Junior Festival for Robotics, was implemented from February to April 2019 engaging 120 students, ages 6 – 10 years old in STEM & Robotics (eduact n.d.).

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4.3. Identified gaps recommended to Erasmus+

The basic gaps identified through our research that can be implemented into the Erasmus+ program:

- **Basically Private - Not Massive Initiatives for STEM Education**
  - Erasmus+ can help more students to have the opportunity in STEM Education
- **Sufficient STEM training for teachers.**
  - If possible, Erasmus+ can enhance the teacher trainer training through the robotics camps that can be offered together with the curricula.
- **No customized STEM curriculum.**
  - Erasmus+ can contribute to this, by making a curriculum that provides a complete package: teaching plan, mission/challenge, expected learning outcomes, teacher´s guide etc.

5.0. Conclusion and further research

The desk research and the questionnaires used in our EU research underline the importance and the focus given in STEM Education and Educational Robotics in Greece and Europe. The outcomes of our current research are in compliance with the research already conducted the previous years and indicate the next steps needed to move from theory to practice. A strong theoretical background that supports our hypotheses exists, so we hope that through this Erasmus+ Project we will offer sufficient to the identified gaps in:

- The training of Teachers in STEM and Robotics.
- The lack of a curriculum for the teachers for STEM and Robotics.
- The access to equipment for more students.

Further research can be made to measure the effects of these initiative in the carrier choices of the participants. Yet, research regarding the design of the next steps for enhancing student's performance in STEM and Robotics is really important if we want to continue and improve all the work done in the current project.

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Output 1

Erasmus+ Robotics 4.0 All

The aim of this report is to conduct a European research and needs analysis over the current state of STEM education and pedagogical robotics. The results of this report will be used by the "Erasmus+ Robotics 4.0 All" -project to develop a European curriculum for STEM education in relation to robotics.

1. Current level of STEM

1.1. Definition of STEM in Croatia

The definition of STEM in Croatia is straightforward. It is the area of science, technology, engineering and mathematics and is quite widespread and generally understood by all teachers, students and public. The STEM become quite popular as Croatia is undergoing the great curricula reform for the primary and secondary schools. There is, more of less consensus that the significant upgrade of STEM teaching is desperately needed. The data on choice of carriers is not favourable for the area. The enrolment in the STEM tertiary level education institutions was 40% (12.075 in 2015), and drop out in the STEM area was 41% during the first year of university, so the statistics are rather bad. Nevertheless, the debate in Croatia regarding the introduction of the new curricula was not around the STEM, but the social sciences and humanities, STEM was not a controversial issue.
The education in Croatia is centralized, and all schools of the same type has to provide the same curricula for their pupils/students.
So, the STEM education is covered in all primary schools, as well as secondary depending on the type of school (general – called gymnasiums or VET schools). The robotics education not so much. In the primary schools there are two lessons (90 to 180 minutes) dedicated to the robotics in the framework of Technical education in the 8th year of primary school (age 14) and usually it is not a practical work, but a bit of theory and a bit of demonstration of school robots. It can be on the video as well. Some schools may introduce practical work depending on whether they have a robots or not and the interest of individual teachers. At the level of secondary education, there is no formal robotics education at all, with the exception of the specialized VET schools within the curriculum for mechatronics technician where there is a lot of robotics.

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Wh ssons dedica y curricula i although it is not to be expected due to the small amount of time dedicated to Tecl recommendation given in Curriculum is to organize extracurricular activities in the schools or send pupils/students to local clubs for technical culture (they include robotics education in their activities). The real education in robotics is done within the framework of extracurricular activities in the primary and some secondary schools (with exception of already mentioned VET schools for mechatronics) and within the robotics clubs that are organized in local communities.
That being said, there is some important work to introduce robotics in primary schools through private initiatives and the enrolment of children and youth in local robotics clubs is raising.
The consensus of all is that situation is improving.

1.2. Publications aimed at analysing the development and implementation of STEM in education

Politehnika: Časopis za tehnički odgoj i obrazovanje, Politechnics is journal published by University of Rijeka covering articles related to technical and technology education in primary and secondary schools.

ABC tehnike, journal with paper and on-line edition covering technology for students and teachers, important for the popularization of technologies published by Croatian Association of Technical Culture.

1.3. Types of STEM methodologies applied

1.3.1. National, regional, local policies

National curriculum for Technical Culture	Curriculum applied in all primary schools, two lessons in robotics in 8th grade, providing basics recognition of main concepts, based on the learning outcomes that are established at low level
Extracurricular activities in primary and secondary schools	Possibility to start extracurricular activities in mostly primary schools, costs covered by Ministry for science and education, not covered by curriculum at all, the content of the lessons devised by teacher themselves according to the state of equipment and needs of children
National curriculum for VET schools – mechatronics technicians	Curriculum that has to be applied in all schools educating future mechatronics technicians, same for the all of Croatia
Additional education for teachers provided by Ministry for Science and Education	Education and Teacher Training Agency within the framework of official professional development is organizing seminars for teachers of STEM and informatics as well as

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	different t robotics from time to time)
Local initiatives by certain municipalities	Some municipalities that do not have local robotics clubs attached to Croatian Robotic Union are planning to start local robotics education initiatives within the community centres

1.3.2. Croatian Association of Technical Culture

Croatian Association of Technical Culture	The association of different unions related to different fields of technology education, including Croatian Robotic Union gathering local clubs that provide robotics education for children and youth in local communities outside the schools, strongly dependant on local enthusiasts, common in urban areas, rare in rural areas or small municipalities, financed by national, regional and local funds and by National Lottery

1.3.3. CSO´s and others providing education to children and youth in STEM and robotics

Croatian Robotic Association	16 local members provide robotic education to children and youth, professional development for teachers, organize competitions and summer camps
Institute for Youth Development and Innovation (Institut za razvoj i inovativnost mladih)	Private foundation that introduced STEM revolution in Croatian primary schools securing equipment, teacher training, content and workshops for children and youth in coding and robotics, introduced several new approaches combining grass root with institutionalization, the main idea is to spread initial knowledge of simple coding and work with robots to the sixth graders in elementary schools in whole Croatia, paying special attention to rural areas and small municipalities
Local formal or informal organizations providing some robotics education	Different type of organizations (NGOs, informal groups of enthusiasts etc.) providing space and some equipment for children and youth with strong interest in robotics (some of it quite advanced)

2. STEM education in Croa

2.1. Types of education offered in Croatia

Based on the desk top research and interviews with the key stakeholders

Organizations offering STEM education in relation to robotics - examples	Type of education offered
Institute for Youth Development and Innovation	IRIM used private funds and the biggest crowdfunding campaign in Croatia ever to introduce basic coding in all Croatian elementary schools providing equipment initial training for teachers and first workshops for children; IRIM also started the robotics in schools on massive scale with provision of equipment, training and content for the teachers. It started Croatian Makers Robotics League attached to the schools, thus trying to secure continuity of robotics education in extracurricular activities
Croatian Robotic Association	Roof organization of numerous local robotic community based clubs provide education for teachers and trainers, organizes Robo Cup Junior since (HLR-HROBOS) since 2011 and through its members provide community based continuous robotic education for those really interested in robotics (age 8 to 17) organizing different workshops, seminars, summer and winter camps, providing space and equipment for children and youth
SuperSTEM	Community based organization providing basic knowledge on robotics for pre-schoolers in kindergartens and children 6 to 10 years old, development of methodology for work with young children in order to encourage and channel their curiosity in STEM (with emphasis on technology)
Centre for Technical Culture Rijeka	Community based organization (member of Croatian Association for Technical Culture) providing retraining in ICT area for unemployed, engaged in different activities with youth in STEM with emphasis on social inclusion and social responsibility and ethics of STEM

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Act providers of roatia for c

The four-abovementioned organizations are the examples of variety of robotics ed

The two major approaches can be identified and both are needed:

- ✔ Go for large sweep and get all the children involved

That is approach of IMRI that introduced coding in all primary schools in Croatia providing simple equipment, teacher training and initial workshops in coding for children. The introduction of basic, simple coding on m:bits have finally get some experience with coding in Croatian schools for all children in 6th grade. Later, it moved to introduction of robotics in the primary schools providing simple and more advanced robots. Also, it started the Croatian Makers Robotic League that have more than 11.000 school children involved in the League. The approach is important because it provides children with some understanding of 21st century technologies and in some sparks interest for greater involvement.

- ✔ Pick up interested children and freak them out with robotics

That is approach of community based robotics clubs that may or may not be linked to Croatian Association of Technical Culture and Croatian Robotic Association. They organize workshops, seminars, courses, summer camps, robotic leagues for the children that are already interested in technology and robotics. Those children have to seek by themselves (usually encouraged by their teachers, parents or peers) the places where they can work and develop serious abilities in robotics.

2.2. Are offers sufficient in order to increase kid´s STEM education in your country?

It seems that there is sufficiently differentiated offers that provide different approaches, methodologies and levels of robotics education. Anyway, not all approaches, methodologies and levels are accessible to all kids due to the geography and lack of information.

It is not possible to evaluate the quality of provided education, as it is extracurricular or in-formal.

The regional dispersion of education is uneven with more possibilities concentrated in urban areas.

The IMRI results are not properly evaluated yet, as the initiative is still young and it will take time to see the level of sustainability and impact in pushing children into STEM.

It looks like the main issue in Croatian robotics education is sustainability of activities of different initiatives as it is hard to secure funding. Also, as the education is extracurricular or community based it is fragmented. It is not supported by national action plan that would allow for more networking and information spread, as well as for some evaluation of the education impact.

Actually, it is not possible to determine if the offer is sufficient for all children and youth in Croatia. Most of the key stakeholders were leaning to the insufficiency of STEM and robotics education in

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Croatia, although all of them recognize some good examples and claim that situation is improving but too slowly.

2.3. Identified gaps and recommended improvements

- ✔ **Lack of basic education on robotics in national curriculum for primary and secondary schools (except some VET schools curricula). Robotics are still considered an extra-curricular activity and not a mainstream skill that should be included in curriculum with more practical approach instead of 90 minutes of theory.**

Possibility for improvement:

Provision of more time and practice in newly debated national Curriculum for Technical Culture and moving it in earlier grades (5th or 6th) in order to sparkle interest and guide interested and talented students to more in-depth extra-curricular activities.

- ✔ **Robotics as extra-curricular activity**

Extra-curricular activities in Croatian school system depend on the willingness of schools to introduce them. Usually, they are initiated by individual teachers who are enthusiasts or lack some teaching classes to full time job. Both motivation can not last for a long time and that leads to the volatility of robotics education.

Possibility for improvement:

Not foreseen in near future. Robotics as extra-curricular activity is only feasible at the moment.

- ✔ Lack of national action plan for popularization of STEM (including robotics)

Possibility for improvement:

National action plan that will develop measures to overall popularization of STEM and robotics in order to introduce a system of information gathering and spreading and networking

- ✔ Lack of continuous financial support for community clubs in order to secure their stability

Possibility for improvement:

Encouraging the regional authorities to organize and support a network of local technology clubs that will have robotics

- ✔ Lack of educational materials for teachers and trainers working in robotics education

Possibility for improvement:

Organization of on-line repository of training/teaching materials by some appointed organization

- ✔ Lack of on-going professional development for teachers/trainers in STEM/robotics education

Possibility for improvement:

Within the framework of professional development organized by the Education and Teachers Training Agency more seminars should be dedicated to STEM/robotics education methodology

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Possibility for improvement:

Development of curriculum

- ✔ Lack of criteria for evaluation of the impact of existing initiatives

Possibility for improvement:

Development of system of self and peer evaluation

- ✔ Lack of quality control

Possibility for improvement:

Not feasible in Croatia at the moment

3. Best practices in Croatia

3.1. Criteria for defining best practices

- ✔ Children and youth willing to participate in them
- ✔ Encourage logical and critical thinking
- ✔ Develop self-esteem
- ✔ Develop interest in technologies and robotics
- ✔ Encourage practice and engage potentials of all children
- ✔ Show the progression of easy tasks to more complicated
- ✔ Everybody is able to participate in some activities

3.2. Best practices

Croatian Makers League is part of the Croatian Makers project of the IRIM. The goal of the league is to include robotics, automatics and programming in the primary schools in Croatia. The schools are applying to participate in the league and are provided with robots (mBot Bluetooth version that is simple to use but allow advanced usage) that become their property after one year of active participation. The league has two categories (1st to 5th grade and 6th to 8th grade). In the year 2018/2019 more than 550 primary schools are participating in the league with more than 11,000 pupils and students. The competitions start at local than regional and end at national level. There are also on-line competitions. It allows for the continuous extra-curricular robotic education in primary schools.

The league is covering all of the Croatia, and lot of schools participating in the league are from rural areas, thus allowing usually deprived children to develop their competences. Also, the initiative is interesting as it combines private initiative with national institutionalized education and circumvent the usual problems of equipment acquisition.

The *ed robotic cl* courses, su access to different robotic leagues for the children and youth with well-developed i and advanced skills. The safe space that is provided by the clubs for the talented and interested children and youth is of outmost importance to foster their skills and interests developing innovative mind set.

Robocup Junior Croatia exists since 2011 and is part of international organization. In Croatia it is run by Croatian Robotics Association. At the competition more than 100 teams (3 persons each) were compiting in 12 categories (Speed Line Follower, Robo Bowling, Rescue Line Beginner, Rescue Line, Rescue Maze Beginner, Rescue Maze, Rescue Simulation, On Stage, On Stage Advanced, Soccer Beginner, Soccer Light Weight, Soccer Open). The teams usually originated from secondary schools or from local robotics clubs. Some categories are for more advanced teams. The league is important, as it already exists for eight years showing the sustainability that is not always granted in Croatia.

3.3. Possibility of adaptation of best practices for Erasmus+

The Erasmus + can adapt some of the characteristics of the best practices:

- ✔ Co-operation of private initiatives and national public education system
- ✔ Community based technological clubs supported by local and regional authorities
- ✔ Sustainability of the initiatives
- ✔ Availability of the education
- ✔ Progression in complexity of challenging tasks.

4. Policy initiatives

4.1 National policies

Developed Strategy for Education and Science but not really implemented regarding STEM

4.2. Regional policies

Possibility to develop VET schools that will become centres of excellence – some counties decided to develop VET schools in the area of technology

4.3. Local policies

Some municipalities decided to develop STEM hubs that include communal in-formal STEM education for children and youth or for all citizens (including elderly)

4.4. Identified gaps that can be implemented in Erasmus +

- ✔ Lack of national action plan for popularization of STEM (including robotics)

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- *makers on national level) and can serve as source of data and ins*
- *preparation of action plan*

- ✔ Lack of educational materials for teachers and trainers working in robotics education
  - *Curriculum developed by the project can be part of the future repository, until than it will be accessible to all the teachers and trainers:*
- ✔ Lack of on-going professional development for teachers/trainers in STEM/robotics education
  - The ToT methodology used by project can be used in national education
- ✔ Lack of developed curricula for robotics education at different levels
  - Development of curriculum during the Erasmus + project can be beneficial to all teachers in robotic education

5. Conclusion

Croatia has some serious problems regarding STEM education and robotics in particular. Informatics that include some basic coding becomes obligatory in primary education last year in primary and secondary schools (until 2017 it was only elective subject in primary schools). Robotics education is still extra-curricular activity (not an elective) and for the most of interested children and youth still relegated to the care of community organizations. The professional development of the teachers/trainers is sadly insufficient and teaching materials in Croatian not readily available. The robotics education is fragmented and networks of practitioners are small or non-existent.

Although, there are some major improvements in last two to three years additional efforts are needed:

- Larger financial allocations on national/regional/local levels for the improvement of the schools equipment
- Inclusion of robotics as elective subject in primary and some secondary schools
- More local support for community technology clubs
- Development of teachers/trainers materials, curricula etc.
- Improvement of teachers/trainers professional development in the field of STEM and robotics.

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Research Report on the Current State of Robotics Education in Spain

Inercia Digital S.L.

Contents

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Current level of STEM

Status of the regulations for the adoption of STEM-based content into primary and secondary public education

The current offer of STEM-related subjects in studies previous to VET and Higher Education is scarce, and is highly dependent on the region of study, as education is a competence of the autonomous areas of Spain. As such, no current regulations comes from the central government in the matter of robotics, programming or any other computational field.

As per the report *Programming, robotic and computational thinking in the classroom* (Instituto Nacional de Tecnologías Educativas y de Formación del Profesorado, 2018), the regions of Spain which regulation allows the centre to offer STEM-related subjects in the curricula of primary, secondary and high schools are:

Andalucía:

- Secondary school: Technology
- High School: Industrial Technology I and II, ICT I and II, and Programming and Computation

Asturias:

- Secondary school: Robotics. It consists in four blocks:
    - Block 1: *Control foundations*, covers basic elements about automation and programming languages.
    - Block 2: *Robotics foundations*, covers technical aspects and automation design, technical features, processes of integration of the components on a robot, and references of 3D printing.
    - Block 3: *Robotics in society,* covers the applications of robots, its impact in the society, the problems and solutions that it implies, as well as the ethic reflection on its impact in the society.
    - Block 4: *Robotics projects*, integrates the knowledge that the learners have acquired and that should use in the design, construction and control of a

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robot, including the necessary technical documentation for the development of a project.

Balearic Islands:

- Secondary school: Technology. Block 1 covers information and communication technology, including basic concepts of programming languages. Block 4 covers control and robotics.
- High school: ICT I and II. Block 1 covers programming.

Castilla y León:

- Secondary school:
    - Robotics and control. Covers design, production and assembly of a robot, as well as developing the computer software that controls the robot.
    - Computer programming. Block 1 covers the basics of problem solving. Block 2 covers visual programming and the concepts of programming languages (variables, statements, operators...). Block 3 covers coding. The learners will develop videogames and mobile applications.

Castilla-La mancha:

- Secondary school: Robotics. Covers design, production and assembly of a robot, as well as developing the computer software that controls the robot.

Cataluña:

- Primary school: programming, robotics and computational thinking concepts are included in the areas of Mathematics and Environment.
- Secondary school: Technology, ICT.

Valencian Community:

- Secondary school: ICT, Technology, Computing.
- High school: ICT, Technology.

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Extremadura:

- Primary school: Practical Scope and New Technologies
- Secondary school: Technology, ICT, Industrial Technology I and II
- High school: ICT I and II

For all of them there are blocks dedicated to basic concepts of computer programming and/or design, making and programming of robots.

Galicia:

- Secondary school: Programming. Covers the knowledge needed to solve problems by designing algorithms and codifying programs.
- High school: Robotics. Covers the evolution of these machines, the programming and control the process of design, making and assembly.

Madrid:

- Primary school: Technology and digital resources for the improvement of the learning. Covers programming basics through small games made with Scratch.
- Secondary school: Technology, programming and robotics. Covers programming and computational thinking, robotics, technology, project-based learning, Internet and its safe use and 3D printing.

Murcia:

- Secondary school: Robotics. Covers programming, sensors and control. Oriented to learning by challenges.

Navarra:

- Primary school: Programming has been integrated into the Mathematic subject.

La Rioja:

- Secondary school: Technology

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- High school: Industrial Technology I and II, ICT I and II

Summary of the current state of the regulation

In blue we see the regions that have included new subjects or content about programming, robotics and computational thinking in Primary school; in green in Secondary school and in purple, in both.

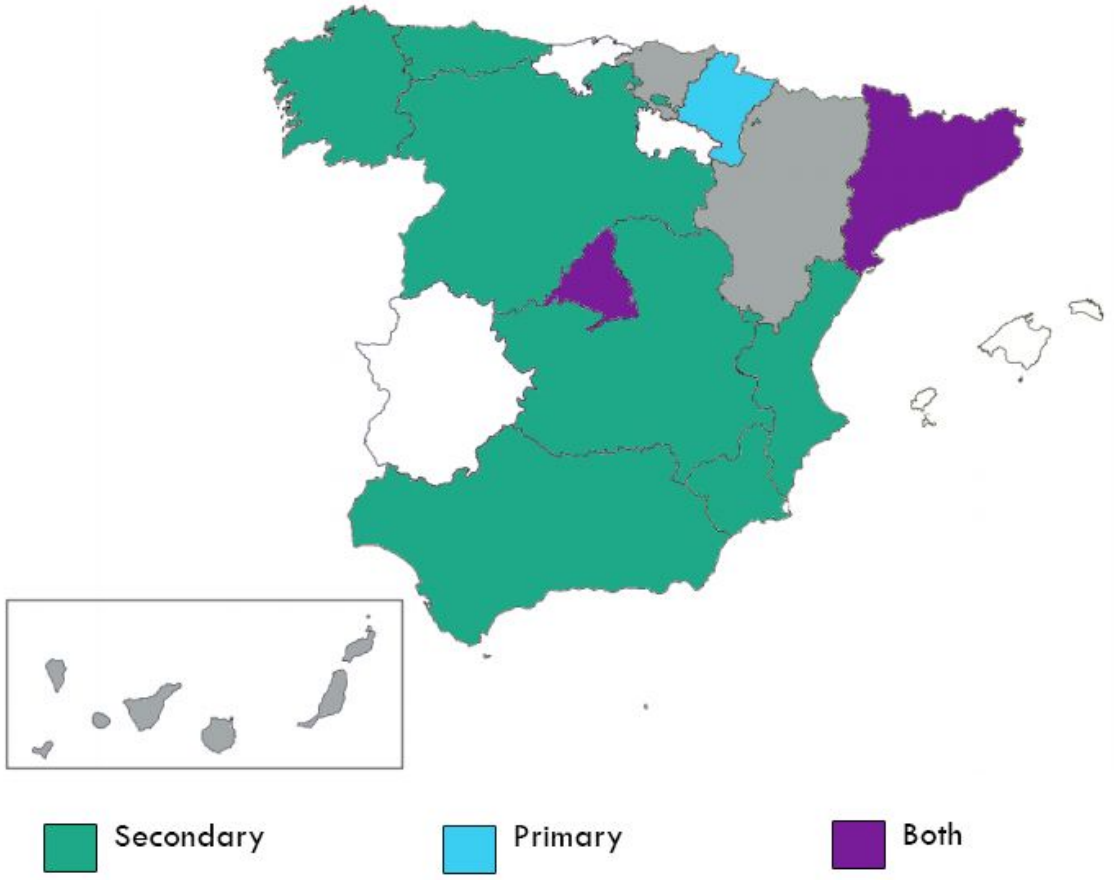

Figure 1: Map of the implementation of regulation for STEM subjects in Spain

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As we can see, Navarra has included this content in primary education, integrating them in Mathematics.

Andalucía, Asturias, Castilla-La Mancha, Castilla y León, Galicia, Murcia y Comunitat Valenciana have introduced new subjects for robotics and programming in secondary education. Madrid and Catalonia have included them in both.

Finally, Balearic Islands, Cantabria, Extremadura and La Rioja have not created any new subject nor included its content in any existing one.

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Organisations offering STEM activities to students and/or teachers

As the regulation is different per region and the implementations differ, the organisations and institutions that offer any kind of training for STEM vary enormously. As such, not every teacher and student have the access to the same kind of teaching.

Nevertheless, most regions have several activities organised either by the public or private institutions aiming to involve the centres in the development and learning of robotics with contests, workshops or extracurricular activities. Some examples of activities being offered are:

Clase de Tecnologías Creativas, in Andalusia. Developed in 2015, it offered to around 3.000 students of secondary education a collaborative teaching programme designed for secondary schools that intended to include new technologies in their Technology subjects. It promoted free software and was divided in four phases:

- Phase I, teacher's training, where teachers from 75 schools participated in several workshops to acquire the required knowledge
- Phase II and III, where students experimented with their kits and produced their final projects
- Phase IV, the Technology Fair, where the students present their projects to the rest of the students and to the public in general

Malakabot, in Andalusia. They're a workshop in Málaga about robotics organised by the Electronic Department of the IES Politécnico Jesús Marín, with the collaboration of the Image and Sound Department. Includes several modalities for contest and exhibitions from the Universidad de Málaga and several private companies. Every year more than 100 robots are presented, and several workshops, tutorials, competitions and collaborations take place.

RobotIB, in Balearic Islands. With the aim of boosting the introduction of robotics among the students of secondary school, several centres receive a grant of material for robotics as well as training for the involved teachers. The regional government organises the training and the materials for the centre (Arduino toolkit and robots for one classroom), disseminate the best practices and evaluate the results, while the school will design and implement a project of introduction to robotics with a group of secondary education students.

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Status and feasibility of the current adoption of STEM-based subjects

The *Kindergarten and Beyond LifeLong Learning* (KGBL3), a group consisting on researchers from the Universidad Rey Juan Carlos and the Universidad Nacional de Educación a Distancia, has developed several researches proving that the development of computational thinking through programming has a positive impact when learning several disciplines, such as mathematics, languages, sciences or narrative.

Particularly, this group investigates two issues of special relevance in the educative scope: the different results found depending on the age of the students, and the training requirements of the teachers to achieve the goals.

Some relevant conclusions to our research come to the following:

- It is important to introduce this knowledge in primary education, even if it is in the final years, when the students have enough cognitive maturity to increase the transferability chances.
- First, include it in Social Sciences, so that the students "can be confident and self-sufficient". Later, integrate it in more complex subjects such as mathematics.
- The proper training of the teachers is key in the learning outcomes that the students can reach. This problem is accentuated by the high demand of professionals in the field of computing that is already happening in many countries, and that will exceed the offer. According to the estimations of Code.org, the specialists will only last 3 years in the schools before they decide to change to another professional field.
- As such, it's necessary to hire urgently specialists in teaching and learning computing in the faculties of education, to properly train future teachers.

Sociedad Científica Informática de España (SCIE) manifests the necessity to include the subject "Computer Education" into the Spanish education system as a mandatory subject from primary education until high school. They understand that a complete training for the information society can't only demand the acquisition of the digital competence, but also the methodological and conceptual basics of computing. As such, a complete training must include both digital literacy (computing knowledge as users) and computer sciences (the study of the scientific and technical foundations of computing). "Computer Education" must be defined legislatively defining its content, evaluation criteria and learning outcomes, same as the rest of the subjects.

They understand that the proportion of content of digital competences and computer sciences should vary depending on the education stages and the corresponding degree of maturity of the students:

- Primary education: Should include mostly contents of digital competence that ensure the knowledge and skills for the efficient and ethic use of the information technology. It will also include basic knowledge of programming and computers.
- Secondary education: Should include mostly content of computer sciences that ensure the knowledge of programming, algorithms, logic, computers and other fundamental branches of computing. The digital competences will be developed as a medium user level.
- High school: Should be offered slightly customised in the modalities of Sciences, Social Sciences, Arts and Humanities. It will cover the knowledge of computer sciences that require a higher abstraction level and in digital competences as an advanced user level.

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INTEF survey

In the same report, INTEF has developed a survey with 351 teachers regarding their work in STEM-based subjects.

When asked about the scope of their teaching, whether it was specific (focused around the technology) or transversal (focused on supporting other subjects not related to computers or technology), most of them used an specific approach (Figure 2), though most of them agreed that the transversal approach is better for pre-school and primary (Figure 3).

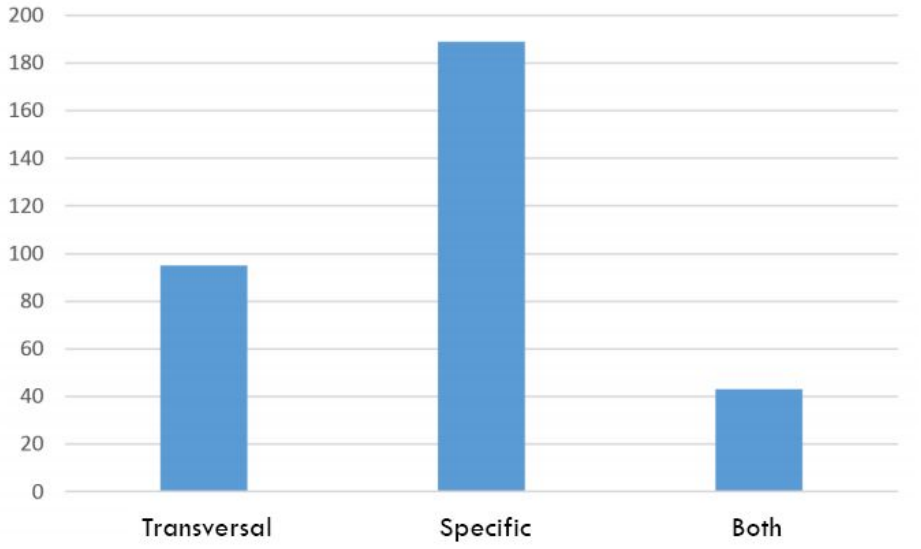

Figure 2: How do you use include programming, robotics and computational thinking in your classes?

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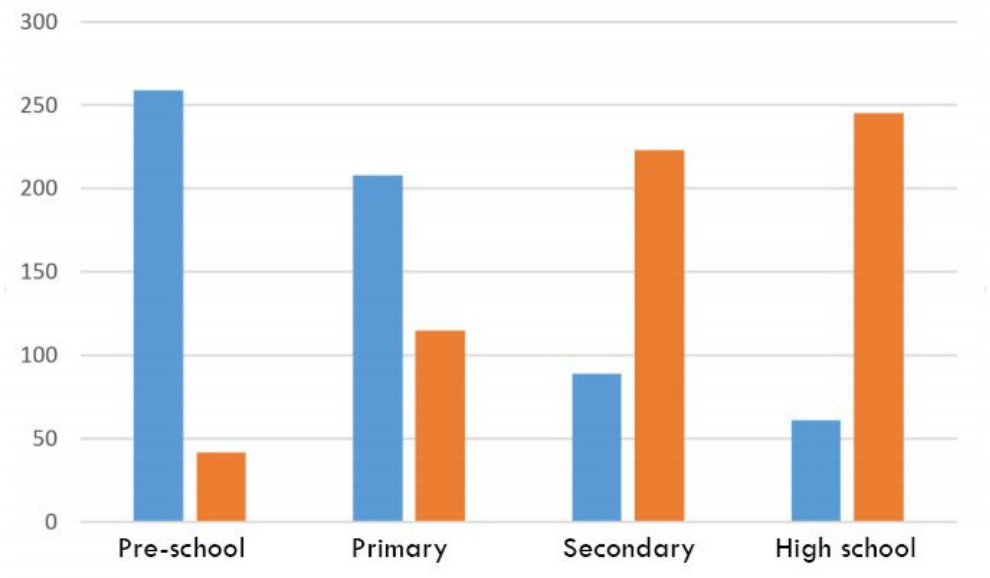

Figure 3: Teaching approach per level. In blue, transversal. In orange, specific.

When asked about the number of yearly hours dedicated to work in programming, robotics and computational thinking, most of them would declare less than 50 hours per year (Figure 4).

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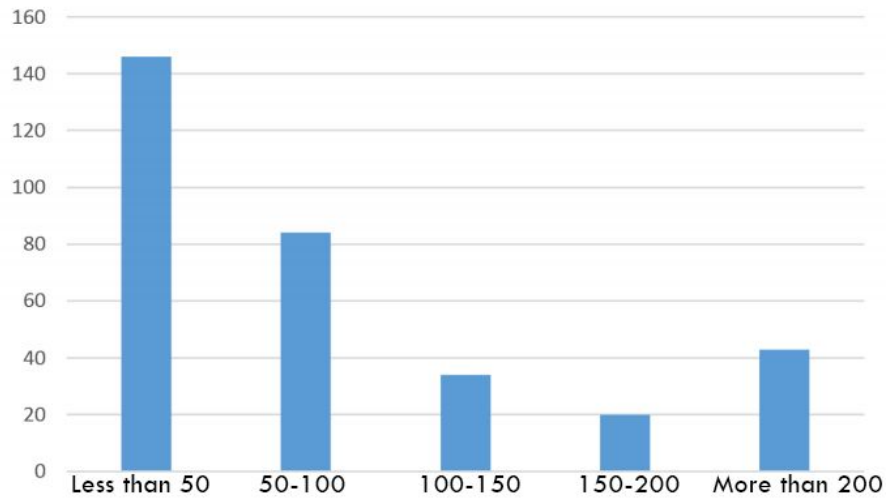

Figure 4: Number of yearly hours dedicated by the teachers to work in STEM

When asked about what kind of training they received, most of them learned on their own, while some received training from official courses. The number of teachers with a higher education degree in the matter is very reduced (Figure 5).

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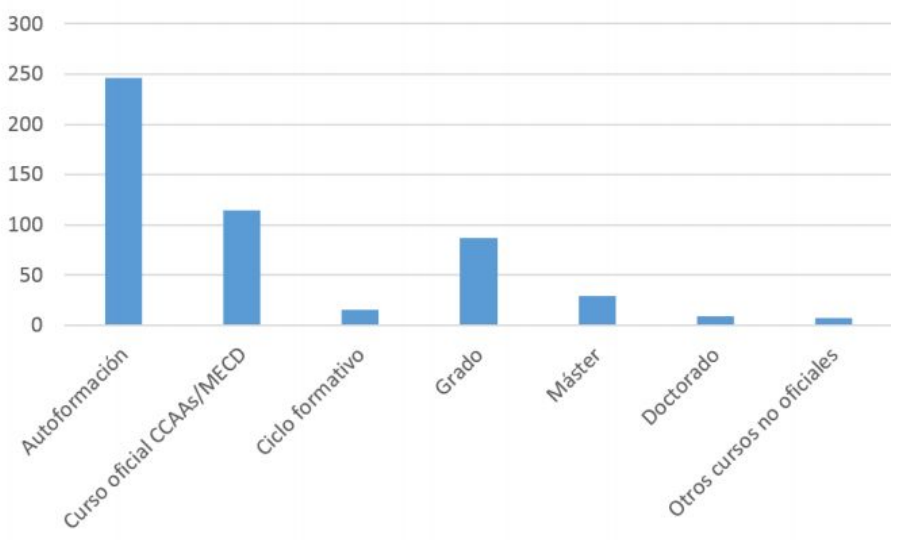

Figure 5: Training received. From left to right: On their own, official courses, VET degree, University Degree, Master, PhD, other unofficial courses

When asked about the kind of boards or robots they used, most of them would use Arduino, followed by Lego WeDo, and none at all.

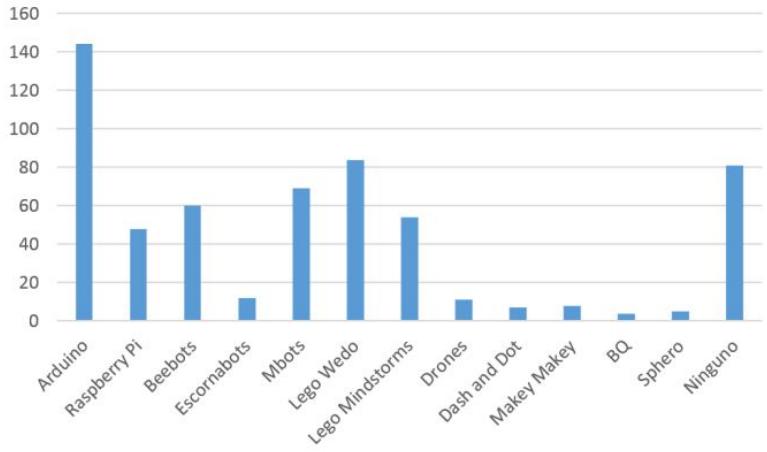

Figure 6: Boards and robots used by the teachers

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Finally, they were asked how they evaluated their own programming/robotics skills, in which most of them approved with good marks, as seen in Figure 7 (their own skills) and Figure 8 (the learning outcomes of their students).

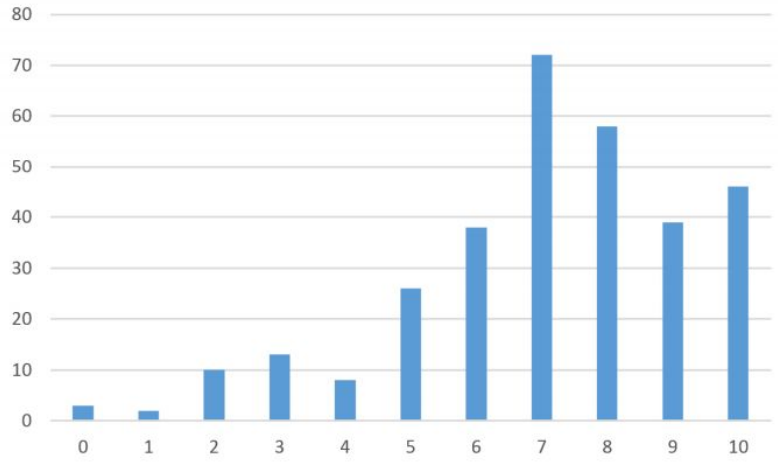

Figure 7: How would you evaluate your own skills in programming, robotics and computational thinking?

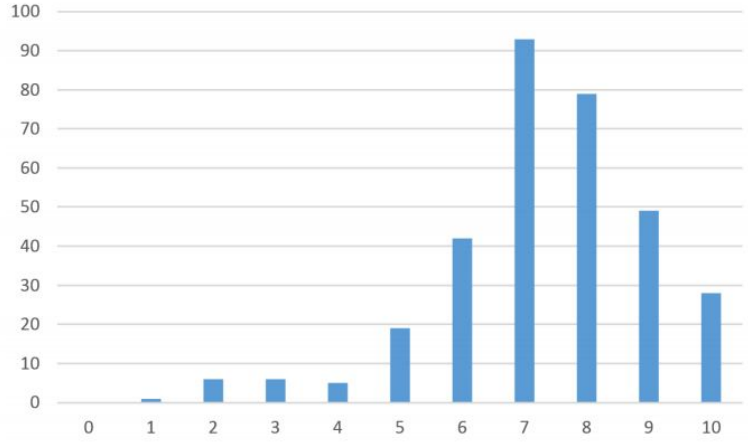

Figure 8: How would you evaluate your students' learning outcomes related to programming, robotics and computational thinking?

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Robotics 4.0 Spanish Survey

As part of this research, every partner conducted a survey among the teachers of the centres offering any kind of robotics content. Inercia Digital was responsible of conducting the survey.

As of 17th of April 2019, 6 teachers and 1 HEI student answered the questionnaire. The first part relates to this section of the report.

4 of them worked as public secondary school teachers (one of them also in a VET centre), 2 of them in private secondary schools (one of them also in a private primary school) and 1 of them in a Higher Education institution (Figure 9).

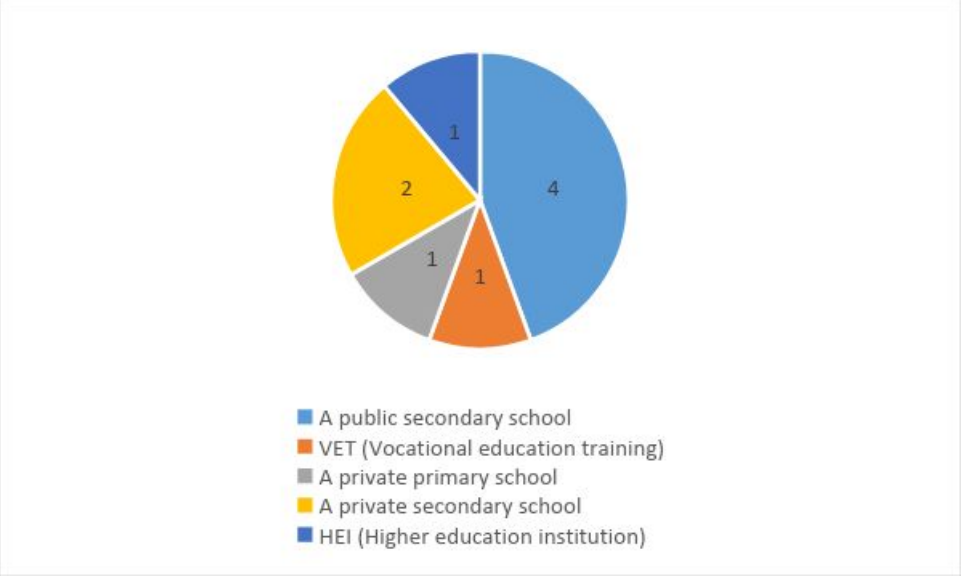

Figure 9: 1.2 What type of organisation do you work for?

When asked if their organisation offered any STEM education, only one of them (a public secondary school teacher) said no.

When asked about the kind of STEM activities they offered, they answered the following:

- Besides of the regular subjects, our center offers others based on the robotics and computer programming: Scratch,LEGO Mindstorms, Arduino, Raspberry, 3D Printing, etc.
- VET degrees of Electricity-Electronic and Computers

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- Templates with Colby (spatial orientation in the reproduction of the different templates), templates of vocabulary with Beebots (in which the vocabulary worked on in English and Spanish is reinforced, as well as the spatial orientation, the numbers...)
- Nothing from the centre. Some teachers that organise activities in their subjects.
- Biology and Geology, Physics and Chemistry, Mathematics, Technical Drawing, Technology, Computers.
- Minecraft and Lego
- Extracurricular activities

When asked “In your opinion, what is the current level of STEM education in relation to robotics in your organisation. 1 being the lowest level = needs improvement 5 the highest level = very good quality”, majority voted for the lowest half of the spectrum, clearly indicating the overall dissatisfaction with the current implementation of the STEM activities in the centres (Figure 10).

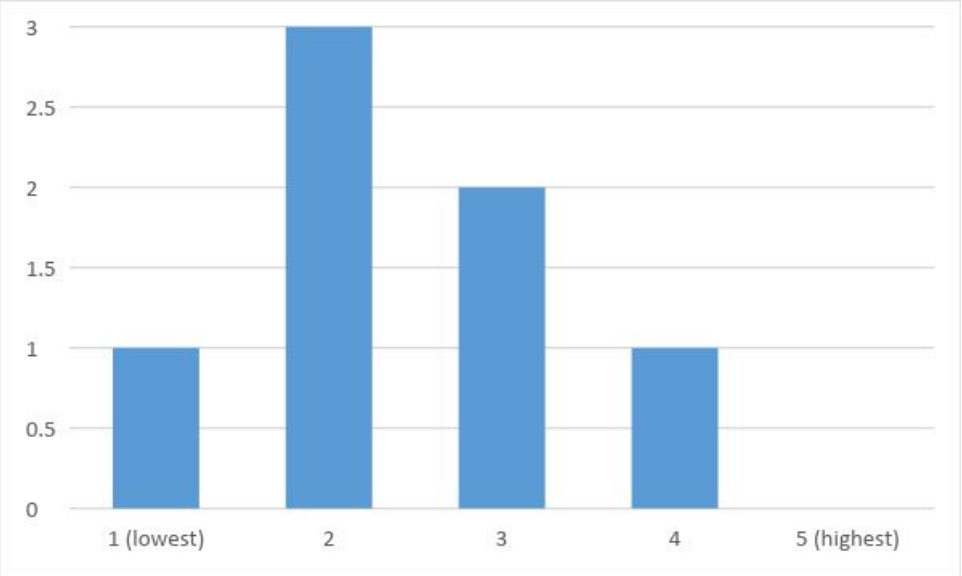

Figure 10: 1.4 In your opinion, what is the current level of STEM education in relation to robotics in your organisation. 1 being the lowest level = needs improvement 5 the highest level = very good quality

When asked “Does your organisation offer any other STEM activites in relation to robotics than what is listed above? If so, please specify below”, they answered:

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- National Tournment (FLL, Tenerife),
- HEI degree in Automation and Industrial Robotics
- Extracurricular activites for primary education
- No (x2)
- Lego and Minecraft
- Extracurricular activities

When asked "How many students in your organization have participated in these initiatives in 2018?", they answered as following (Figure 11):

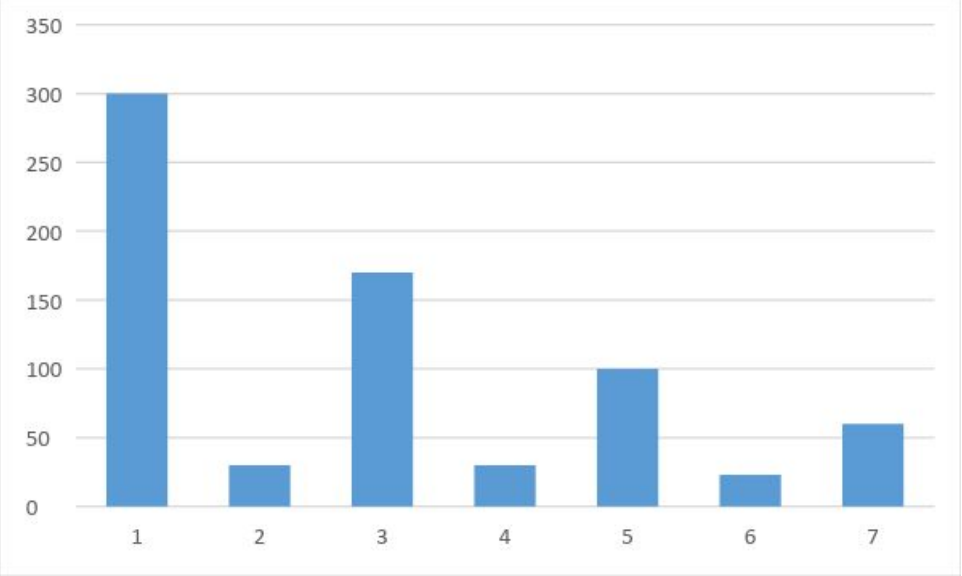

Figure 11: 1.6 How many students in your organization have participated in these initiatives in 2018?

When asked "What age group do the students belong to?", most students were in the range of 10 to 19 years (Figure 12).

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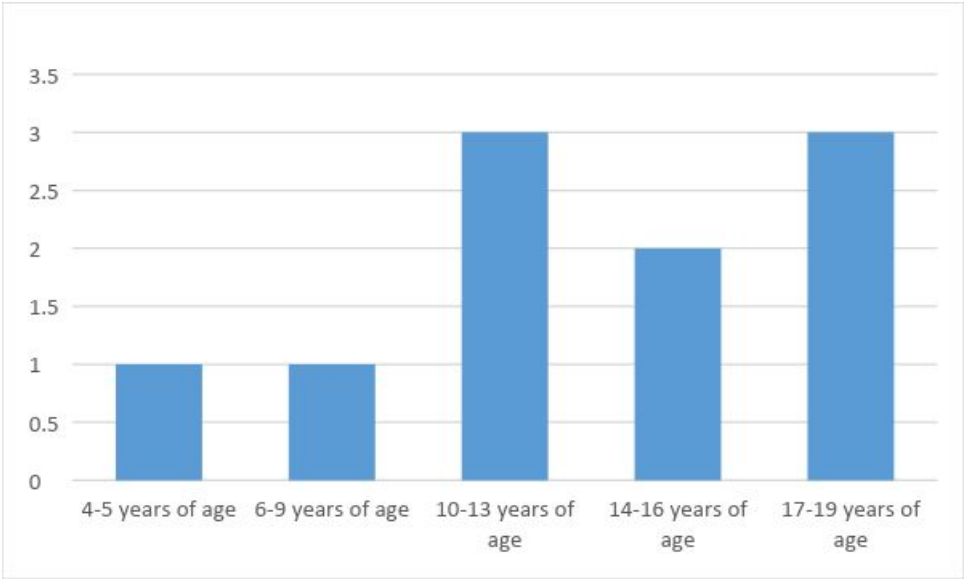

Figure 12: 1.7 What age group do the students belong to?

When asked how is the program offered, most of them chose Nationally, followed by Regionally (Figure 13):

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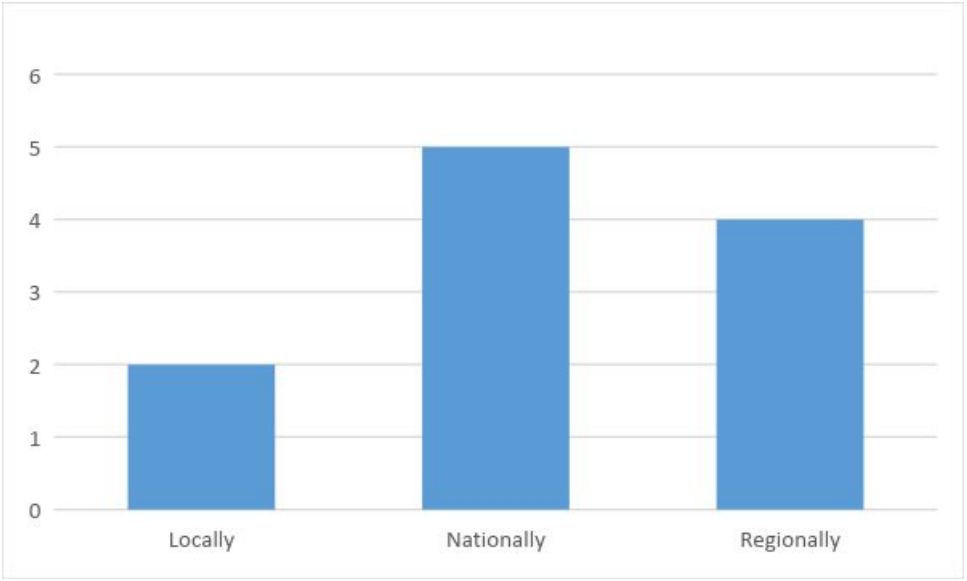

Figure 13: 1.8 Is the program(s) offered

When asked "Do you think the activities/programs you offer are sufficient to give children good experiences, and provide them with basic skills in STEM education in relation to robotics?", most of them agreed it was not enough (Figure 14):

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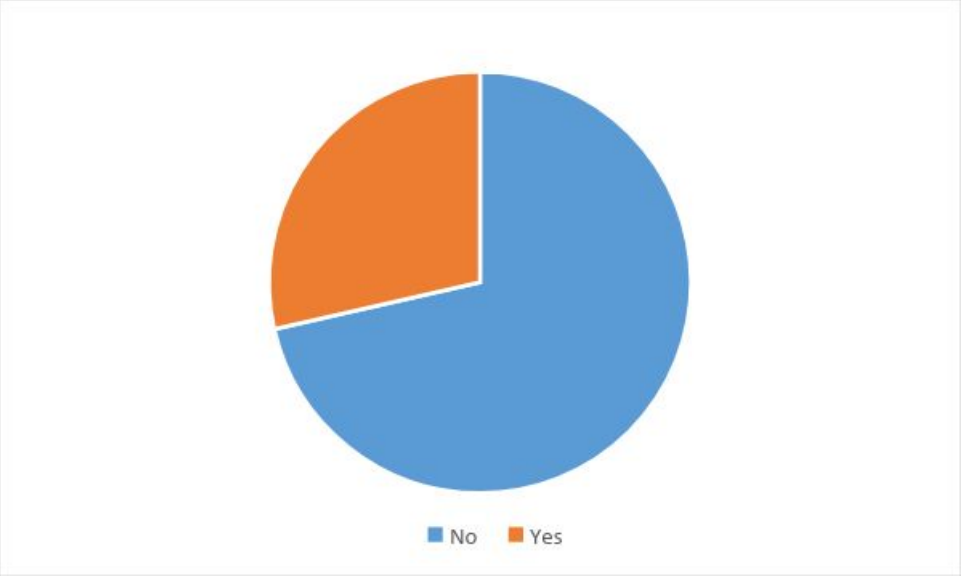

Figure 14: 1.9 Do you think the activities/programs you offer are sufficient to give children good experiences, and provide them with basic skills in STEM education in relation to robotics?

When asked "Which policy initiatives have been implemented in central government to increase the competencies of both children and adults in STEM education and robotics", the answers are as follows:

- In a generic way, the objectives of the stage include the acquisition of skills related to robotics
- They were added in the Official Newsletters competences related to STEM
- Inclusion of the computational thinking in the area of technology and computing
- The CTC-101 Arduino training programme

When asked "Which policy initiatives have been implemented in regional government to increase the competencies of both children and adults in STEM education and robotics", the answers are as follows:

- A few units have been included in the books of the subject called Technology (2nd and 3rd year)
- They were added in the Official Newsletters competences related to STEM
- The PRODIG project

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- The Arduino training programme and others to know applications to develop for those devices

When asked “Which policy initiatives are being implemented in the next few years, that aims to increase the competencies of both children and adults in STEM education and robotics”:

- We haven't heard about any. There is new government in Andalucia so it's difficult to say...
- From the public administration very few, almost none. Some courses for Technology teachers
- I only know those referring to the students

When asked “What policy initiative gaps have you identified?”:

- The curriculums are obsolete. New contents take too long to appear in official programs.
- The centre is immerse in daily problems related to disciple and functioning
- Lack of training of the teachers
- Few hours dedicated to STEM activities
- The training can be improved for the teachers, and the development of activities in class

When asked “Feel free to include any additional information regarding policy initiatives you consider relevant and/or important for the purpose of this project”

- New contents should be include in official programs such as programing and robotics for all students
- We lack the time, resources and support to develop STEM activities
- ... in earlier ages

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Conclusions

The main problem identified is the lack of mandatory, transversal nationally defined subjects covering robotics, programming or any other computational field. Most of the subjects offered by the different regions in their regulation are optative: most of the times, a student can finish their mandatory education without passing through one technological subject.

Another problem is the fact that many centres offer these activities as extracurricular. As such, they're often outsourced to a company, so not only they're not available to every student, but the teachers don't receive the knowledge to deliver a STEM-based class.

The lack of training of the teachers prevents the proper implementation of these subjects. It's surprising that, with the amount of teacher's trainings being offered both from official institutions and non-profit organisations, most teachers have to resort to self-learning.

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1.0 Current level of STEM

1.1. Meaning/definition and difference of STEM in Cyprus

Due to the global division of labour, the outsourcing of industrial production to other parts of the world and the rise of a knowledge-based economy, scientific and technological innovations have become increasingly important. According to the "Research and Innovation Study" contacted by the European Commission in 2017, Cyprus ranks below the EU average. The report notes that "Cyprus has a very high tertiary education attainment rate, but a relatively low proportion of graduates in the fields more strongly linked to innovation" (Research and Innovation in the Country Semester Report 2017). Also a country analysis made by the European Commission in 2018 on Education and Training concluded that "Digital skills are improving but STEM graduates remain rare. Half of the population reported to have at least basic digital skills vs 43 % in 2016. However, Cyprus' share of STEM graduates (9.8 %) remains the lowest in the EU (European Commission, 2018c). To boost digital skills, the National Coalition for Digital Jobs has introduced cost-free digital certification for students and school competitions in fields such as coding and robotics. Furthermore, computer science is taught in all-day primary schools and secondary schools." (EC report on Education and Training Monitor 2018 – Country analysis)

STEM education is a new, more effective way of teaching/learning Science, Technology, Engineering and Mathematics, embedding more than learning just sciences. This is why some are using the term STEAM, by adding "A" for Arts (inferring to the capacity of creativity) and others go beyond to call it STREAM by also adding "R" for Read and Write (inferring the capacity to express and present ideas).

What separates STEM from the traditional disciplinary education is the blended learning environment, teaching children, from a very young age, how the scientific methods can be applied to everyday life as it focuses on the real world applications of problem solving. Through the STEM teaching methodology, the students develop hands-on skills, critical and

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analytical thinking, social and communication skills, while learning how to operate as part of a team.

STEM Education is a relatively new concept in Cyprus and it is often confused with other closely related terms, like robotics. Thus, the entire STEM education ecosystem remains undefined, confusing and misleading.

As STEM Education has been around in Europe for the past 10 years, some Cypriot organisations have used European projects, especially Erasmus+, to draw experiences and knowledge.

“Engine4F – Engineers For Future” addressed a common European need related to the lack of qualified staff within technical and engineering professional areas, especially women. The project had intervened among 8th and 9th grade students, and female students in particular, to increase their exposure to technical areas and engineering professions by promoting the learning of STEM related subjects through creative and innovative teaching practices. Cypriot partners was the Neapolis University Pafos.

“GiGS - Girls into Global STEM project” aimed at increasing the employment potential of young Europeans, especially girls, by improving their interest and engagement in STEM linked with wider awareness of global issues and facilitated through digital skills. It alse had supported teachers in the embedding of digital skills and global learning methodologies into their STEM teaching. Cypriot partners were CARDET Ltd and The Grammar School Nicosia.

Another Erasmus+ project was EL-STEM which aimed at fostering an innovation “ecosystem” that will facilitate more effective and efficient user-centric design and use of AR/MR resources for personalised STEM learning and teaching. Cypriot partners were the Open University of Cyprus, the European University of Cyprus and the Pallouriotissa Lyceum.

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1.2. Publications aimed at analysing the development and implementation of STEM in education

1.2.1. Cypriot publications

The publications found through the desk research were mostly produced by private initiatives, or as products of the very few STEM conferences which took place the last couple of years. Furthermore, stakeholder who have direct interest in STEM education often publish articles on the local developments as the reform plan of the Ministry of Education is currently in progress.

Cypriot Journal of Educational Sciences (CJES) is a refereed journal published quarterly. The journal seeks to serve the Professional interests of individuals working in various educational disciplines to related theories and practices. Preferred articles; experimental researches, reporting educational researches, suggested models, reviews of recent literature should be relevant to educational concerns and issues.

The IEEE Transactions on Learning Technologies (Volume: 12 , Issue: 1 , 1 Jan.-March 2019) Article : SciChallenge: A Social Media Aware Platform for Contest-Based STEM Education and Motivation of Young Students. SciChallenge European project, which aims at increasing the interest of pre-university students in STEM disciplines, through its distinguishing feature, the systematic use of social media for providing and evaluation of the student-generated content.

Digital Cyprus: Catalyst for Change
This is a study produced by various digital stakeholders. The intent of the study is to serve as a direct call for action for Cypriot companies, institutions and policymakers, so as to urgently promote a shift towards Digital. This challenge is of paramount importance and will create significant long-term value for the country. Cyprus has all the potential to become a frontrunner in the “new” economy.

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Cyprus STEM Conference 2019
The conference aimed to bring together researchers, practitioners and stakeholders from around the world to discuss issues pertaining to the role of language and culture in STEM. The conference is organized in May 2019 by the University of Nicosia and ASERA (Australasian Science Education Research Association).

1st Pancyprian Conference: STEM and Robotics in Education 2018
The conference dealt with a new learning model: the pedagogical value of STEM & Robotics integration in education. Some good practices such as MakeITReal were presented. The conference was organized by Pancyprian Institute (principal teacher training authority) and ENGINO®, a local fast growing construction toys company.

Pliroforiki Magazine by Cyprus Computer Society
This is a bi-monthly publication addressing Technology related topics. Articles on STEM and Robotics are often featured as they seem to be high on the agenda of the Ministry of Education as their reform in education.

CyI Women in STEM
The Cyprus Institute is launching a series of short videos of CyI women scientists presenting their work in the field of their expertise, sharing their thoughts on choosing a career in science, identifying the challenges for women in Science, Technology, Engineering and Mathematics (STEM). The Institute aims to increase visibility of women in STEM professions in Cyprus and encourage the new generations of women to be actively involved in the STEM fields.

1.2.2. EU publications

European Journal of STEM Education

The European Journal of STEM Education is an academic international journal that publishes original research related to STEM education. The aim is to contribute to scholarly understanding of teaching and learning practices and policies in the area of STEM, as well as to contribute to the improvement of educational practices.

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EJSTEME welcomes studies and reviews that may be empirical or reflective in character. There are no specific methodological guidelines, except that the method of investigation should be in concordance with the research questions.

Articles may focus on formal and in-school education, from early childhood and pre-school education to well into university and vocational schooling and to continuous professional development. They may also focus on learning in informal and out-of-school settings and on co-operation with the community, science centres, businesses, or other organizations.

EJSTEME accepts articles from all over the world. The fact that the journal is based in Europe, with its forty-plus countries and a multitude of educational systems and practices with regard to STEM education, should remind authors not to take their own situation and curriculum for granted, but to write for an international audience that may be unfamiliar with this system

STEM Education Practices in Europe
STEM Education Practices Survey is looking to collect information about how STEM teachers throughout Europe organise their teaching practices. This report on Education Practices in Europe, published in December 2018, provides an analysis of the 3,780 responses from teachers to the survey (Scientix 2018).

EU STEM Coalition
The EU STEM Coalition brings together relevant publications, reports, policy documents and other documentation from our partners in a single portal. Some such articles already on the portal are: Coding in STEM Education: Teachers become programming experts (by Science on Stage Europe), Building and Transforming Skills for a Digital World (European Roundtable of Industrialists), Charting a Course for Success: America's Strategy for STEM Education (US National Science & Technology Council).

1.3. Types of STEM methodologies applied

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The Ministry of Education is about to officially unveil its STEM strategy. Officials from the Ministry who have been involved in the development of the upcoming strategy hindered that the Ministry will adopt the Constructivism approach.

1.3.1 National/regional/local policies	
New National Curriculum (see analytical hour allocation per subject below)	The broad aim of the new curricula is to contribute to the development of people that: • Possess a satisfactory and connective body of knowledge from all areas of science; • Develop behaviors and attitudes that characterize a democratic citizen; and, • Possess, to the maximum possible degree, abilities, skills and competences that are required in the 'knowledge society' of the 21st century, which include: critical thinking; theoretical thinking and the ability to transfer theory into practice; analysis and planning abilities; problem solving; creativity; cooperative abilities; optimal and sensible use of ICT; empathy; and, communication skills. The curriculum is common to all public primary schools. All the subjects are compulsory and they are taught in Greek. There are no core curriculum options and no subjects are taught in a language other than the language of instruction. The time allocated to each subject varies according to the school type, for example whether the school operates with one class, two classes, three to five classes or six or more classes.
Flexibility within the National Curriculum for Primary Schools.	Teachers in Primary School have the flexibility to implement new Projects during the curriculum hours provided these projects

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	are related to the obligatory material to cover.
Municipalities can offer Educational Programs	A very small number of municipalities support STEM Education as there is no official strategy in place yet. Therefore as municipalities reflect the national policy on educational matters, these refrain from taking any initiatives.
«Innovative Schools»	In 2008 and in an effort to modernize STEM teaching in Cyprus, the Ministry of Education and Pedagogical Institute of Cyprus launched a pilot programme called 'Innovative Schools' (Innovative Schools and Education Kernels 2008). This programme was introduced to increase the competencies of teachers and pupils with regards to the use of Information and Communication Technologies in the STEM teaching process. It also includes guidance for the preparation of teachers to use those technological means including Robotics in their STEM teaching. 'Innovative Schools' is a fully documented programme promoted by the Ministry of Education. There is an official guide containing an Action Plan and Procedures to successfully establish the foundation of such a school.

Subject allocation in weekly periods in primary schools with six or more teachers

SUBJECTS	GRADES						TOTAL
	1	2	3	4	5	6	

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Language and Civilisation (Greek Language/Literature/Theatre)	12	12	10	10	9	9	62
Mathematics	7	7	7	7	6	6	40
History	1	1	2	2	2	2	10
Religion	2	2	2	2	2	2	12
Knowing my world (Geography / School Garden/ Knowing Mother Land)	1	1	2	2	2	2	10
Natural Sciences and Technology	2	2	2	2	3	3	14
Art	2	2	2	2	2	2	12
Music	2	2	2	2	2	2	12
Physical Education	3	3	3	3	3	3	18
Design and Technology/Health Education - Home Economics	--	--	--	--	2	2	4
Life Education	1	1	1	1	--	--	4
Environmental Education – Education for Sustainability	3	3	5	5			16
TOTAL	35	35	35	35	35	35	210

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1.3.2 National centers that work for the Research in the fields of Science, Technology & Informatics offering educational programs and content

Cyprus Science and Research Centre	The establishment of a Science and Research Centre for promoting innovative research of excellence in Science, Technology, Engineering, Arts and Mathematics (STEAM) Education and in Science Communication was an initiative of all public and private universities in Cyprus aiming to promote scientific literacy, responsible citizenship and innovation. The objectives of the centre are: • To become a Centre of Excellence in research that will attract, train and retain a critical mass of young researchers to generate interdisciplinary collaborative research on innovative systems, applications and installations for physical interactive learning and immersive environment based on Science Education and Science Communication principles and models. • To provide a platform for visitors of all ages where interactive exhibits developed at the Centre will take the visitor for digital journeys of exploring the scientific challenges of the modern world and of the cultural heritage of Cyprus in an engaging and entertaining way thus promoting Cyprus science capacity.

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	• To communicate scientific evidence and interpretation of scientific facts to the public, through events (science research and innovation, public debates, scientific conferences) and other outreach activities and thus promote a Responsible Research and Innovation culture that will empower the public and the policy makers. • To promote ICT use in education through provision of teacher professional development programs, training and use of innovative ICT tools for formal STEAM education and curricula development. • To promote innovative business generation and Cyprus economic growth through provision of a platform to researchers, students and the public for designing, building and testing new ICT applications and prototypes of commercial value and world-wide impact
Cyprus Research and Educational Foundation - CREF	CREF promotes the advancement of knowledge and its humane and benevolent applications throughout the Eastern Mediterranean, highlighting the role of Cyprus as a gateway of knowledge and innovation between EU and the region and to help in the transformation of Cyprus' economy into a knowledge-based economy. To realize its vision and objectives, CREF, from the very beginning, planned the establishment of a new research and educational institution, which will promote research and education in Cyprus and its region. CREF designed the new institution, The Cyprus Institute (CyI), aiming at benefitting the public interest at large.

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1.3.3. CSO´s

and others that work to engage kids and youth in STEM, and to give them good experiences with science and technology

Mensa Cyprus Chapter	Mensa Cyprus is a non-profit organisation looking after the interests of intellectually gifted people. It was originally founded in Oxford, England in 1946. Their aims are to create a society that is non-political and free from all social, racial or religious distinctions. Mensa's official objectives are: - to promote a stimulating intellectual and social environment for its members, - to identify and foster human intelligence for the benefit of humanity, - to encourage research into the nature, characteristics, and uses of intelligence.
Cyprus Mathematical Society (CY.M.S.)	CY.M.S. is a non-for-profit organization established in Cyprus since 1983. The Cyprus Math Society is manager and developed by volunteering work of its members. Its purposes are to promote Mathematics Education and Science. It's a member of the European Mathematical Society (EMS) and a founding member of the Mathematical Society of South Easter Europe (MASSEE). The CY.M.S. activities include the organization of all national Mathematics competitions and is in charge for training and organizing the Cypriot National team representations for the participation of Cyprus in all levels of the International and Balkan Mathematical Olympiads.

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Cyprus Computer Society (CCS)	CCS is a professional and independent not-for-profit organization, seeking to improve and promote high standards amongst informatics professionals, in recognition of the impact that informatics has on employment, business, and society as well as on the quality of life of the citizen. Through the advancement of IT Science and good practice our organization promotes wider social and economic progress, bringing together industry, academics, practitioners and government to share knowledge, promote new thinking, inform the design of new curricula, shape public policy and inform the public.

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2.0 STEM education in Cyprus

The below answers are based on information gathered in the EU Survey and interview of key stakeholders.

2.1. The following offer STEM education in relation to robotics in Cyprus	2.2. Type education offered
The Grammar School Nicosia	The Grammar School Nicosia is a private primary and secondary school which maintains a dedicated and trained team in STEM education using robotics. For this purpose it has created the Robotics Academy which aims at promoting team spirit, leadership and event-organizing skills. The goal of the Academy is for students to develop skills and experience for STEM (Science Technology Engineering Maths) related careers while having fun at the same time. Students learn the basics of building and programming miniature robots using LEGO MINDSTORMS. They also have the opportunity to practise team work, decision making and evaluation of possible solutions as well as hands on experience in designing, building and testing. Student members are selected to take part in national competitions and undergo further intensive training so that they can participate in National Robotics Competitions hosted by the WRO (World Robotics Organisation).

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Cyprus Computer Society-CCS & Robotex Cyprus	CCS is the organiser of the Pancyprian Robotics Competition ROBOTEX CYPRUS for the third consecutive year. This event is supported by the Ministry of Education and Culture and other prestigious stakeholders. The aims of this event are to promote educational robotics, to introduce robotics in the educational process, to upgrade STEAM (Science, Technology, Engineering, Arts, Mathematics) fields and to promote new forms of learning. The objectives of the event are to attract students in STEAM fields, 21st century skills development, interdisciplinary analysis and problem solving, the development of communication spirit, teamwork and collaboration among students
Robotics Academy - Frederick University	The Robotics Academy of Frederick University promotes and conducts research in the area of educational robotics. It researches how to best integrate robotics in the educational system as a subject-matter, as well as a cognitive-learning tool within the teaching and learning process. It examines the development of students' knowledge and skills as well as it develops educational robotics exercises and activities (aiming to develop a comprehensive curriculum grounded to the official curriculum of the Ministry of Education). Additionally, it investigates the effectiveness of educational robotics and its connection to learning theories. Additionally, in collaboration with the Robotics and Automated Systems Lab (RAS

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	Lab) of Frederick University the Robotics Academy conducts research on system development, on computer application development, and on other robotics related topics. Besides its research activity, the Robotics Academy offers courses employing various robotics packages for robot building and programming, for integration of robotics as an educational tool and for preparation for participation in the World Robotics Olympiad and other robotics competitions. The target audiences are the following: teachers and students (all educational levels) and anyone interested in robotics (hobbyists and professionals).
Epiteugma Robotics Lab - powered by Wargaming	Epiteugma Robotics Lab has created a specialized robotics laboratory with the support of Wargaming. Wargaming (also known as Wargaming.net) is a Belarusian video game company headquartered in Nicosia. The laboratory has a specially designed room with laboratory-designed cabinets, a special workbench and a huge robotics circuit. Their teams have won first prizes in Robotex Cyprus in 2017 and 2018 as well as in other competitions.
European University – Robotics Club	The Robotics Club helps its members acquire the programming skills and knowledge of the hardware required to build and program robots capable of executing tasks autonomously. The Club also organizes on-campus competitions between members' robot creations, as well as taking part in international contests.

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Private primary or secondary schools	In-classs practical activities, in-class theoretical activites, robotics and stem after school clubs, attending robotics Competitions
Public primary or secondary schools	Robotics and STEM after school clubs, attending robotics Competitions
Private Institutions	In-classs practical activities, in-class theoretical activites, workshops, attending robotics Competitions

2.3. Are offers sufficient in order to increase kid´s STEM education in your country?

The absence of an official STEM strategy from the side of the Cyprus Ministry of Education and Culture has created a confusing situation and has given the private sector enough room to convert it to a business opportunity. Even worse, the lack of any legislative regulations has allowed opportunists to enter the market and to claim “a piece of the pie” using marketing gimmicks.

The evident positive impact of Robotics in STEM Education gave private education institutions plenty of ammunition to differentiate from their competition. The response from the market was so immediate that it was enough to drive even the most ignorant to that direction. In no time, the market had many to offer, good and bad blended together. The result was to create confusion and deception as some of these institutions use in their marketing strategy the successful participation of teams in competitions as a proof of the good work being done. In the majority of these cases, the driving force behind each success is the educator who does most of the coding and leaves the easy part for the students to complete.

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The STEM education curricula of many such institutions has never been submitted to the Ministry of Education to be certified. Even though the Ministry has knowledge of this, the absence of legislation does not leave any room for legal intervention.

Better late than never, the Educational Reform which is currently in progress will hopefully eliminate all these distortions. There is a task group already dealing with the STEM Education strategy and announcements are imminent. Our interviews with Ministry officials revealed that the preparation to implement the new STEM Education strategy has been in full gear since some time ago. Every primary school has at least one teacher trained on how to deliver SME Education under the new reform scheme. The new STEM Education curriculum will dictate the combination of STEM topics at the delivery stage. This will commence at the final class of primary education. As far as secondary education, computer science is a compulsory subject and students learn coding (C++) from their second year. Robotics is considered to be a tool for delivery parts of STEM Education. Each school is equipped with 6-8 robot kits (Edison Programmable Robots) and has at least one fully equipped computer lab.

2.4. Identified gaps and recommended improvements

The interviews performed stressed the absence of a national STEM Education strategy as being the major source of distortions created in the market. Despite the wide offerings of STEM Education from the private sector, the citizens must feel insecure about their selections. Gaps and improvements have been identified through the Survey and the interviews of key stakeholders:

Qualified STEM Educators

Most STEM Education offerings are not being supported by qualified educators. The majority of the educators being used in the private sector are either computer programming teachers or robotics hobbyists. Educators serving STEM education must accumulate specialised training and experiences in order to be considered as qualified STEM Educators. Hopefully

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when the state STEM Education reform is revealed, the issue of specialised educators will be addressed.

STEM Education Infrastructure

There is a considerable investment behind the delivery of STEM Education which some private institutions cannot afford. The lack of having the proper robotics package (i.e. robots, building blocks, bricks, sensors, wires, accessories) as well as the proper computer lab defeats the purpose of the complete learning experience. The certification of STEM education infrastructures by the Ministry will ensure the proper conditions for the delivery of education.

Robotics Competitions

As the successful participation in competitions constitutes a huge marketing tool for most private institutions, the way of conducting these competitions must be transparent. The organisers of the competitions must make the necessary provisions so that the composition of the judging committee to include qualified people who do not have any conflicts of interest. The Ministry will put under its auspices only competitions whose organisers can prove the autonomy of the judging committee.

3.0 Best Practices

Regarding STEM Education best practices, Cyprus has very little to show. The size of the market does not allow major investments to take place. Another factor which has negative impact is the lack of an official state policy which implies no steady grounds for investments to happen. Nevertheless, there are a couple of initiatives that are worth of mentioning:

Cyprus Science and Research Centre - CSRC

CSRC is a product of collaboration of all major universities and stakeholders of the island of Cyprus. It is a Science and Research Centre for promoting innovative research of excellence in Science, Technology, Engineering, Arts and Mathematics (STEAM) Education and in Science Communication. It aims to enhance everybody's awareness of scientific and technological endeavours by becoming a unique landmark to be visited by students, educators, entrepreneurs, start-up founders, the wider public and tourists.

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Robotics Academy by the Grammar School Nicosia

The Grammar School Nicosia was the first private school to consider alternative teaching methods. It had recognised that the conventional classroom teaching was no longer the most suitable to teach STEM subjects. The projects undertaken by the Robotics Academy aim to align with the Sustainable Development Goals. These are a collection of 17 global goals set by the United Nations General Assembly in 2015 for the year 2030. The Sustainable Development Goals are: 1) No Poverty, 2) Zero Hunger, 3) Good Health and Well-being, 4) Quality Education, 5) Gender Equality, 6) Clean Water and Sanitation, 7) Affordable and Clean Energy, 8) Decent Work and Economic Growth, 9) Industry, Innovation, and Infrastructure, 10) Reducing Inequality, 11) Sustainable Cities and Communities, 12) Responsible Consumption and Production, 13) Climate Action, 14) Life Below Water, 15) Life On Land, 16) Peace, Justice, and Strong Institutions, 17) Partnerships for the Goals.[

4.0. Policy initiatives

4.1 Central government initiatives

STEM Education is offered in Cypriot schools for the past 15 years. The problem is that time has brought about a myriad of developments that have made the current delivery of STEM subjects obsolete. The Government's educational reforms that are currently in progress also touch STEM Education. It seems we are at the end of a long road and the announcement are imminent. During the interviews with five Ministry of Education officials, very little was revealed about the upcoming changes. The message though that was loud and clear was that the Ministry will not just announce a national STEM Education strategy but will offer a

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full blown curriculum. Furthermore, the Ministry has also prepared the conditions to implement this new reform. The infrastructures have been prepared and the teaching staff has been sent for specialised training. The realisation of this new strategy is set to begin very soon, as soon as the next academic year.

The state delayed reaction has led opportunists to gain easy profits. The state responsible authority, the Ministry of Education and Culture, should grant a grace period to all private primary and secondary education institutions to submit their curricula for approval. Only state certified curricula should be considered valid for implementation. As for other institutions who offer STEM education and Robotics, approval of their curriculum by the Ministry will become a certification of quality and therefore it will constitute another marketing tool for them to use.

4.2. Regional government initiatives

Regional governments follow national policies. In the case of STEM Education where there no official state policy, regional governments had no worth mentioning activity. Some hosted speakers on the very subject in order to inform their citizens on the impact of using Robotics in STEM Education.

4.3. Identified gaps recommended to Erasmus+

The basic gaps identified through our research that can be implemented into the Erasmus+ program:

- **No homogenous STEM Education curriculum offered by private initiatives**
  - Erasmus+ can help streamline STEM Education curricula
- **Specialised STEM training for teachers.**
  - If possible, Erasmus+ can enhance the teacher trainer training through the robotics camps that can be offered together with the curricula.
- **No customized STEM curriculum.**

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- Erasmus+ can contribute to this, by making a curriculum that provides a complete package: teaching plan, mission/challenge, expected learning outcomes, teacher´s guide etc.

5.0. Conclusion and further research

The desk research, the interviews and the questionnaires used in our EU research underline the catching up Cyprus has to do in order to reach other countries. The lack of state strategy in STEM Education has caused a setback which was properly necessary in order to introduce a more robust strategy. The Educational Reform in STEM Education is about to be announce but indications are that after this is made the developments will be immediate.

The announcement and immediate actions taken by the state authority will not offer solutions to all barriers and challenges, especially those encountered by the private STEM Education providers. All these challenges and barriers have an immediate impact on the quality of the education offered: (1) the confusion in the applied STEM curriculum, (2) the training received in STEM and Robotics by the educators and (3) the sufficiency of the infrastructure.

It is evident that our Erasmus+ project can contribute significantly to the challenges described above, namely:

- The training of Teachers in STEM and Robotics.
- The lack of a curriculum for the teachers for STEM and Robotics.
- The access to proper equipment.

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1.0 Current level of STEM

1.1 Meaning/definition and difference of STEM in Bulgaria

The Bulgarian education system has been traditionally supportive of STEM, providing students with numerous opportunities to broaden their experience in the STEM fields outside the curriculum.

Currently several non-government and academic organizations are responsible for the bulk of the STE(A)M initiatives in Bulgaria and most of them work closely with policymakers, trying to ensure the sustainability of their initiatives, some of which have been standing for decades and have turned into an institution of their own.

The longest standing form of extracurricular STEM activities have been the various Olympiads – mathematics, informatics, information technologies, physics, chemistry, astronomy, mathematical linguistics etc.

Bulgaria has been a founding member of most of the international Olympiads in these fields and last year founded EJOI (European Junior Olympiad in Informatics). Bulgaria is also one of the few countries, where students receive direct support and mentorship from active researchers. Every Olympiad has three rounds – school, district and national – with the more popular fields, such as mathematics and informatics, also having additional national competitions.

Schools are encouraged to provide extracurricular courses, preparing the students for the Olympiads through various funding programmes such as the Operative programme “Science and Education for Smart Growth”, under the EU Structural Funds.

High school research is another well-established traditional STEM activity, due to the tradition of research organizations in mentorship and access to resources to talented high school students.

The High School Students Institute of Mathematics and Informatics has been functioning since 2000, initially modeling its structure and activities after the US Center for Excellence in Education and then gradually expanding and diversifying its methods.

Currently it organizes two annual high school conferences, an interview-based grant initiative supporting high achieving students to participate in international research programs, and an international summer school, which gathered 45 students from ten

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countries in 2017. The summer school is three week long and each participant is provided with a personal mentor and research topic in the field of mathematics, computer science, ICT or astronomy.

To sum up, STEM education has been present in Bulgaria through various extra-curricular activities that are mainly supported by private initiatives, sometimes in cooperation with the public sector. Nevertheless, these STEM activities and initiatives focus mostly on more traditional domains, such as mathematics, physics, informatics, etc. although it is evident that the engagement with those domains can form the base for an increased interest and understanding of robotics in terms of engineering, coding, etc. Therefore, and through the development and mainstreaming of new technologies, more and more robotics initiatives have spread during the last few years.

1.2 Publications aimed at analysing the development and implementation of STEM in education

1.2.1 Bulgarian publications

Journal of the Bulgarian Academy of Sciences

The main purpose of the Journal is to contribute to the spiritual growth of the Bulgarian people and to inform the Bulgarian diaspora around the world about the achievements of Bulgarian scientists, the problems of Bulgarian science, the scientific life in the Bulgarian Academy of Sciences and the country through book exchange.

The Constellation of Good Practices in STEM Education

Bulgarian set of good practices in STEM education consists of: Electronic Platform for Science Education in Secondary Schools, Use of Online and Remote Labs, Learning by Doing Using ICT. The strong online character of these good practices is mainly based on ideas of behavioral learning theories. Again, as in other partner countries, who are focusing on behavioral approach in STEM teaching, Bulgarian examples testify for transformative action towards learners. STEM teaching appears here through subject integration emphasizing logical-mathematical intellect development. Selected good practices are attractive for students, because of fun, novelty and modernity it brings into learning process, for this reason they distinguish such aspects as: use of ICT, work in different way or with new

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equipment, overall coolness. Teachers outline the empowering behavioral aspect of good practices, i.e. encouragement of students, creativity, learning to learn.

The Modernization of Mathematics Education in Bulgaria

Presents a theoretical background of teaching methods and tools for modernization of mathematics education in Bulgaria. An analysis of some Bulgarian strategies and programs in education is given. Classifications of teaching methods and computer programs, and the main prospects and restrictions on their usage in mathematics education are outlined. Some examples about the modernization in mathematics education for different age groups are presented.

Implementation of ICT-based Teaching in Bulgarian Schools

In today's society, ICTs are an essential part of everyday life. They are integrated in work and leisure and therefore have to be engaged in large scale in the education process. ICT offer teachers and students a powerful support in teaching and learning experience. The paper investigates the Bulgarian teachers' attitude to the ICT-based teaching. The purpose is to define the place of ICT in the context of traditional education.

Educational Robotics: A Methodology to Develop Competences

Educational robotics, that is the teaching methodology that involves the use of robotics to generate competences in regular curricula, has the aim to involve students of all ages, from kindergarten to high school, in the study of scientific and technological subjects with a new approach. Learning emerges from cooperative working, from a new role of the teacher, who becomes simply a facilitator of the learning process. Educational robotics introduces a new concept of error, considered as an incentive to do better.

1.2.2 EU publications

Robotics in Education: Research and Practices for Robotics in STEM Education

This proceedings volume showcases the latest achievements in research and development in Educational Robotics presented at the 7th International Conference on Robotics in Education (RiE) held in Vienna, Austria, during April 14-15, 2016. The book offers a range of methodologies for teaching robotics and presents various educational robotics curricula. It includes dedicated chapters for the design and analysis of learning environments as well as evaluation means for measuring the impact of robotics on the students' learning success. Moreover, the book presents interesting programming approaches as well as new

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applications, the latest tools, systems and components for using robotics. The presented applications cover the whole educative range, from elementary school to high school, college, university and beyond, for continuing education and possibly outreach and workforce development.

STEM Education Policies in Europe

This report is based on data gathered from sector experts. A survey was sent to STEM representatives from 14 European countries with questions on the place of STEM in the education system, the reform projects linked to STEM education, the situation regarding the professional capacity-building of STEM teachers and the development of specific pedagogical and learning resources. The structure of the report reflects that of the survey. The data collected was enriched with interviews with industry and university representatives to obtain feedback and points of view from the field.

SCITECH Europe Quarterly

The SciTech Europa Quarterly digital publication brings together the key voices in the European scientific community and the leading trends in science, research and innovation. In an increasingly competitive world, scientific enterprise is the lynchpin of collaboration, which drives human endeavour and addresses key challenges for the benefit of citizens in Europe and around the world.

Does the EU need more STEM graduates?

A report submitted by Danish Technological Institute in association with Technopolis Limited, Danish Technological Institute, 3s Unternehmensberatung GmbH, ICF Consulting Services to the European Commission, Directorate-General for Education and Culture.

1.3 Types of STEM methodologies applied

1.3.1 National/regional/local policies	
National Science Fund of Bulgaria	The National Fund for Scientific Research of Bulgaria helps financially scientific projects, as well as research in accordance with the

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	priorities of the European Union. Along with the "Strategy for development of science in Bulgaria" 2020. The fund finances the universities and scientific organizations on the basis of programs and projects, as well as the projects and work of young scientists.
Days of Science	The event is held within the framework of "Days of Science" at the Technical University of Sofia and has been organized by the Department of Applied Physics for more than 15 years. The main purpose of these days is to promote the physics among the students of TU-Sofia. For the students are presented scientifically popular and scientific lectures and reports by students and lecturers from different universities, as well as by well-known Bulgarian physicists in the country and abroad.
DSS Datathon	Datathon 2018 was organized by Data Science Society - an international digital community and their team has been building a strong core of members digitally around a body of Data Science knowledge while having fun. So far, the team has organized multiple Data Science Meetups and International Datathons with attendees from more than 30 countries. In 2018 Data Science Society created the first weekend long online competition where data scientists and experts have worked with real data from the companies that provided real cases from the areas of computer vision, NLP and AI. The challenge was located at Sofia University, but every data enthusiast was able to join the Datathon online. So far, the organization has made partnerships with business giants such as Worldquant, Telelink, Kaufland, Telenor, Ontotext, Vmware, Identrics, SAP, and Receipt bank which have led to various improvements and automations in their operations. Data

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	Science Society aims to collaborate with universities from all over the World and continue to organize challenging global data science competitions and education summits. Another project of the society is a data platform for all enthusiasts, data geeks and experts who love to share their knowledge and learn more in the data science field. Data Science Society also contributes to various causes – for example in 2018, the society helped solving the data challenges of Air quality in Sofia and made a DNA analysis for I-Gem.

1.3.2 National centres that work for recruitment and further engagement among kids and youth	
Robotics and Automation Lab	The new lab would allow students to learn how to code, test and deploy industrial robots, machine vision systems, servo systems, industrial communications, etc. The lab was built by the Bulgarian engineering company Ehnaton Bulgaria, in partnership with Mitsubishi Electric, at the initiative of Technical University – Sofia. The Robotics and Automation lab is one of the most advanced training facilities in Bulgaria and has an industrial robot MELFA, four different types of industrial stands, a 3D printer and machine vision software applicable to different industries. The lab is equipped with 17 ultra-fast computers and licensed software for robot programming, so up to 17 students can be trained at the same time.
The Cyril Popov High School of Mathematics	The first high-school program in A.I. (Artificial Intelligence) started at the Cyril Popov High School of Mathematics in Plovdiv. The curriculum was jointly developed by experts

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	from the Plovdiv University "Paisii Hilendarski" and the High School and apart from A.I. and neural networks, it would include IoT (Internet of Things), machine learning, and additional lessons.
The Professional High School of Computer Programming and Innovations	The new Professional High School of Computer Programming and Innovations, which was publicly opened in September, will include self-training facilities and a high-tech robotics laboratory. The school's curriculum in ''Software'' will include classes in robotics, A.I. as well as in programming languages C++, Java and Python.
ICT School	ICT School's goals are improving the ICT education in Bulgarian schools, stimulating the youth's interest in them and overcoming the differences between the education in school itself and the needs of the employers in the ICT sector. The co-founders of this association are 12 young and enterprising people, with rich experience in the business sector, as well as in the educational system.

1.3.3 CSOs and others that work to engage kids and youth in STEM, and to give them good experiences with science and technology

DigitalKidZ	DigitalKidZ is an organization which aims to increase digital literacy and adapt the educational methodology according to the 21st century trends – making it fun, effective and digital-wise. The NGO was among the innovative projects of Europe that transformed education. The Embassy of Finland Sofia and the European Commission Office in Bulgaria have

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	recognized DigitalKidZ foundation as partner to collaborate with. DigitalKidZ provides everything a teacher needs to deliver a highly engaging STEM learning experience in a classroom. This includes curriculum-aligned lesson plans, emotional intelligence game, coding boards and "learning by doing" challenges that help students understand our relationship with technology, cultivate digital hygiene habits and turn textbook theory into real-life activities. Apart from a successful 2018, DigitalKidZ foundation has taken a challenging project for 2019 – DigitalKidZ GO. DigitalKidZ GO was created with the support of educational experts from Finnish Education Export and Embassy of Finland. DigitalKidZ GO is a series of educational boxes that contain a programming board (created by the NGO), a study project that explains in practice the theory of STEM textbooks, a teaching plan (for teachers), and school aids.
Data Science Society	Data Science Society is an international digital community and our team has been building a strong core of members digitally around a body of Data Science knowledge while having fun! So far, we have organized multiple Data Science Meetups and International Datathons with attendees from more than 20 countries. We devote ourselves also to our own Data platform for all enthusiasts, data geeks and experts who love to share their knowledge and learn more in the field!
Bulgarian Research and Education Network	The Bulgarian Research and Education Network (BREN) association is a non-profit legal entity, registered under the Non-profit Legal Entities Act.

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	BREN aims at deploying, developing, and operating the Bulgarian research and education networks, as well as facilitating the integration of Bulgarian educational, scientific, and cultural resources in the global information space. BREN provides the Bulgarian Universities and scientific institutes with access to the pan-European and global research and education networks through high performance information infrastructure.

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2.0 STEM education in Bulgaria

The below answers are based on information gathered through the research, the questionnaires and the interviews of key stakeholders.

2.1 The following offer STEM education in relation to robotics in Bulgaria	2.2 Type of education offered
Robopartans School of Robotics	Robopartans Group develops one of the world's largest robotics and engineering training platforms. The platform includes students, specialists and lecturers from over 60 countries. It also provides training textbooks, necessary software solutions infrastructure, and appropriate support for organizing robotics training. In Bulgaria, the popular project of the group is the Robopartans School of Robotics with 10 local academies across the country reaching students mainly from the larger cities. The academies include students from 2 to 12 grade, who are consistently and purposefully prepared by small engineering specialists. The training organizations in the group participate with a student in many different international robotics competitions where they present our country.
EduTechFlag	EduTechFlag designs and creates branding materials for the educational organisations - start with a concept to the last stage of the design of your logo, promo video for an event or new project, cups or New Year decorations. The training e-Learning platforms is designed for experts, teachers, trainers, and all the other specialists who perform activities related to training.

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	The trainers will develop practical skills for implementation of annotation approach in class. Also, EduTechFlag plans, organises and conducts events, meetings, workshops, as well as another valued event for you "The event of the Year", "Edu Excursion" or "Contests" and hackathons.
Robotics Club, Technical University Sofia	The main mission of the club is to support the scientific, professional and spiritual development of its members, as well as to express and defend their common interests and rights. What are we doing? We design PCBs, assemble robots, program them. We train neural networks. We win hackathons. We create products. We're flying with drones. We beat them. We make sites. We organize the strongest events.
Tinusaur	Tinusaur is an educational platform and set of tools that focus on programming, robotics, and electronics and applying modern learning methods in an effort to present science and technology in an interesting and entertaining way to the students. It is a mixture of software and hardware. Described in 3 steps, the platform allows you to: (1) assemble the hardware yourself by soldering your board; then (2) learn how to program it using puzzle-like blocks; then (3) learn how to write C code. The Tinusaur project and its tools are currently being used in universities, schools, and other educational initiatives all around the world. Tinusaur is an open source project - the software and the hardware along with most of the tools and the materials which makes it ideal for use by volunteers and enthusiast around the world.

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Software University	Software University (SoftUni) is based on the idea of an innovative and modern educational centre that creates real professionals in the programming world. For us, as well as for the entire software industry, the real practical skills are the most important. That is why we use the "learning by doing" model, providing our students with programming training combined with real practical experience and knowledge in the most demanding and advanced technologies, ready to start their career as successful software engineers.
Bulgarian Academy of Sciences (BAS) – Institute of System Engineering and Robotics (ISER)	The Institute of System Engineering and Robotics (ISER) "Saint Apostle and Gospeller Mathew" of Bulgarian Academy of Sciences (BAS) is established in 2010, based on joining the former Institute for Control and System Research (ICSR) and Central Laboratory for Mechatronics and Instrumentation (CLMP). The activity of the Institute of System Engineering and Robotics is directed to creation of knowledge, ideas, inventions and know-how in the frame of the globalizing knowledge society corresponding to the priorities of the European Council in areas like sensors, micro and nano-systems, robotics, mechatronics, bioprocesses; measurement technologies, embedded intelligent systems, etc. Completing the full cycle of implementing the principle “science to the key” – from the idea and the invention via scientific investigation to the prototypes and technology transfer into industry.

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2.3 Are offers sufficient in order to increase kids' STEM education in your country?

The Bulgarian responses to the questionnaires and the interviews of key stakeholders, as well as the extensive desk research that we have carried out, indicate that there is a wide variety of organizations that are sufficient to increase kids´ STEM education in Bulgaria. In fact, we have managed to identify organizations offering STEM education over more "traditional" domains (such as general sciences, mathematics, etc.), as well as organizations offering robotics-centred STEM education which encompasses all other necessary domains (such as engineering, coding, etc.) and fosters kids' creativity too.

Moreover, it has been indicated that those kids who engage with STEM education have some considerable advantages from their peers not involved with STEM; they succeed in integrating metacognitive tasks that are needed for their preparation activities when applying for graduate schools; they strengthen the overall link between VET (Vocational Education and Training) and business; and, consequently, they strengthen their link to real job opportunities after graduation, increasing their chances of employability in and out of Bulgaria – which is probably the most important factor.

Nevertheless, STEM education is not yet available to everybody and we have managed to identify two important reasons why; first of all, although some organizations have subsidiaries in other cities, most of the STEM organizations are based in the capital of the country, Sofia, making the participation of youth from around Bulgaria more challenging; secondly, almost (if not) all STEM education providers are private, i.e. requiring a fee, which makes the participation of under-privileged kids very difficult. Therefore, both of those shortcomings create inequalities in STEM education within Bulgaria, either geographical or income-related.

2.4 Identified gaps and recommended improvements

Gaps and improvements identified through our research, the EU surveys and the interviews of key stakeholders are as follows:

- **STEM initiatives exist, but they are not available for everyone geographically**
    - *Improvement potential*: As most STEM education providers are headquartered in the capital of the country, Sofia, and operating a subsidiary in another city might be difficult for many reasons, a simple recommendation would be to initiate e-learning

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platforms for whoever is interested to be involved in STEM courses online from all over the country – or even from outside Bulgaria. Through our research we have managed to identify some e-learning STEM platforms currently in existence, but the potential is much higher to fill in this gap going forward.

- **STEM initiatives exist, but they are not available for everyone financially**
  - *Improvement potential*: Obviously a private organization needs a profit in order to operate and even a non-profit organization needs and income in order to cover its operational costs. The solution to overcome the financial barrier is to add STEM education to the formal curriculum of public schools, thus making it available for all kids. This requires a central policy initiative to be implemented from the Bulgarian Government, but the benefits will be huge for the young students who will become the future professionals and researchers of the country. What's more, this will help align the STEM education offered throughout the country, while it will also allow for a formal recognition of the learning outcomes deriving from STEM – based on best practices from other countries that have implemented such a policy.

- **Teachers, trainers and educators overall are not familiarized with modern STEM methods and learner-centric approaches**
  - *Improvement potential*: If a central approach is implemented all around the country, it would be very important that school stakeholders help to frame and develop the vision for this change to the formal curriculum. In other words, for such a program to succeed, educators must become comfortable utilizing the new teaching methods, techniques and pedagogical strategies related to STEM, and should be trained on how to do so in a similar manner. Independent initiatives do exist, but they vary in accessibility, quality and applicability.

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3.0 Best practices

3.1 Best practices

Below is a listing of the top five best practices identified through our desk and field research activities. They have been selected based on the practices criteria listed under section 3.2.

3.1.1 FLL Bulgaria

FIRST LEGO League (FLL) Bulgaria is organised by the non-governmental organisation (NGO) ICT School and the School of Robotics "Robopartans" with the support of SAP AG and SAP Labs Bulgaria. From 2006 to 2010 Bulgarian students had participated in one of the local tournaments in Germany, organised by SAP AG. Coaches of those teams were employees of SAP Labs Bulgaria and the members – students from Sofia High School of Mathematics. The greatest success was achieved by the team in 2009 on the local tournament in Sankt Leon-Rot, Germany. Together with their mentors, the Bulgarians became sixth among other 24 German teams. From 2011 on SAP is general sponsor of the first FLL competition in Bulgaria. Eleven teams took part In the Bulgarian local tournament. Hands-on-Technology is the international partner in the organization of the event.

3.1.2 Electronic Platform for Science Education in Secondary Schools

The electronic system for science education is based on the open-source Moodle learning platform. The platform provides many different functionalities, easy to be used by both teachers and students. It contains learning materials (presentations, movies, tests, statistics of the performance etc.).

The scientific content of each lesson and each section of the textbook is represented in the platform in an attractive and understandable interactive way. Each interactive lesson is followed by a test of the knowledge acquired by the students. There are also questions appearing during the presentation of the lesson. The answers of the students can be used by the teachers as a proof that the students have successfully passed through the whole presentation and understood the lesson. Teachers can create and upload video lessons as well as scientific problems for solving.

The system also provides much functionality for the development of tests. It allows teachers to make analyses of the performance of individual students or classes, as well as to analyze the questions of the tests (e.g. if the questions are well formulated and understandable for

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the students). The analyses allow teachers to check the test results and to track the development of student's knowledge during the school year. The system allows teachers to assign homework to the students.

3.1.3 Learning by Doing in Science Education Using ICT

Students are required to prepare interactive presentations on preset scientific topics by themselves. In order to complete the task, students learn how to use different software programs and how to prepare presentations, movies etc. For more complicated tasks they need to find additional information which leads to new knowledge in different areas. This approach stimulates students' imagination on how to present something purely scientific in ways that are creative, understandable and attractive for their classmates. On the other hand, this cultivates new skills and knowledge.

All the presentations are published in an open platform and are available for other students to learn.

Students are encouraged to use free on-line platforms and resources (like Screen recorder, Voice recorder, Text to speech, piZap, Screencast-o-matic, etc.) in order to prepare their interactive presentations.

3.1.4 Use of Online Virtual and Remote Labs in Science Education

Online laboratories are aimed at supporting education based on research and provide opportunity to conduct scientific experiments in virtual environments. For optimal learning results it is important that the study process is well-structured. Software tools help students in different tasks – for example to create hypotheses, experiments, to interpret data etc. Virtual labs simulate real equipment. Remote labs enable students to collect data from real laboratory with real equipment.

Go-Lab Project for example provides online science labs (Virtual and Remote). Another interesting on-line resource is Sally Ride EarthKAM – NASA sponsored programme.

3.1.5 MARCH project

MARCH project was an international 3-year project supported by the Lifelong Learning Programme of the European Commission, which involved partners from 7 European countries: the UK, Greece, Germany, Serbia, Lithuania, Bulgaria and Portugal. Altogether, partners form a network bringing together key players in the field of science education, science communication and relevant policies, who shared a common concern with science education and motivation to improve it.

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MARCH project sought to address a number of educational challenges that are linked to perceptions on science and existing science education methods and practices in secondary schools across Europe: lack of effective educational methods; shortage of well-qualified science teachers capable of providing a positive experience with learning science in schools; need for linking science educational content to 'real' life; need for a joint European approach.

3.2 Practices criteria

The best practices fulfil the following criteria, which the respondents of the EU Survey and the interview participants believe to be important factors for a successful STEM initiative. They:

- engage kids and youth;
- facilitate in-depth learning;
- last for a longer period of time;
- provide opportunities for progression in complexity;
- have the potential to reach kids and youngsters from all across the country, including all age groups and social background;
- are cross-curriculum based, enabling kids and youngsters to use a lot of their own knowledge and experience, and make sure that all participants feel like they have something to offer;
- come at no cost for the end user (kids and youngsters).

3.3 Are practices adaptable into the Erasmus+ programme?

Based on the findings of this report, the practices are adaptable into other projects of the Erasmus+ programme. In addition to the criteria listed above in section 3.2, the Erasmus+ programme should also:

- Run over a certain period of time;
- Enable in-depth learning;
- Focus on cross-curricula work;
- Be challenge-based;
- Create awareness of STEM in our everyday life;
- Use a set curriculum and teaching plan ("plug and play").

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4.0 Policy initiatives

4.1 Central government initiatives

The Bulgarian Ministry of Education and Science has set the following priorities in order to enhance STEM education initiatives:

- Involvement of the three interests' parties in STEM skills intensification – kids/students, parents, school/education authorities;
- Funding for STEM education innovations and interdisciplinary projects development aimed at foster collaborations for sharing and co-creation of new knowledge among High Schools or/and Education Institutions;
- Better STEM through better STEM teachers: fostering change management in education and development of education change management strategies for each High School/education institution;
- Improvement and digitalization of STEM infrastructure (STEM Labs), facilities, and libraries (digital STEM libraries at High Schools/education institutions);
- Overcoming the inequality and better integration through learning communities and development of STEM knowledge map and paths (STEM BUS Bulgaria);
- Pragmatism, transparency, and visibility of STEM efforts: ideas and contributions of all interest parties can be achieved through the development and sustainability of Open Data STEM portal Bulgaria;
- Integration with the foreseen EIT community hub in Bulgaria.

Furthermore, the Bulgarian Government has implemented the following programmes that included STEM as part of their educational policy:

- The National Reform Programme of the Republic of Bulgaria (2011-2015) in Implementation of "Europe 2020" Strategy;
- The Bulgarian Operational Programme "Science and Education for Smart Growth" (SESG) for the period 2014-2020.

4.2 Regional government initiatives

Does regional government have any policies implemented to increase the competencies of both children and adults in STEM education and/or robotics?

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Unfortunately, both the stakeholders interviewed and our primary research, have managed to reveal only central and no regional government initiatives in place, concerning STEM education in Bulgaria.

4.3 Upcoming policy initiatives

The following policy initiatives are being implemented in the next few years, that aim to increase the competencies of both children and adults in STEM education and/or robotics:

Every two years Science on Stage Bulgaria is organised by an elected committee from the National unions of Scientists, Physicists, Chemists and Biologists, while the Ministry of Education and Science in Bulgaria is co-organiser of the initiative.
The main objective is to provoke and support the interest of young people towards the whole cycle of STEM subjects as a main region of human's knowledge and future career. The festivals are organised like competitions between teachers presenting projects together with a team of pupils.
The evaluation of projects is made by a national jury of teachers, university professors and scientists, and the best presentations are proposed for participation in the following European Science on Stage festival (https://www.science-on-stage.eu).
Participating teachers can benefit from a fruitful connection, cooperation and exchange of good practices within the scientific community.
The next Science on Stage Bulgaria festival will take place in 2020.

4.4 Identified gaps and our project's contribution

Our project, "Developing STEM Competences with Robotics (Robotics 4.0 All)", aims through this transnational research activity to investigate the current level of STEM in each participating country, as well as to identify the gaps existing in STEM education, both formal and non-formal. Hence, we have categorized the following gaps in which our project could make valuable contributions:

- **Good STEM initiatives exist, but they are not available for everyone.**
    - We need to make sure that the curriculum created through "Robotics 4.0 All" is accessible from everyone.

- **No standardised STEM training for teachers.**

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- If possible, “Robotics 4.0 All” should cooperate with other similarly-focused projects in the framework of the Erasmus+ programme and create teachers’ training material that can be shared together with the curricula.

- **No customized STEM curriculum.**
  - Subsequently, an overall contribution can be made to this by providing a curriculum that will provide a complete package: teaching plan, mission/challenge, expected learning outcomes, teacher´s guide etc.

- **Some school leaders do not facilitate STEM activities.**
  - By disseminating the “Robotics 4.0 All” project widely amongst the school communities, we can inform and evoke awareness of the importance of facilitating STEM activities in schools.

- **Create awareness of the positive sides and learning opportunities in gaming and programming, for both teachers, parents and students.**
  - We can contribute in changing negative attitudes towards these fields, and have a great effect on young people, which can lead to more youngsters choosing programming and technology as their future career path.

5.0 Conclusion and further research

Based on the literature review and the findings of our desk research, based on the results of our questionnaires and interviews with relevant stakeholders, as well as based on the overall knowledge and understanding of the Bulgarian reality, one can come to the conclusion that Bulgaria has traditionally had a variety of STEM activities available for the youth, but, these activities were – and to an important extent still are – focused mostly on the basic STEM domains such as mathematics, physics, engineering, etc.

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Nonetheless, STEM initiatives related to robotics have been increasing throughout the last decade especially, as Bulgaria became a member state of the European Union (2007) and, at the same time, new technologies have been developed and informatics and other similar domains that lead to an understanding of robotics principles became more popular and created enthusiasts all around the country – either it is for education, business, or recreational activities.

Still, there are points for improvement regarding STEM education in Bulgaria and we have highlighted the following ones:

- Most STEM initiatives, especially as related to robotics, are private, meaning that they come with a fee and are not accessible for everyone. Moreover, they vary in quality and are sometimes not quite what they seem for the parents. If STEM-robotics becomes a central priority of the Bulgarian Government and is integrated into the formal curricula of schools, it will allow for many more kids to be included, as well as for an alignment of the STEM competences offered and recognized across the country, in parallel with the private initiatives in place;
- Consequently, this will also eliminate the geographical disparities that many kids and their families face, as most STEM organizations are based on Sofia or a couple of other cities, thus making the offered opportunities unbalanced throughout the country. This can be also faced with an increased offering of STEM education through e-learning platforms, although some online learning initiatives already exist.
- Lastly, there has been an identified gap regarding the educators' skills and their capability to effectively teach the new STEM domains to the pupils. If the Bulgarian Government decides to integrate robotics into the formal curricula of schools, it goes without saying that a new generation of teachers will have to be adequately trained in order to overcome the challenges of the fourth industrial revolution in relation to education.

6.0 Reference guide

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STEM Education in Estonia

Report

Tartu 2019

Co-funded by the
Erasmus+ Programme
of the European Union

Contents

Current level of STEM in Estonia

STEM meaning and methods

STEM Education is named differently in Estonia. It is called LTT (Loodus- ja täppisteadused) which includes following learning subjects: (Riigi teataja 2019)

- Biosciences
- Natural sciences of physics
- Math and statistics
- Computer sciences

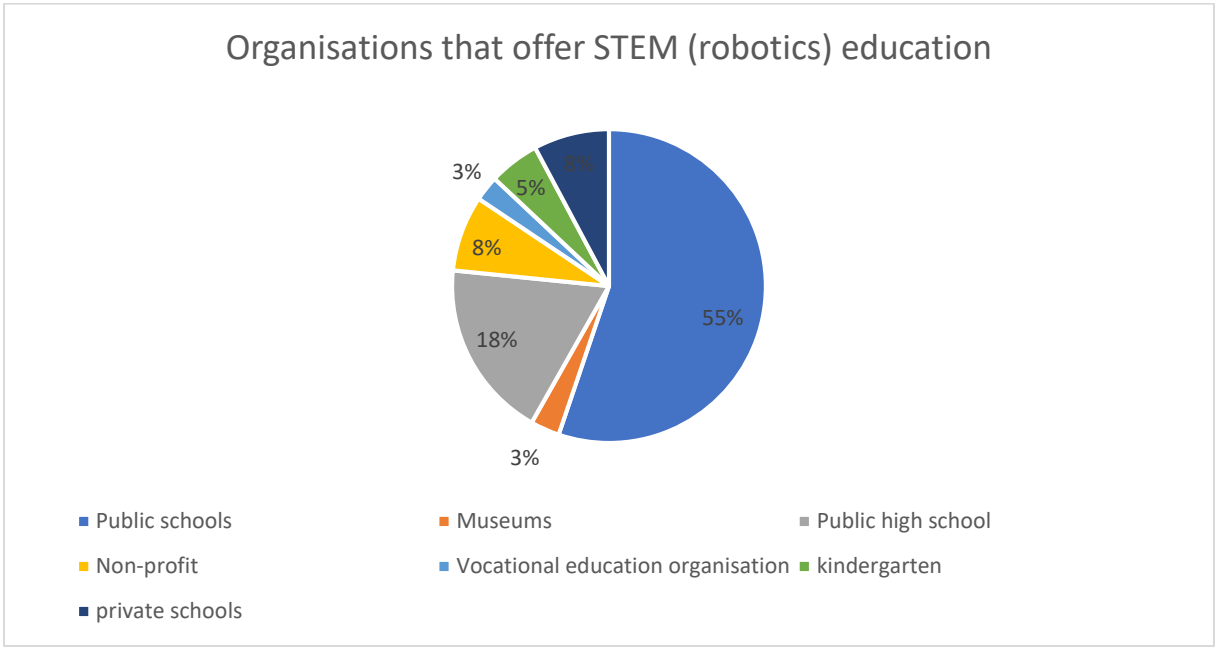
Word STEM has similar meaning, but little different in terms of engineering. We conducted several interviews and set up questionnaire (Erasmus+ Robotics 4.0 All questionnaire) that was shared among robotics community. We received 49 answers from different types of institutions.

Robootika has also conducted several analyses in the past regarding use of robots in education. Results of those studies and papers will be used in this report. References are provided.

- Methods that are used to teach robotics in science education. Altin, H.; Pedaste, M. (2013)
- How to get schools involved in robotics based programs? Altin, Heilo; Aabloo, Alvo; Pedaste, Margus (2010)

Who offers STEM-education and/or STEM-education in relation to robotics in your country?

Research indicated following results:



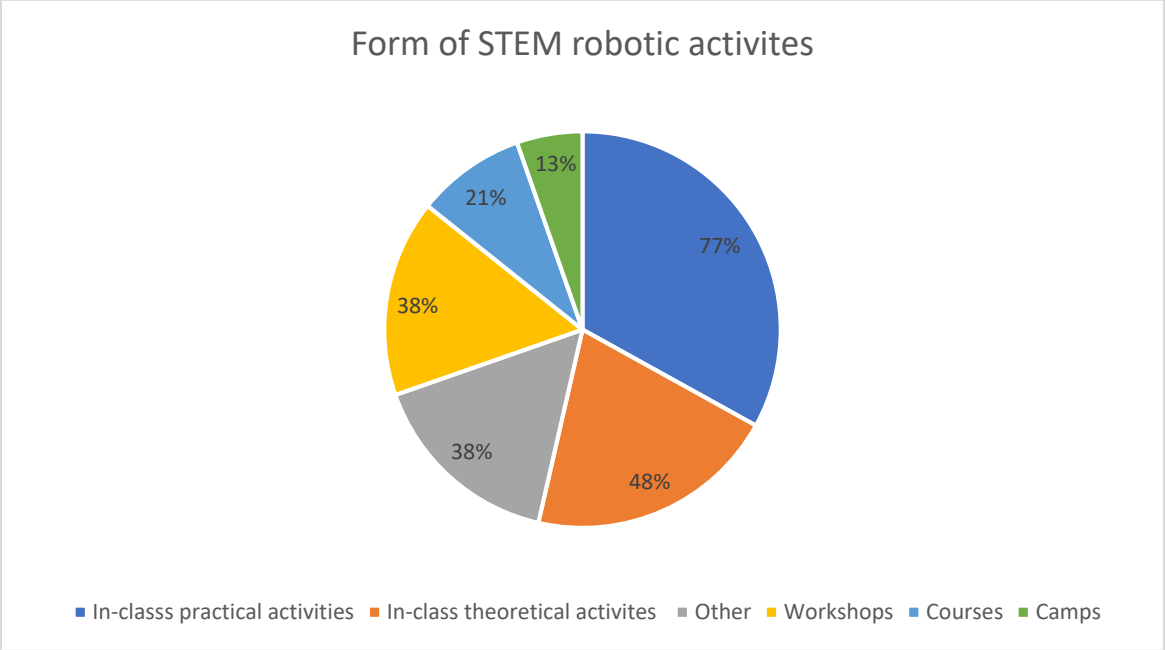
This division is expected in Estonia since most of STEM connected to robotics is done in clubs in schools as we can see from the next data section. There are also high schools involved and in smaller amount other organizations. Non profits go from one school to another with their own equipment to run one or two clubs per day (NPO Nukutuba, NPO Nutivõlur).

What kind of education do they offer?

Here is the word cloud out of the results received through the questionnaire that contains only unique values.

Most answers are connected to robotic clubs that take place afterschool. There are also examples of schools that have robotics compulsory in 1st-3rd grade. Some schools use robots to teach math, physics, chemistry and natural sciences. Most used platforms are WeDo 2.0 and EV3 robots. Electronics is part of high school facultative course list which includes Microbit and Arduino.

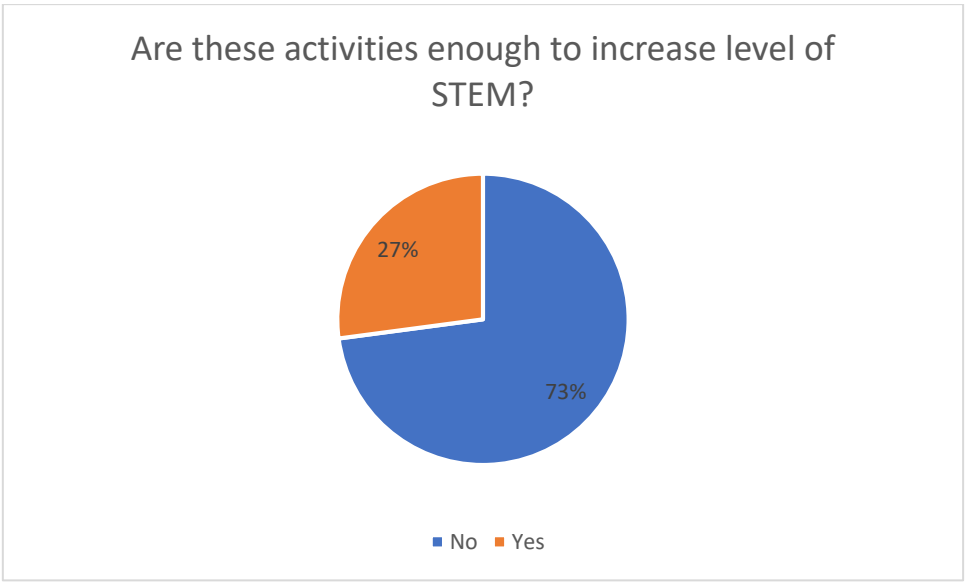
Out of answers, teachers do also 3d modelling and 3d printing courses. Kindergartens use more open approach in form of discovery learning with technology.



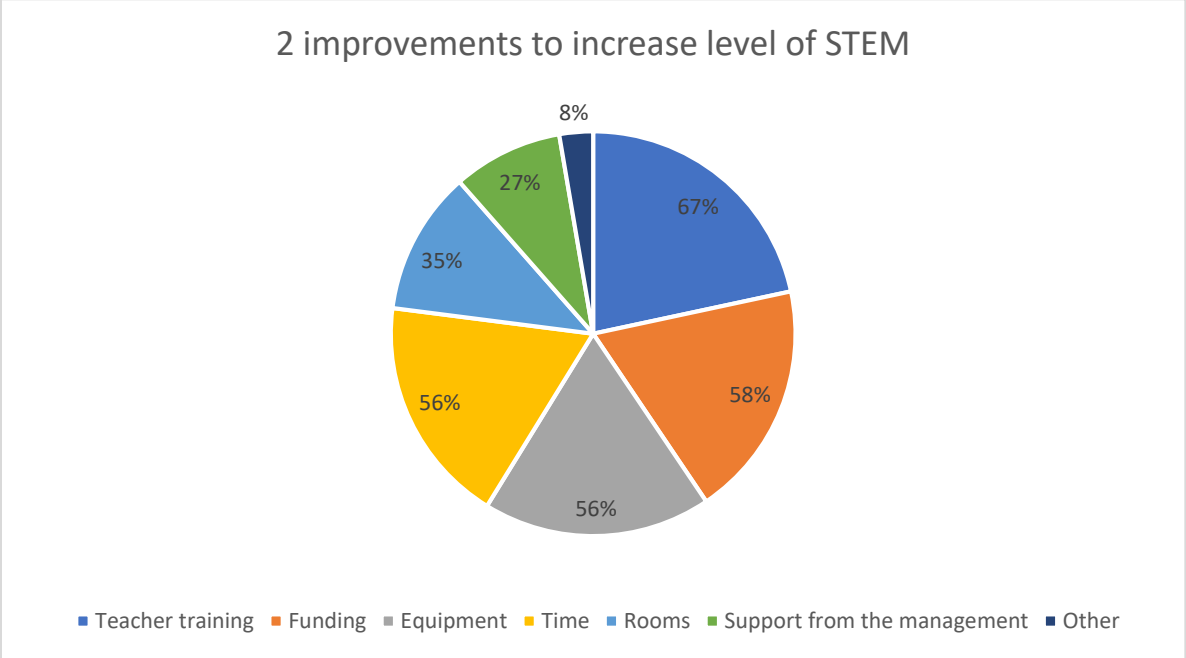
In this question, multiple answers were selected. It means that 77% of teachers said that they are doing STEM robotic activities as in-class. Other includes:

- Extracurricular clubs of robotics
- Extracurricular clubs of programming
- Preparation and taking part in competitions like FIRST LEGO League
- Competitions

<u>Teachers do not find these activities to be enough for increasing level of STEM in Estonia.</u>



Results of „What are the top 2 resources that would best improve organization's STEM education in Estonia"



There were altogether 148 answers for this question.

Other includes:

- Teachers themselves as young interested teachers
- Regional STEM trainings/competitions for interested people
- Coaches
- Teaching materials and literature. Preferred robotic handbook for children
- Need for more volunteers that would help with different activities. Organizers are quite overloaded, plan is to get young people to take over activities

Explanation: Teacher training has always been something that teachers want more and more. This feedback is given in trainings, competitions and other events. From trainers perspective, teachers are seeking confidence through participation. They are not ready to solve problems and discover new things on their own. Funding is not primary shortcoming because Ministry of Education has been supporting schools and other educational organizations financially to buy robotic kits, computers and other things to enhance and enrich education in Estonia. Level of support is up to 70 % of the cost.

Bigger shortcoming is teachers/coachers salaries. Most of robotics happen in clubs as extracurricular education. Fee for one hour is times smaller than for teachers. This has been demotivating and sometimes reason why teachers are not extending their work hours. It means that people working with pupils in STEAM education are doing it out of passion and not for the money. That kind of people are already involved in very many activities and they lack time. Not having time to do more STEM activities was pointed out as third-fourth reason for not increasing level of STEM.

Another reason is rooms. STEM is quite new direction in education and has started to require resources (equipment, funding, time) – rooms are one of the factors. Computer classes are mostly used in terms of robotics. But computer classes do not have the best space setup. Many robotic activities take place in corridors and halls. When clubs become more popular, number of participants increase and computer class itself will limit activities as there is not enough room to keep the robots, FIRST LEGO League table etc. Lauri Vilibert from Kristiine high school in Tallinn mentioned a very fun strategy to get own robotic rooms. He used to be a teacher that had to use computer class and since it was annoying and he had been asking for robotic classroom from principal, he came up with an idea. He started to extend activities to narrow school corridor – outside of computer class. He rolled down mats and fields where pupils tested their robots. He did that especially in times where there was a delegation visiting and principal was taking them around the school. When reaching Lauri's temporary robotics testing site, everybody had to step over robots, mats, pieces, pupils. It did not take long when Lauri was granted his own robotic classroom – previous ballet room. There are several other examples where robotics in school have taken over garage etc.

Support from management is pointed out as teachers are not getting acknowledgement to start or continue STEM activities. This does not include only after school lessons, but also experiments that could enrich subjects. Biggest fear is that results of exams will drop and school will lose it's credibility. Less pupils means less head funding from MoE.

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Best practices and policy initiatives

Best practices

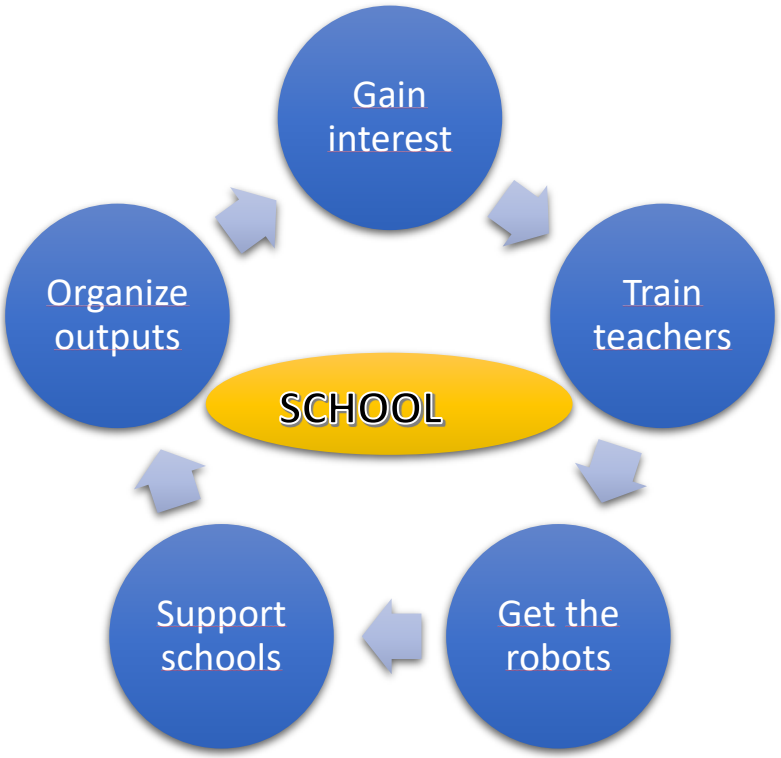
Here is the word cloud out of answers for best practices:

Most mentioned four best practices:

1. FIRST LEGO League program – a learning experience for pupils 9-16. In Estonia, almost 1,7 % of school aged pupils take part in the program.
2. Robotex and Robomiku battle – multidiscipline competitions (line following, folk race, sumo, taxi drive, pulling the rope etc)
3. HITSA – Information Technology Foundation for Education (HITSA 2019). Govermental institution that supports schools with funding, offers trainings, network and materials.
4. Rocket 69 TV show (Rocket 69). It is a TV show where high school students compete in science challenges. In each show, one participant is excluded, leaving in the end the winner – who gets 10 000 EUR for studies. This show has been running in Estonia for more than six years and is extremely popular among young kids.

According to answers, competitions are successful because of being motivating for kids, have more than one aspect connected to it (FIRST LEGO League) and have been organized for a long time – are known. Other remarks that were mentioned: novelty, having proper level of difficulty, support from parents, school board, being accessible, support from organizers, new methods (from practice to practice, experience-based learning, upside down classroom, project based approach where solution is in focus, not the process.

In Estonian context, there has been big support from Robootika towards the schools that run robotic clubs. On the other side – there is HITSA with financial support. This is a holistic approach for the school that would be otherwise alone.



Having this type of support is vital in any country to start or increase STEM robotics related activities.

Policies

In Estonia, Programming Tiger is a national program implemented by the government since 2000. At the moment it is run by HITSA (Progetiiger 2019).

From HITSA website (https://www.hitsa.ee/ict-in-education/improvement-of-competencies)

The aim of the Information Technology Foundation for Education (HITSA) is to ensure that teachers at all levels of education have modern digital skills and they know how to use them in their area of teaching.

The HITSA's Innovation Centre develops an evaluation model of educational technological skills, which is meant as a self-analyses tool and professional development support tool for teachers and for their evaluation. The evaluation model and the development of training courses are based on the digital skills standards of the

International Society for Technology in Education (ISTE), which provide an ideological framework for learners, teachers and educational managers to follow.

To improve these competencies. Innovation Centre organises briefing sessions, training courses, seminars and conferences.

Digital mirror is a tool for schools to map their digital maturity and run digital innovation through setting targets (Digital mirror 2019)

HITSA robotic trainings for teachers that are free.

Programming Tiger, Digital mirror and training as policies were clearly identified. Most important was HITSA's funding support for schools.

Quite recent policy government is implementing is connected to extracurricular education. It states that each kid (7-26) should have enough possibilities to work with their interests. For that government is funding local governments to increase possibilities in extracurricular education in three categories equally: sports, culture and STEM (2017. aasta huvihariduse ja huvitegevuse toetus, Riigi teataja)

Although this is dedicated to activities outside of classroom, there is a movement towards threading informal and formal education. Idea is for schools and educational system to take more into account what pupils do in their afterschool time (robotics clubs, sport, dancing) and include this as part of their curriculum.

Gaps that exist in STEM education policies according to answers:

- Schools are missing a person with good project writing skills – they miss a lot of opportunities
- Teachers are aging – old teachers won't take new things into classroom so easily
- Materials and curriculums are aging, teachers are missing proper materials
- High school level is missing it's output in robotics. There are plenty of solution until the end of middle school, but there is a gap in educational technology in high school
- Competition based learning is not supported financially – competition days are not working days
- Limited time for national curriculum
- Get young teachers to schools
- Weak strategy – too much project based
- STEM and robotics are not part of compulsory curriculum

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