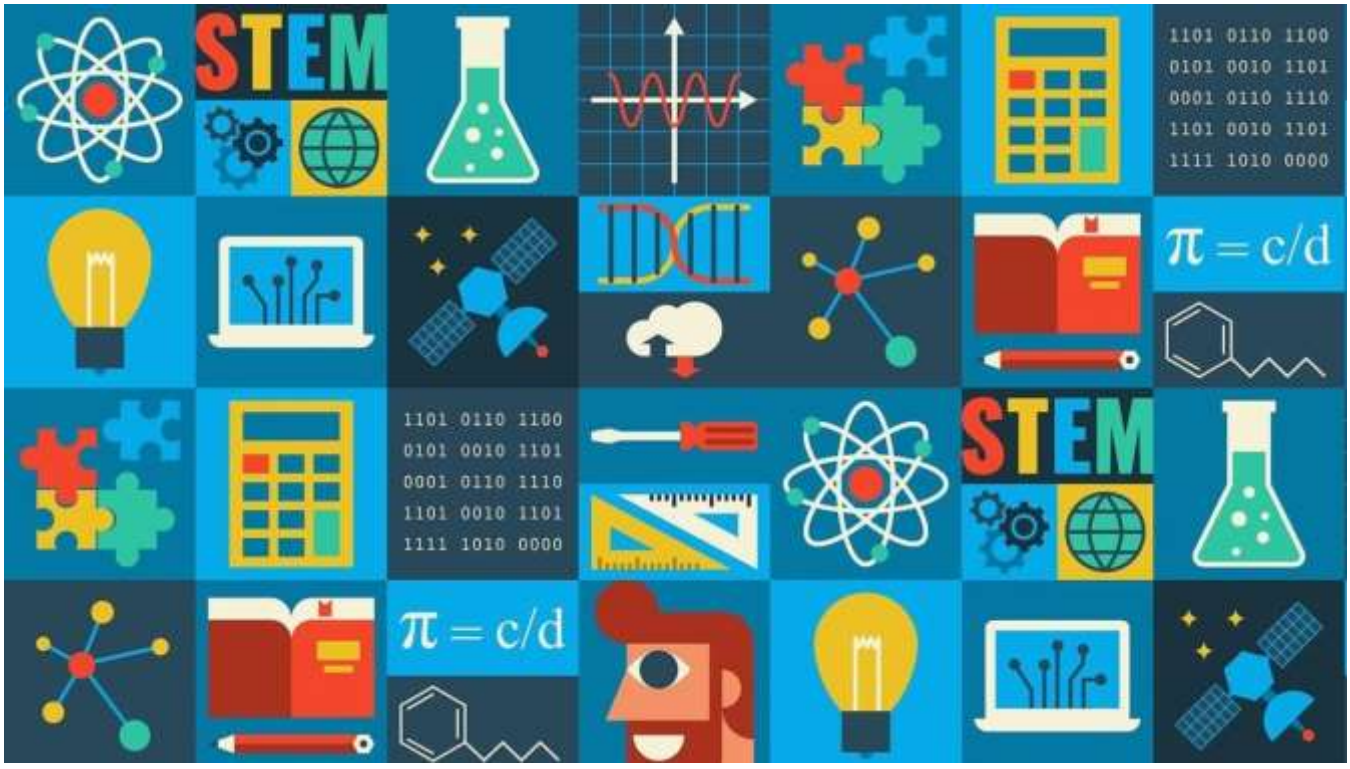
Co-funded by the
Erasmus+ Programme
of the European Union

ATLAS

of Best Practices in STEM Education



Finland, Ireland, Sweden, Turkey, Russia, Kazakhstan

Contents

Introduction

STEM education which is considered as “an interdisciplinary approach to learning where academic concepts are coupled with real-world lessons as students apply Science, Technology, Engineering, and Mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy, is engineering the future workforce all over the world“.

The aim of the package „Best policies and practices” is to lay the foundations for further “Integrative approach to STEM Teacher Training” project activities. The WP is divided into 2 parts: 1.the development of project policies and strategies to ensure smooth running of the project and cost-effective achievement of results; 2. Identification of best practices in STEM strategies implementation at national levels, on the one hand, and of real needs of different target groups in STEM skills, on the other hand.

Atlas of Best Practices in STEM Education is a progress indicator of second part of the WP „Best policies and practices”. The aim of this atlas is to collect best practices and initiatives based on reports on STEM policies and best practices at respective national and regional level given by EU partners, RU and KZ participants of the project shaped into an atlas. This atlas is a key indicator for development of the Project book «STEM best practices in EU and Partner countries».

The content of this atlas will be a) used in order to develop a master's program in the field of STEM education and, therefore, to organize new staff in the field of STEM in the countries participating in the project b) included into T&L resources to be developed in WP3.

Further, the best STEM practices of EU partners of the project will be reviewed in details. Thus, the content of the atlas begins with Finland best STEM practices, such as for example LUMA, F2k, EpiSTEM, PaikkaOppi, Summamutikka etc. The other part is represented by Ireland best Stem practices (ATSSTEM, ENERGE, Maths4All.ie, 3DIPHE, Open Schools for Open Societies etc.). Then comes Sweden with its best STEM practices such as CETIS, NRCF, NCM, NATDID, KRC etc. Another part of the atlas describes Turkey’s best STEM practices (FATİH project, BİLTEMM, IYTE, Istanbul Aydın University STEM Laboratory etc.).

The other two parts of atlas are represented by RU and KZ best STEM practices.

It goes without saying that STEM qualifications and skills are necessary for current and future workforce in the Russian Federation due to political and economic pressures as well as improvement of knowledge delivery and employability skills

development. STEM-subjects are the basis for staff training of the scientific-technological elite for the innovative development of the country in the context of Scientific and Technological Development Strategy of the Russian Federation, as well as for the implementation of the national program “Digital Economy of the Russian Federation and „National Technological Initiative“. There are also a lot of authentic STEM practices and initiatives such as NTI STEM-related education projects and practices, STEM-related “Sirius” education practices, STEM Centers of the All-Russian Festival of Science 0+, Skolkovo MAKERspace STEM Education Center for schoolchildren etc., that will be thoroughly described in this atlas. In the end of the atlas KZ best STEM practices are represented, such as NIS, RFMSh, MIRAS INTERNATIONAL SCHOOL etc.

Thus, the following Atlas of Best Practices in STEM Education represents a big variety of best national STEM practices and could be used as T&L resources for the future STEM teachers, students of the Master program in STEM teacher training.

STEM-EDUCATION IN FINLAND

Context

Since the 1970s, the education system has been reformed in Finland. It became decentralized, as each school or educational institution received autonomy to improve its education. The reform focused on three aspects:

- new approaches in pedagogy;
- new learning environments;
- digitalization of education;

The goal of the reform was to improve learning outcomes, take into account future competencies, renew pedagogy through experimentation, and turn to learn into an inspirational process throughout life. Nowadays, STEM education technologies are included in all areas of Finland's school curriculum. STEM technology is not an additional set of standards in a problem-oriented approach to the creation of educational materials and their combination with educational standards for the formation of new competencies of the 21st century. The STEM approach can contribute to the development of student curiosity and creativity. Building a problem-oriented material is not as difficult as it might seem since the topics for projects can be environmental issues, food production, energy and other topics that are relevant around the world.

Characteristics of the Finnish education ecosystem[1][2][3]:

- cooperation in strategic work
- long-term shared vision through collaboration: higher education quality for everyone
- educational partners work closely
- cooperation with social services and health care
- equity in education
- education is free (books, food, healthcare)
- well-organized specialized training and counseling
- school social assistance group as part of the ecosystem
- quality through decentralization

[1] Laukkanen R (2008). Finnish Strategy for High-Level Education for All. Teoksessa NC Soguel & P Jaccard (toim.), Governance and Performance of Educational Systems. Springer. ss. 305-324

[2] Niemi H (2011). Educating student teachers to become high quality professionals – A Finnish case. Center for Educational Policy Studies Journal, 1(1), 43-66.

[3] Sahlberg P (2011). The Professional Educator: Lessons from Finland. American Educator, 35(2), 34-38.

- leadership, management and quality work at the school level
- teachers are responsible for the local curriculum and assessment

The secret of national policy is the importance of education for the development of a country, as well as for the adoption of unorthodox educational methodologies (as STEM) designed for the present and future of the younger generation.

The STEM approach requires students to self-identify a problem, conduct research, develop a solution, test and evaluate the solution, and report the results. These competencies overlap with global scientific and technological competencies. This allows students to develop the skills of creativity, research, cooperation and communication that they need in order to realize global problems and prospects and become part of the solution to existing and future problems.

Teaching in Finland is considered one of the best professions. Teachers are on a par with doctors and lawyers, so there is a lot of competition to work in the education system. Even a master's degree in research is one of the teaching requirements. This means that teachers have five to seven and a half years of preparation before they lead a class. Future STEM teachers not only learn teaching methods but also spend a year at the university, learning how to teach this approach. They are taught how to participate in joint project teams and create such teams. Natural disciplines at all levels of instruction are taught through STEM technology. Teachers are given a lot of freedom to try innovative approaches, such as developing an “outdoor math curriculum,” or joining forces with others to implement a team-based teaching method. Thus, Finnish schoolchildren demonstrate a rapid increase in horizons and an integrative approach to knowledge, as evidenced by their consistently high results in the PISA test (The Program for International Student Assessment). There is also a craft curriculum in Finland. In 2004, it was decided to include technology in the curriculum for crafts.

Education in Finland uses a pedagogical model of dialogue. This means that “the Finnish teacher is a kind of a guide in the classroom, and not as an authority model as in other systems. This requires more of the students, ponders their answers and triggers a dialogue between them under the guidance of the teacher. Argumentation and exchange of ideas are encouraged. " This same aspect will help the student to develop with greater confidence in their learning. Even in education in Finland, teachers “can choose their teaching methods, textbooks and other materials,” says the Finnish General Directorate for Education.

Thus, students in schools learn in a more autonomous and equitable space, where it is important that all students study at the same time as others and given that the

school is an example in which they receive a less rigid education. Finnish students are "more concerned with understanding the phenomena", along with the fact that one of the most characteristic features of these phenomena is that they are very organized and disciplined.

STEM-Related National Policies and Initiatives

The country's national curriculum urges teachers to teach science through integrated and inquiry approaches[4]. Project-based science learning (PBSL) is one of the approaches that could motivate and engage students in learning science by actively involving them in the knowledge construction process[5][6][7]. Therefore, learning science through projects has the potential to increase students' interest in learning science.

The distinctive feature of project-based learning is problem orientation, that is, the idea that a problem or question serves to drive learning activities. The second feature of PBL, constructing a concrete artefact, is what distinguishes project-based learning from problembased learning. Helle, Tynjälä and Olkinuora[8] add three other features to PBL. The first, learner control of the learning process, which leaves scope for decisions regarding the pacing, sequencing and actual content of learning. The second, the contextualisation of learning is evident in student projects. The value of authentic or simulated learning contexts has been argued for both cognitive reasons and by the situated learning camp. The third, characteristic of the project method is its potential for using and creating multiple forms of representation. In modern working life, most tasks require the combined use of interdisciplinary knowledge in different forms.

The core curriculum mainly defines the mission, values and structure of basic education. It also defines the objectives and content to be learned in each subject. The core curriculum is a national regulation prepared and issued by the Finnish National Board of Education and all municipalities are expected to prepare their own local curricula in compliance with the core curriculum. The local curriculum is expected to implement the national targets but is also expected to take into consideration the local contextual needs. However, the municipality and schools have

[4] Finnish National Board of Education (FNBE), 2016.

[5] Phyllis C. Blumenfeld, Elliot Soloway, Ronald W. Marx, Joseph S. Krajcik, Mark Guzdial & Annemarie Palincsar (1991) Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning, Educational Psychologist, 26:3-4, 369-398, DOI: 10.1080/00461520.1991.9653139

[6] Balemen, N. and Keskin, M. (2018) The Effectiveness of Project-Based Learning on Science Education: A Meta-Analysis Search. International Online Journal of Education and Teaching, 5, 849-865.

[7] Aksela, M. & Haatainen, O. (2019). PROJECT-BASED LEARNING (PBL) IN PRACTISE: ACTIVE TEACHERS' VIEWS OF ITS' ADVANTAGES AND CHALLENGES.

[8] Helle, L., Tynjala, P., & Olkinuora, E. (2006). Project-Based Learning in Post-Secondary Education—Theory, Practice and Rubber Sling Shots. Higher Education, 51, 287-314. https://doi.org/10.1007/s10734-004-6386-5

considerable freedom to interpret the curriculum as they want[9]. The idea that students are active agents of their own learning forms the basis of the core curriculum's conception of learning (FNBE, 2016). One aspect of the core curriculum that is worth noting in relation to this study is that of the Transversal Competences. The seven transversal competences stated by the core curriculum are designed in order to prepare students for the changing world. Transversal competences represent the values and attitudes required for using the knowledge and skills from different fields for personal growth, study, work, and civic activity (FNBE, 2016). These competences are part of everyday teaching 36 and learning activities of the school. These competences also clearly align with the need for incorporating teaching methods like project-based learning in schools. The seven transversal competences stated by the core curriculum are Thinking and learning to learn (T1), Cultural competence, interaction and selfexpression (T2), Taking care of oneself and managing daily life (T3), Multiliteracy (T4), ICT competence (T5), Working life competence and entrepreneurship (T6), Participation, involvement and building a sustainable future (T7).

Finnish students receive also periods of phenomenon-based learning, a type of inquiry-based learning[10]. A phenomenon is defined as something that exists and can be seen, felt, tasted, etc., especially something unusual or interesting. Examples of phenomena include scientific discoveries, trends in technology, and natural disasters. Learning about or witnessing phenomena sparks our curiosities. With PhenoBL, students interact around real-world issues to investigate a problem or explore a curiosity from multiple vantage points. Students study phenomena as complete entities in their real contexts along with related interdisciplinary information and skills. It is the process of exploring questions using evidence collected from research. The information that is gathered is studied with and against existing models and theories. The insight gained from their investigations lead students to new understandings. Finnish students use this hands-on approach to explore themes ranging from entrepreneurship to space exploration. During PhenoBL, students *create*. Finnish students explored design during their phenomenon-based learning week. After researching famous Finnish designers, students used Tinkercad, a 3D design program, to make their own creations.

[9] Lähdemäki J. (2019) Case Study: The Finnish National Curriculum 2016—A Co-created National Education Policy. In: Cook J. (eds) Sustainability, Human Well-Being, and the Future of Education. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-78580-6_13

[10] https://blogs.edweek.org/edweek/global_learning/2018/10/phenomenon-based_learning_in_finland_inspires_inquiry.html

Some Finnish seventh grade students researched the amount of water usage in their community and in their homes. They created graphs depicting this information along with facts and statistics to show the need for conservation. In addition to the research, students programmed LEGO robots to solve a set of missions that pertained to water—how we find, transport, use, or dispose of it. At the end of the project, groups presented their research, programmed robotics, and proposed water conservation solutions to a panel of judges. The project began with students' desire to explore real life phenomenon and create their own models, which led them to advocate for action. PhenoBL also promotes teacher *collaboration*. At Espoonlahti School in Finland, teachers from different disciplines team up to develop and implement interdisciplinary phenomenon projects [11]. For example, art and physics classes collaborate to learn how to use lighting when photographing. Biology and cooking classes collaborate on projects to learn about marine life before preparing special seafood dishes.

To promote STEM technology in Finland, a national development program, LUMA, was launched to support the competence of children and youth in mathematics and science.

- LUMA – national platform of STEM education[12]

  LUMA Center Finland is a network of 13 LUMA regional centers in Finnish universities. The network provides a national and international collaborative ecosystem for the development of mathematics, science and technology education, providing activities and access resources across the country. The current LUMA ecosystem is a social innovation in which universities, schools, teachers, students, and industry work together to engage all children and young people from 3 to 19 years old in mathematics, science and technology, and support research-oriented teachers to study in throughout life. The LUMA Center in Finland encourages and develops both national and international cooperation between educational institutions from kindergarten to universities, the business sector, administration, science museums and centers, teacher associations and the media, as well as all other relevant organizations. Annually, 400,000 people (children, youth, parents, and teachers) take part in the activities of the center. LUMA centers are represented in various universities in Finland:

[11] https://blogs.edweek.org/edweek/global_learning/2018/10/phenomenon-based_learning_in_finland_inspires_inquiry.html
[12] https://www.luma.fi/en/

- Aalto University Junior
- Central Finland LUMA Centre (University of Jyväskylä)
- LUMA Centre Lapland (University of Lapland)
- LUMA Centre of Central Ostrobothnia (Kokkola University Campus Chydenius)
- LUMA Centre of Ostrobothnia (University of Vaasa)
- LUMA Centre of Southwestern Finland (University of Turku)
- LUMA Centre of the University of Eastern Finland
- LUMA Centre of the University of Oulu
- LUMA Centre Päijänne Tavastia (Lahti University Campus)
- LUMA Centre Saimaa (LUT University and Saimaa University of Applied Sciences)
- Skolresurs (Åbo Akademi University)
- Tampere LUMATE Centre (Tampere University and Tampere University of Applied Sciences)
- University of Helsinki Science Education Centre

The University of Helsinki coordinates the entire network. Each center has its coordinator and director, working part-time or full-time. Coordinators regularly conduct web conferences. LUMA National Days are held once a year. STEM research and innovation in STEM training are being expanded through the national online portal LUMA.fi, the LUMA newsletter, and LUMA TV. Over 10 years ago, the Tämä toimii! (It works!) school technology contest started in the technology industry in Finland. Since 2013, LUMA Center Finland has taken responsibility for organizing this competition. The main projects of the LUMA Center are described in more detail below.

STEM-related Collaborative Projects (Government/Business/University) and Best Practices of Non-Formal/Informal STEM Education

- **Tampere LUMATE Centre**[13]

  The LUMATE Center in Tampere was the first LUMA technology-oriented center in Finland (the additional "TE" in the name comes from the word "Technology"). The center was founded in the spring of 2011 by the joint efforts of Tampere Universities, the Bureau of Economic Information, the Tampere Chamber of

[13] https://www.lumate.fi/

Commerce, the Tampere Technology Society and the Federation of Finnish Technology Enterprises. The center operates on the campus of Tampere University of Technology. The LUMATE Center organizes science clubs for children (grades 1 through 8): Lego robotic clubs, electronic clubs, programming clubs, and science clubs. Most of these events take place in the evening at LUMATE's study room, located within the Tampere Technology School. Also, every two weeks LUMATE organizes an event called “Tiedepysäkki” (science station).

During the school holidays, LUMATE organizes science camps every summer and autumn. Camps are designed for children from preschool to grade 8. In addition to activities for schoolchildren, LUMATE organizes monthly Science Cafes in the Old Library building in the center of Tampere. These are public events designed for older students and adults. Science cafes provide a unique forum for exploring interesting STEM subjects for high school students and students, as well as for the general public. LUMATE invites experts to popularize mathematics and coordinates national tours with other LUMA centers.

Teaching and training for teachers and student advisors: LUMATE provides a variety of learning resources. The first of these is the “Bank of Experts”, from which teachers can invite various specialists to conduct presentations in their schools. Each expert is a specialist in a certain field, and their visits can be organized in such a way that they correspond to the teacher’s timetable, thereby improving students' understanding of the subject at hand. LUMATE also maintains a central “laboratory equipment bank”. Schools can be provided with special equipment to demonstrate scientific phenomena in the classroom. Most of this borrowed equipment is available in sufficient quantity to allow an entire class to participate in the experiments. The LUMATE web page also has a training material bank, which includes a collection of instructions for scientific experiments and various methods for presenting various scientific concepts and ideas.

- LUMARTS[14]

In 2012, Aalto University began building a special LUMA laboratory for schools. It was called LUMARTS. LUMARTS Laboratory is a learning and teaching environment that supports and develops science, technology, and art. LUMARTS laboratory was developed in conjunction with Biofilia. Biofilia is the LUMARTS functional unit for biological arts, which also strives to maintain a positive STEAM image (STEM + ART)

[14] https://junior.aalto.fi/

and offers unique educational alternatives in the fields of science, art, and technology. School teachers can book time at LUMARTS and bring their students to experiment. The teacher is responsible for the group, and Aalto University offers an assistant to do the work in the laboratory. Study tours for pupils and students aged 10–20 years vary from one hour to a longer time. For high school students, LUMA Center Aalto offers lectures and courses, for example, lectures and courses in mathematics, chemistry, astronomy, and biology, taught by teachers and university professors. Lectures in the natural sciences are organized on average twice a month; students from several universities participate in them.

- StarT Finland[15]

  StarT is the flagship program of LUMA Center Finland (Finnish platform STEM). Launched in 2016, the main goal of the program is to bring science, mathematics, and technology closer to children and youth through interdisciplinary project co-education. The program is implemented by LUMA Center Finland (a network of regional STEM training centers at Finnish universities) through "learning communities" with the support of cooperation partners, including the Finnish National Education Agency and science and technology companies such as IBM.

  The StarT program is implemented at three levels: 1. Local-level: Kindergartens, elementary schools, high schools and after-school groups participating in StarT. 2. Regional level: StarT festivals organized throughout Finland by LUMA centers together with local partners (does not apply to foreign participants). 3. National / international level: LUMA Center in Finland organizes a StarT gala concert, which awards teams selected by the StarT jury, as well as foreign teams. In the 2016-2017 school year, the StarT program supported 400 learning communities from Finland and 350 learning communities from abroad with participants from 36 countries.

- BioPop[16]

  The BioPop Center is a resource center for science education at the LUMA Center at the University of Helsinki. The main goal is to inspire and motivate children and adolescents in the field of biology, to support the study and enthusiasm of biology in children and adolescents, and to support all biology teachers in teaching and professional development. They organize school visits to the university, clubs,

[15] https://start.luma.fi/en/

[16] https://www.helsinki.fi/en/science-education/biopop

camps and teacher training on the job, and produce electronic educational materials for the site and blog.

- F2k[17]

  F2k's main goal is to foster understanding and interest in physics and technology among Finns. The center works as part of the training of physics teachers at the Faculty of Physics, University of Helsinki. F2k provides on-the-job teacher training by offering workshops and summer courses for physics teachers and classroom teachers. Science clubs and summer camps for children aged 8 to 14 years have been held since 2004. For high school students, the F2k laboratory offers practical experiments in modern physics and an understanding of modern research in the field of physics. He also organizes outreach activities in collaboration with organizations whose goal is to make science more famous.

- PaikkaOppi[18]

  PaikkaOppi is a free online learning environment for schools. It includes tools for mastering the basics of geographic knowledge and recommendations on how to use geographic knowledge in different disciplines.

- Summamutikka[19]

  Summamutikka is a resource center for teaching and studying mathematics as part of the LUMA National Center and the Department of Mathematics and Statistics. Summamutikka offers ideas on how to teach mathematics based on project activities. He supports and develops the teaching and study of mathematics.

- Tutki-Kokeile-Kehitä[20]

  Tutki-Kokeile-Kehitä is a competition aimed at inspiring children and young people in science and engineering activities. Providing participants with the opportunity to receive feedback on their research and get to know other like-minded people, this opens up a world of endless possibilities.

- SciFest[21]

[17] https://www.helsinki.fi/en/science-education/f2k-student-laboratory
[18] http://www.paikkaoppi.fi/fi/#
[19] https://www.helsinki.fi/en/science-education/summamutikka
[20] https://tukoke.tek.fi/
[21] http://www.scifest.fi/home_en.php

SciFest is an annual international festival that brings together thousands of students, high school students and teachers to discover new experiences and learn about science, technology, and the environment. SciFest is held every year during one spring weekend in Joensuu, Finland. The festival is free and open to all.

- The Innokas Network[22]

The Innokas Network helps schools organize their 21st Century skills training activities and participate in educational development. They support schools by organizing training, consultations, and events in different parts of Finland. The network was created by a group of practicing teachers. To date, the network has more than 600 schools throughout Finland, as well as international partner schools.

Innokas training is based on the Innovation School model developed in collaboration between Finnish schools and the Faculty of Education at the University of Helsinki. This network is involved in many projects that are discussed in other sections.

- Co4Lab[23]

The goal of the Co4Lab project is to research and develop knowledge-based teaching methods, collaborative design, collaborative learning, and collaborative regulation. The project aims to improve the quality of science, technology and craft education in primary and lower grades of secondary school by organizing a series of design experiments. School projects focus on the study of complex real-world phenomena, the integration of knowledge and competencies in subject areas, the invention, testing and design of various products, as well as the accumulation of knowledge about the teaching process. The project creates guidelines, models, and resources for knowledge-based learning to support teachers and schools in developing and implementing STEM practices.

- Growing Mind[24]

The Innokas Network is a partner in the Growing Mind research project funded by the Academy of Finland. This project, operating in 2018-2022, is aimed at the development of school activities of the 21st century and its study in the framework of digitalization of society. The Growing Mind project aims to create funds for the

[22] https://www.innokas.fi/en/
[23]http://co4lab.helsinki.fi/en/
[24] https://growingmind.fi/theproject/

renewal and development of schools, teacher development, and student learning at the personal, social and institutional levels. Project activities are carried out in collaboration between schools and academic research. The events support the goals of the new core curriculum, the skills of 21st-century students and the professional development of teachers.

- Uutta luova asiantuntijuus (ULA)[25]

  Innokas Network is a partner in a teacher training project funded by the Finnish Ministry of Education and Culture - "New Creative Expertise - Combining Primary and Continuing Teacher Education" (ULA). The project aims to develop new structures and content, allowing to connect both the training of new teachers and the retraining of teachers on the job. Interdisciplinary topics in teaching and teaching include knowledge of different languages, equal and democratic school, research work, collegial cooperation, student motivation, interaction, and digitalization, as well as cooperation between curricula.

- Finnable project[26]

  In 2012-2015 Innokas network was responsible for the implementation of the Innovation School project, funded by Tekes. The project studied the school and its surrounding community as a complex of networks of learning environments. For the Innovation School, new methods of using technologies have been developed, including new ways to use digital technologies to support students. So, the Finnable project was created. FINNABLE 2020 contributes to the creation of new learning ecosystems that go beyond the traditional boundaries of where, when and with whom learning takes place. This project conducts research and development of collaborative, technology-oriented learning environments for the 21st century - locally and internationally. FINNABLE 2020 is supported by contributions from research institutes, practitioners in schools, and industry partners. FINNABLE 2020 consists of four work packages: Boundless Classroom, Teacher's Toolkit, Exergames in Learning and Emergent Learning Technologies and Communities.

- Ekopaku[27]

[25] https://www.uuttaluova.fi/
[26] http://www.finnable.fi/index.php/home.html
[27] http://www.ekopaku.fi

Ekopaku acts as an environmental school. The car includes all equipment for nature research and training materials, as well as pre-designed training aids. Ecovan – an outdoor classroom (Aulikki Laine, Finnish Association of Schools of Nature and the Environment). In new curricula, memorable, experiential and phenomenon-based learning plays a very important role in teaching. One way to expand learning is through outdoor learning. Ecovan has everything you need for outdoor learning.

- ScratchJr[28]

  ScratchJr is an introductory programming language that allows young children (5-7 years old) to create their own interactive stories and games. Children connect the graphic programming blocks so that the characters move, jump, dance and sing. Children can change characters in the color editor, add their voices and sounds, even embed their photos - and then use the programming blocks to spice up their characters. ScratchJr was inspired by the popular Scratch programming language (scratch.mit.edu), which is used by millions of young people (ages 8 and older) around the world. ScratchJr is available as a free app for iPad and Android tablets.

- Arkki International Ltd[29]

  In 1993, the Finnish National Education Agency created the basis for a curriculum on architectural education. It was then that the schools of fine art, music, and dance had a new partner - the school of architecture. The curriculum for architectural education is divided into early education, basic art, and advanced education. Early education is for children and parent groups for children from 4 to 6 years old, basic education is for children from 7 to 14 years old, and advanced education is for children from 14 to 19 years old. Arkki uses a wide range of methods but focuses on 3D working methods. By creating miniature models, as well as on a 1: 1 scale, children can make discoveries on their own, rather than receive answers from adults. Teaching at Arkki is about art and the environment. One of the main goals of architectural education is to provide children with ways and opportunities to observe and evaluate their surroundings. In family groups, the goal is to help children begin to form interactive relationships with their environment. Education improves their sense of space, shape, movement and materials, and structures. The student plays an active role in studies and training.

[28] https://www.scratchjr.org
[29] https://www.arkkiinternational.com/

Teaching is based on the special approach of each age group to the perception of the world and experiences.

- SuoMu[30]

  SuoMu, the Finnish design training association, promotes the use of design education on a variety of learning platforms. SuoMu conducts seminars and lectures for schools and various cultural events. At SuoMu Design School events, you can enter the image of a designer and go through the entire design process with SuoMu assistants in various subjects. The Mutku project - "Design Education for Elementary Schools" was launched in 2012, and as a result, in 2014, a design manual for primary school teachers "Mutku" was published. A tour of SuoMu Design Ambassadors to elementary schools disseminates information on design and creative learning. In the fall of 2015, a pilot project began with teachers of an elementary school in Helsinki, which aims to update teaching practices throughout the curriculum.

- ITEEA[31]

  ITEEA's mission is to expand technological and engineering capabilities for all people, as well as to educate and promote the professionalism of those involved in these activities. ITEEA is committed to meeting the professional needs and interests of its members, as well as improving public understanding of technology, innovation, design and engineering, and their contribution to human life.

STEM-Teacher Training Programs and Courses

The Finnish National Board of Education emphasized the following core values for the development of teaching profession competences[32]:

- life-long learning
- knowledge and research-based orientation
- effectiveness
- anticipation of future needs and competences in education

The teaching profession is a learning profession, and teachers are expected to develop their work and profession throughout their careers. Finnish teacher education is based on a strong research orientation. This reflective and critical

[30] https://muotoilukasvatus.info/eng-swe/

[31] https://www.iteea.org/About/ExploreSTEM/43398.aspx

[32] Rajakaltio, H. (2014). Towards renewing school. The action model of the school development - Integrating in-service-training and the development process. (In Finnish), Reports and 2014:9. Reports and reviews 2014:9. The Finnish National Board of Education, Helsinki, Finland.

knowledge creation approach is also important for in-service training. In Finland, there is a strong movement from individual in-service training days towards more long-lasting development projects and programs that could be more sustainable in their effects. FNBE outlined that staff training must integrate the latest research, knowledge from education evaluations, new knowledge creation, and competence development. Most universities have education centers for teachers' in-service training. It is important that research-based and research-informed orientation of pre-service teacher education continues, and teachers can learn the most up-to-date and advanced knowledge of their subject matters as well as pedagogy through in-service training. University centers' in-service training provide more projects and longer development processes than short courses. The aim is that teachers critically reflect on their own work and create small design-based action research projects through which they learn new competences and also share new ideas with their colleagues.

LUMA Centre Finland also promotes effective continuous professional development for STEM teachers. the University of Helsinki launched a Massive Open Online Course, MOOC (in Finnish) that aims to provide support and ideas for teachers to find and utilize a suitable nearby business as learning environments. In addition, the course provides tips for planning and implementing a good visit and for creating a learning material. The current LUMA ecosystem is a social innovation in which universities, schools, teachers, students, guardians, and industry collaboratively engage children and young people from ages 3 to 19 in math, science, and technology and support research-oriented teachers at all levels for lifelong learning[33]. The core value of this collaboration is shared expertise. The LUMA Center Finland encourages all collaborating partners to share their ideas, experiences, and practices freely, in the spirit of open education. The center supports communality among children, youth, and teachers. Their natural interaction with the scientific community in the universities and industry is fostered, and their voice is a part of the design process of the LUMA activities. The LUMA Center supports teachers' lifelong learning through a continuum model[34] that includes the following components: (1) pre-service training, (2) an induction stage, and (3) in-service training. LUMA activities have been integrated into the training of both elementary and subject teachers at Finnish

[33] Vihma, L. & Aksela, M. (2014). Inspiration, Joy, and Support of STEM for Children, Youth and Teachers through the Innovative LUMA Collaboration. In H. Niemi, J. Multisilta, L. Lipponen, & M. Vivitsou (Eds.), Finnish Innovations & Technologies in Schools: Towards New Ecosystems of Learninng (pp. 72–84). Rotterdam, NL: Sense Publishers.
[34] Aksela, M. (2008). The Finnish LUMA Centre: Supporting teachers and students in science, mathematics, and technology for life-long learning. Lifelong Learning in Europe, 13, 70–72.

universities. During their studies, preservice teachers are provided with authentic and regular experiences to interact with children and youth by leading different activities in the LUMA Center. Pre-service teachers also use the latest research information to actively produce teaching materials and ideas that benefit all teachers of STEM subjects in Finland.

STEM EDUCATION IN IRELAND

Context

In recent years, governments of developed countries around the world and in Ireland also[35] have paid special attention to improving the quality of education in science, technology, engineering and mathematics (STEM). STEM disciplines are extremely important for modern society. They expand our understanding of the world and are key in many important areas of activity[36]. Mathematics and natural science provide answers to fundamental questions of nature, and engineering allows you to turn these answers into technologies. Analysis of the current situation shows that the development of STEM disciplines will accelerate economic development, support innovation, and provide the foundation for future prosperity.[37] High-quality training of graduates of STEM disciplines will ensure the development of the knowledge economy. Ireland aims to be the center of technological innovation and the leader of highly intelligent industries. To do this, Ireland's strategy for research and development, science and technology is being created. This development plan provides qualitative changes in the field of STEM education to support the most talented individuals and leaders of educational institutions and methodological centers.

STEM Education Policy Statement and Implementation Plan for Schools

In Ireland after consultation with experts one of the ways of obtaining highly-skilled workforce was recognized the way of STEM education. This have required a clear understanding of STEM education for the Irish context. The embedding of this understanding across the education system will help transform the STEM education experience of learners from early years through to post-primary. In the development of the STEM Education Policy Statement and Implementation Plan[38], a series of STEM education consultations were undertaken between May and July 2017 to gather the

[35] https://www.gov.ie/en/policy-information/4d40d5-stem-education-policy/#why-we-need-a-stem-education-policy
[36] https://arrow.tudublin.ie/st4/2/
[37] https://www.sfi.ie/
[38] https://www.education.ie/en/The-Education-System/STEM-Education-Policy/stem-partnerships.html

views and opinions of key stakeholders to inform the Policy Statement STEM Education[39]. Implementation of this approach will take place over several phases from 2017 till 2026.

Implementation Phase 1 (2017-2019) – Enhancing Phase 1 will seek to accelerate activity already underway in key areas. It will also seek to build capacity across the system and develop new initiatives. Initiatives from schools themselves through clusters and partnerships will be particularly encouraged. Audit and evaluation of key methods that are crucial to achieving our ambition and developing the benchmarks of success will be undertaken. Phase 1 will focus on establishing what is necessary to provide a quality STEM education experience. Key to this is the analysis of existing baseline data and the generation of new benchmarks to develop targets and indicators which are well-defined, realistic and time-bound.

Implementation Phase 2 (2020-2022) – Embedding the focus of Phase 2 will be on deepening capacity building and supporting a coherent STEM environment. A structured approach, which incorporates monitoring and review, will allow actions to be revised and developed in line with identified needs.

Implementation Phase 3 (2023-2026) – Realising Phase 3 will focus on realising the vision of providing the highest quality STEM education experience for learners. Actions in phase 3 will be informed by reviews of Phases 1 and 2, ongoing research and the changing educational and societal environment.

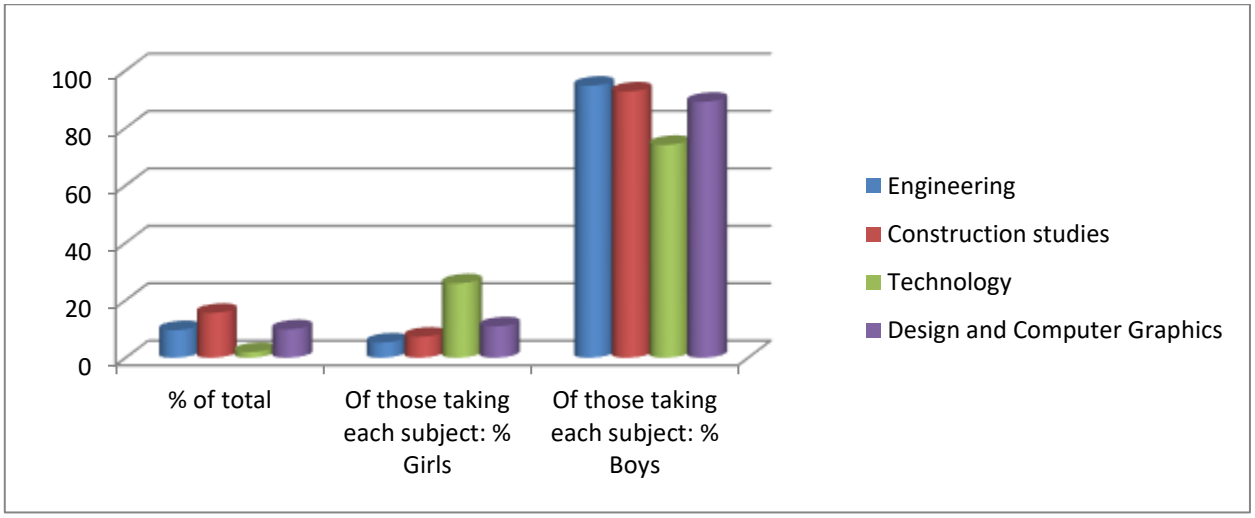
In November 2016 a Report on Science, Technology, Engineering and Mathematics (STEM) Education[40] was published. The agreed Terms of Reference (TOR) for the review were as follows:

1. The preparation of teachers (Initial Teacher Education; ITE) at Primary and Post-Primary Level for STEM education.
2. The best methods of supporting the current cohort of STEM Teachers within the system, with a particular focus on Continuing Professional Development (CPD) programmes.

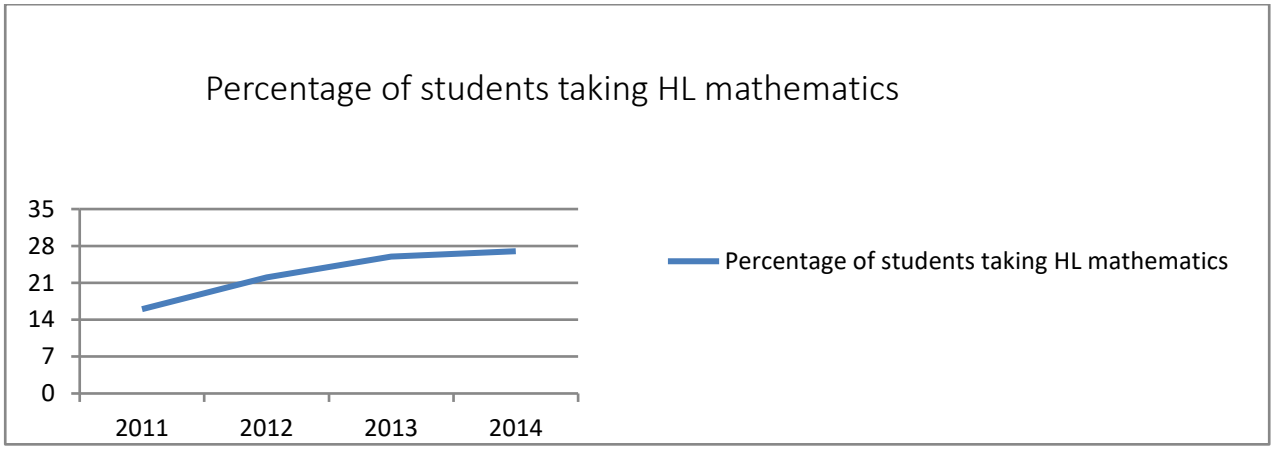
[39] https://www.education.ie/en/The-Education-System/STEM-Education-Policy/stem-education-policy-statement-2017-2026-.pdf
[40] https://pdst.ie/

3. The introduction of new teaching and learning modalities that would enhance STEM education in our schools and for which there is a strong evidence base (e.g. inquiry-based learning and problem-based learning approaches; new assessment modalities).
4. The use of technology to enhance learning (especially digital and/or on-line approaches).
5. The promotion of STEM careers and the identification of methods to enhance the engagement of students in STEM subjects.

Now the STEM subjects are selected[41] by a small number of students and there is a strong gender imbalance. It can be seen from fig. below (the data for the 2014).



The proportion of the students taking the Leaving Certificate Mathematics examination has increased markedly:



[41] https://www.education.ie/en/The-Education-System/STEM-Education-Policy/stem-indicators.pdf

Two factors (Bonus CAO Points and the Project Maths initiative) are likely to have played a significant role in this increase, although their relative impact is difficult to estimate. The award of 25 CAO points for achieving a minimum of grade D in the Higher-Level Mathematics examination in the Leaving Certificate has certainly enticed students wishing to maximize their overall CAO score. The Irish Maths Teachers Association (IMTA) emphasized the popularity of the new 'Project Maths' approach with students, indicating that students enjoyed the teaching methods and the use of more real-life application contexts.

After analyzing current situation, the authors of this report[42] suggested the following:

1. Produce an integrated National STEM Education Policy Statement with input from, and relevance to, all stakeholders across the continuum of education in Ireland (primary, secondary and third level). This Policy Statement should include a detailed implementation plan with responsibilities and timelines clearly outlined.
2. Introduce computer science (including coding) as a Leaving Certificate curriculum subject. This is critical to address the ICT skills deficit in Ireland.
3. Establish the STEM 2020 Partnership – a fixed-duration, public-private (enterprise-exchequer) partnership to create a fund to support a prioritized set of agreed, specific initiatives consistent with the recommendations of this report. This would entail pooling of resources from enterprise partners, philanthropy and crowdsourcing with resource-matching by the exchequer (DES, DJEI, SFI) over a five-year period. A fund of €8M per annum for five years, equally subscribed from public and private interests, is envisaged.
4. Establish STEM education research as a national research priority with multi-annual, sustained funding commitment through SFI. (The following recommendation would be an excellent means of achieving this).
5. Establish a National STEM Education Research Centre, comprising a small number of regionally distributed nodes (based on the highly successful UK Science Centre model). This national centre would act not only as a centre of excellence for research and innovation in STEM education, it would also provide locations for delivery of CPD programs for teachers.

[42] https://www.education.ie/en/The-Education-System/STEM-Education-Policy/stem-education-consultation-report-2017.pdf

6. Create an annual 'Excellence in STEM Teaching' award scheme to recognize those teachers who are pioneering innovations in STEM education and who are outstanding educators.
7. While this report has focused almost exclusively on the STEM disciplines and STEM Education in general, it is now well established that the intersection of these areas with the Arts (visual and performing) and Design offers great potential in terms of both cultural advancement and economic development opportunities. With this is in mind, it is important that any future strategy for STEM in Ireland takes account of the STE(A)M hybrid, where A represents the Arts and Design (including design thinking). It is proposed, therefore, that the Royal Irish Academy play a formal role in advancing the thinking on this topic in the Irish context with a view to influencing future policy decisions regarding STEM Education.

STEM Education Policy Statement[43] (2017-2026) focusses on the many strengths in STEM education while providing a roadmap to address the areas for development. In developing this Policy Statement, three key principles have been identified that will underpin all STEM education initiatives: STEM is about igniting learners' curiosity so they participate in solving real world problems and make informed career choices; STEM is interdisciplinary, enabling learners to build and apply knowledge, deepen their understanding and develop creative and critical thinking skills within authentic contexts; STEM education embodies creativity, art and design. The actions outlined for STEM education will build on a range of reforms and activities already underway such as curriculum reform and innovative teaching, learning and assessment. They are also informed by the STEM Education in the Irish School System Report, research and extensive consultation with stakeholders. Other influencing factors include parents' perceptions and expectations and the evolving STEM education eco-system.

Concepts and Projects

- EPI-STEM

  As a result of A Report on Science, Technology, Engineering and Mathematics (STEM) Education was established EPI-STEM, the National Centre for STEM Education It is based at the University of Limerick. (tel.: +353 (61) 23 47 86, FAX:

[43] https://www.education.ie/

+353 (061) 23 47 99, e-mail: epistem@ul.ie)[44]. The Centre aims to improve STEM education through research into effective teaching, learning and professional development. The mission of EPI-STEM is to conduct an integrated program of research, teaching, and engagement that addresses national and international challenges in STEM education. This goal can be achieved by leveraging distinctive connections between STEM education academics and STEM discipline academics, and by forging connections with policy makers, practitioners, industries, and community groups that have a stake in STEM education.

The vision of EPI-STEM is to be recognized as the premier national centre for STEM education that positively influences STEM education policy and practice as well as public perceptions of STEM. EPI-STEM aspires to international recognition for high-quality, high-impact STEM education research that supports beneficial exchange of knowledge between researchers and the communities they serve and leads to enhanced teaching practices and improved educational outcomes for learners.

Actual EPI-STEMProjects

Numeracy Across the Curriculum Project

In August 2019, EPISTEM launch the Numeracy Across the Curriculum [NAC][45] project for schools in the Limerick region. It is a year-long research and development project that develops strategies for teaching numeracy across the curriculum in both primary and secondary schools.

The NAC project is an excellent opportunity for schools across the Limerick region to establish fruitful and meaningful links with the university. This project seeks to develop teachers' understanding of numeracy, while also guiding teachers on how to recognize and embed numeracy opportunities within their subject area. In order to participate in the NAC project two teachers (of any subject) from each school must attend a summer school (3 days in August 2019) and 2 workshops (1 day in November 2019 and 1 day in May 2020) and engage in 2 action research cycles which involve the delivery of model lessons; classroom observations and

[44] https://epistem.ie/

[45] https://epistem.ie/home-2/professional-development/numeracy-across-the-curriculum-project

supportive feedback from the EPI-STEM research team; and teacher and student interviews.

Common European Numeracy Framework

With financial support of the European Union under the Erasmus+ scheme four countries - the Netherlands, Austria, Spain and Ireland – have initiated the first steps to come to a Common European Numeracy Framework (CENF)[46] and are going to work towards such a framework between 2019 and 2021. As result of this project a Common European Numeracy Framework (CENF) will be established and based on this framework a set of professional development modules for adult numeracy educators will be developed. The CENF will incorporate the latest insights into quality numeracy skills and competencies which are relevant for our technologize and numbers-drenched society.

A Global Approach to the Gender Gap in Mathematical, Computing, and Natural Sciences: How to Measure It, How to Reduce It?

This project[47] started in January 2017, will last till January 2020 and consists of three tasks. Tasks 1 and 2 provide data on which to base conclusions, to direct actions to attract and retain women in science, and to develop and evaluate practical recommendations. Task 3 collects information on effective practices. The relevance of the study is due to the fact that although the description mathematical and natural sciences have long and honorable traditions of participation by highly creative women contributors but however, the percentages of women scientists remain shockingly low and there is a significant gender gap at all levels between women and men.

Pre-service teachers' understanding of the concept of numeracy as a cross curricular subject in post-primary schools in Ireland

At present, internationally and in Ireland, there is a conscious effort being made to improve and raise the profile of the teaching and learning of numeracy. Teachers' perceptions and interpretations of the concept of numeracy relies greatly on their understanding of numeracy. If teachers have a deep understanding of the concept of numeracy, and an awareness of the essential role it plays in allowing an

[46] https://epistem.ie/research/research-projects-2/common-european-numeracy-framework
[47] https://epistem.ie/research/funded-projects/the-gender-gap-project

individual to fully engage in society, then the inclusion of the teaching and learning of numeracy will play a more significant role within their subject(s). This study have begun in September 2016. The purpose of is to assess current pre-service teachers understanding of the concept of numeracy as a cross curricular subject and to identify and quantify the package of knowledge required by pre-service teachers to integrate numeracy into their lessons. This study will be carried out in three universities in Ireland till June 2020 with second year Professional Master's in education students.

Primary and Post Primary teachers' insights into their teaching of algebra

Since January 2018 this research has focused on teachers' insights into their teaching of algebra, particularly during the transition from primary to post-primary school. Data generated in this research specifically investigates upper primary and lower post-primary school teachers' conceptual understanding of algebra. The study was qualitative in nature and involved two phases of semi-structured interviews with a cohort of upper primary and lower post-primary school teachers. The second interviews have just been completed and transcription will be done till December 2019.

Evaluation of the Faculty of Education and Health Sciences Dean's Post-Doctoral Research Fellowship Programme

The Research Fellowship Programme represents a substantial strategic investment by the Faculty of Education and Health Sciences, with the initial cohort comprising six Dean's Fellows appointed for three years from March 2018 till December 2019. The distinctive feature of the programme is its emphasis on mentoring and career advancement to develop future research leaders. The research study will provide essential information about short-term impacts of the programme as well as evidence to support decisions about whether and how it should be continued.

What's the Point? Teachers Perspectives' on the Incentive of Bonus Points for Studying Higher Level Mathematics

In Ireland, a Bonus Points Initiative (BPI) was introduced in 2012 for mathematics. Through this initiative, any student who opts to study higher level mathematics receives an additional 25 CAO points on condition that they pass the Leaving Certificate examination. The main aim of this study is to investigate the

benefits and challenges associated with the BPI from the perspective of mathematics teachers. This project commenced in January 2018 and questionnaires were distributed in April 2018. 800 teachers across 400 post-primary schools were targeted and 266 teachers responded. The data collected is currently being analysed by the research team (April 2018 – December 2019).

WiSTEM2D Scholars Award Program[48]

From September 2018 till September 2019 the awards have fund a woman per discipline who has completed her advanced degree, who is working as an assistant professor and who is not yet tenured at an accredited university or design institution. The goal is to fuel the research passion of the awarded women and inspire career paths in their respective STEM fields

Career Mathways Project

The project[49] received funding under the SFI Discover scheme, SFI's Education and Public Engagement program which seeks to promote the awareness and engagement of the Irish public STEM. According to SFI "...the mission of this programme is to catalyse, inspire and guide the best in STEM education and public engagement. This is done by supporting and developing the education and outreach STEM sector in Ireland by investing in developing and extending capacity in this area and also exploring and encouraging novel means of public engagement and communications."

Career Mathways aligns with the goals of the Discover Programme as it seeks to promote STEM, and in particular mathematics, among Transition Year students; their parents; their mathematics teachers as well as career guidance teachers. The initiative aims to highlight the mathematics underpinning a variety of careers, as a way of enhancing student engagement across all STEM subjects. The project engages with several well-known, high profile personalities (e.g. Jacqui Hurley [RTÉ Sports Correspondent]; Lizzie Lyons [TV3 Chef & Entrepreneur]; Dean Strang ['Making a Murderer' Lawyer]; Joanna Donnelly [Meteorologist, Met Eireann]) and other professionals, who all kindly volunteered their own time to act as STEM Ambassadors. In their role as STEM Ambassadors these professionals recorded an

[48] https://epistem.ie/research/funded-projects/wistem2d-project
[49] https://epistem.ie/research/funded-projects/career-mathways

interview with the Career Mathways research team in which they explored the different types of mathematics they use in their careers and highlighted how important is it to have a good understanding of mathematics and be proficient in the subject. These videos serve to make mathematics more visible and fascinating to students and it is hoped that it will help teachers when faced with the common question "Where will I use this again?" The videos were then used by the team of researchers to develop a suite of resources including detailed and innovative teaching and learning plans; student workbooks featuring authentic, real-world problems as well as a poster series, kindly sponsored by the Irish Independent, to highlight to the entire school how valuable mathematics is in a variety of different professions.

TiME (Time in Mathematics Education)

Dr Niamh O'Meara and Dr Mark Prendergast (Trinity College Dublin) have received funding from the Irish Research Council, under the New Foundations Scheme, to conduct a research project entitled "Is there TiME (Time in Mathematics Education)?"[50]. The introduction of Project Maths in 2010 has prompted a number of reports and studies to suggest that there is an insufficient amount of time allocated to teaching mathematics in Ireland (Department of Education and Skills, 2011; Cosgrove et al., 2012; Irish Maths Teachers Association, 2012; Jeffers et al., 2013; Beggy and O'Meara, 2014). However, none of these reports have provided concrete evidence of the exact amount of time allocated. Thus the main aim of this project was to investigate such issues surrounding the allocation of time for instruction.

Chain Reaction

Chain Reaction[51] is a project focused on creating a sustainable approach to the use of scientific inquiry in the classroom using a cascading model to facilitate its impact. This project ran from 2013 to 2016 across 12 partner countries and located within UL is the Irish partner involved. The Chain Reaction model is cyclical in nature so each year the project was recruited new teachers (10 each year) from different schools ensuring a large number of teachers and students are able to participate. The focus in Ireland is to create a professional learning community

[50] https://epistem.ie/time-time-in-mathematics-education
[51] https://epistem.ie/research/funded-projects/chain-reaction

(PLC) involving teacher educators, in-service teachers, pre-service teachers, practicing scientists and policy makers with the aim of developing a living educational theory of what teachers believe inquiry to represent in their own classroom context. After teachers have engaged in interactive IBSE professional development, their students (in the 14-16 age group) work together to research scientific scenarios. Their work is then summarized in a national "Express Yourself" conference held each year in UL where students present posters related to their investigation and the experience of using an inquiry approach. All methodologies used are coherent with the revised science syllabus and the work is conducted as a community of practice that emphasizes sharing ideas in a truly developmental process.

Student Mathematical Preparedness for Third-Level STEM Degrees

The aim of this project was to explore students' mathematical preparedness for STEM education at tertiary level in the Irish context. The project have taken an innovative approach to the issue of student retention in STEM degrees by investigating the perceptions of three stakeholders – teachers, students and lecturers – on the mathematical preparedness of students for studying science and engineering at tertiary level. This project also examined the existence and perception of interdisciplinary STEM education in preparing students for the transition to tertiary level STEM learning.

- CASTeL

CASTeL is Ireland's largest research centre in Science, Technology, Engineering, and Mathematics (STEM) education (Dublin City University, Dublin 9, tel. +353 (0) 1 700 5862, castel@dcu.ie, eilish.mcloughlin@dcu.ie)[53]. CASTeL's mission is to support the development of STEM learners from an early age and thus enhance the scientific, mathematical and technological potential of Irish society. For nearly two decades, CASTeL has made a significant contribution to STEM education both nationally and internationally. Through evidence-based research, CASTeL leads and advises on the design of innovative and effective curriculum, teaching and learning in STEM education from early childhood to graduate level. What's more, CASTeL is uniquely positioned to conduct interdisciplinary research because of its diverse

[52] http://castel.ie/
[53] http://castel.ie/

backgrounds in STEM disciplines (mathematics, science, biology, chemistry, physics, engineering, digital learning, and technology). CASTeL brings together the research expertise of the Faculty of Science and Health Sciences and the DCU Institute of Education, which is Ireland's leading provider of teacher education. This allows CASTeL to be at the forefront of developing the knowledge and skills of future teachers to teach STEM subjects. In addition, CASTeL can provide Continuing Professional Development (CPD) in STEM education, encompassing both consistency and breadth. CASTeL is known for its leading role in international STEM education initiatives. Many of these focus on inquiry-based learning, in which problem solving and experimentation are based on students' curiosity and observation, allowing them to make sense of the world through critical thinking and reflection.

Current Projects

Assessment of Transversal Skills in STEM (ATSSTEM)[54] is a project of innovative policy experiments, which is carried out in 8 EU countries and includes a partner network of 12 educational institutions. ATS STEM is committed to providing teachers and students with effective and necessary digital assessment approaches to develop the cross-cutting skills of second-level students in STEM (Science, Technology, Engineering and Mathematics). This model is being developed, implemented and evaluated as part of a large-scale classroom pilot project leading to policy recommendations at both national and European levels for further educational transformation. Teachers, researchers, and students participating in the project will help plan new pedagogical approaches and learning outcomes to influence systemic change that will enable them to succeed in achieving their educational goals. The project also aims to ensure that policymakers have a deployment strategy to create a creative learning environment appropriate to their national or regional context.

ENERGE – Energizing Education to Reduce Greenhouse Gas Emissions

As the existing stock of high school buildings ages (it may take years from planning to completion of new schools / major renovations), there is a need for low-cost solutions that ensure long-term resource efficiency in schools and reduce greenhouse gas emissions (GHG). The EU directives on energy in construction and

[54] http://castel.ie/atsstem/

the climate protection measures 2020 and 2030 confirm this need. ENERGE[55] is meeting this need with targeted physical interventions that combine the web platform and building sensors (e.g. electrical, thermal, etc.) with behavioral research and new educational approaches that enable schools to participate in reducing energy and greenhouse gas emissions. This holistic, adaptable and interdisciplinary approach will combine sociological, pedagogical and communication expertise with low-cost technology, ICT interventions and systems engineering. ENERGE will be showcased in schools in France, Germany, Luxembourg, Ireland, the Netherlands and the UK. ENERGE is committed to achieving a minimum 15% reduction in total energy consumption in 12 schools with demonstration sites during the project period and will engage and enable management, teachers, students and support staff (the entire school ecosystem) to reduce energy consumption through the development of a new website. platform tailored for various stakeholders in the school ecosystem. Long-term impacts will be consolidated through the development of additional and revised teaching materials to complement existing school curricula (for students aged 12-18, i.e. ENERGE will monitor the impact of project initiatives outside the school environment on the home environment of staff and students (24 homes) to monitor how school interventions can have a wider impact outside the school environment ENERGE committees will be set up in the demonstration schools to focus on the transnational participation of project schools, long-term impact studies, and empower the entire school community to participate and support energy efficiency and reducing greenhouse gas emissions.

Let's Talk about STEM

Let's Talk about STEM is a pilot project[56], funded by Science Foundation Ireland, and led by DCU's Institute of Education in conjunction with the Centre for the Advancement of STEM Teaching & Learning (CASTeL) in DCU. This project is a collaboration between researchers in psychology and science and technology education to implement a pilot program to tackle the under-representation of women in science and technology, focusing on the early involvement of girls in science. This project, based on twenty years of solid international research and initiatives, is a STEM education program for parents and teachers of young children that highlights the potential impact of language on children's science and

[55] http://castel.ie/energe/
[56] http://castel.ie/LetsTalkAboutSTEM/

motivation to learn. In particular, it emphasizes that girls consider themselves capable of using and researching science. The program invites parents, preschool educators, child class teachers and informal STEM educators to participate in workshops in which they examine evidence on the role of language in girls and boys' different motivations for science learning and their persistence.

Maths4All.ie

Maths4All.ie[57], funded by SFI Discover, is a website designed for and with teachers. It contains activity plans, continuous professional development materials and video clips based on activities carried out in Irish primary and preschool classes. Plans are based on the draft specification of the forthcoming primary mathematics curriculum and Aistear and are suitable from preschool to third class. The website offers a video-based approach to continuous professional development and modules relating to mathematical tasks, talk and the use of play and picture books are available. Currently, we are working to extend the activity plans on offer to include the senior classes of primary school. We are also developing new professional development modules in response to a survey of teachers' needs and preferred formats.

3DIPHE – Three Dimensions of Inquiry in Physics Education

This ERASMUS+ project[58] is focused on different levels of inquiry relevant for physics education: 1) Inquiry based learning for pupils; 2) Practitioners' inquiry for teachers; 3) Inquiry of coaching for partners; 4) Educational research design of 3DIPhE. The goals of the project are to establish professional learning groups (PLG) of teacher practitioners and train them to inquire their own practice of inquiry based learning (IBL). In regular PLGs' meetings, we will discuss the inquiry problems, modes of inquiry, methods, evidence, and conclusions. We will reflect on improvement of the IBL in classroom. PLGs from different countries will exchange their experience, discuss their problems and reflect on methods, evidence etc. Results of these process will be presented at national and international events. Good examples of IBL praxis will be presented in a written, publicly available form. Based on the experience we will develop a course on practitioner inquiry. Based on the experience we will develop a course on coaching

[57] https://maths4all.ie/
[58] http://castel.ie/3diphe/

PLGs. Regular accompaniment and inquiry of all processes within the project will result in an extensive educational design research study.

Open Schools for Open Societies

This project[59] supports a large number of European schools to implement Open Schooling approaches by a) developing a model that promote such a culture, b) offering guidelines and advice on issues such as staff development, redesigning time, and partnerships with relevant organizations (local industries, research organizations, parents associations and policy makers), and c) suggesting a range of possible implementation processes from small-scale prototypes through to setting up an "open school within a school" or even designing a new school while it is testing and assessing them in more than 1,000 school environments in 12 European countries. The themes of the project activities developed and pursuit in participating schools that will take place will focus on areas of science linked with the Grand Societal Challenges as shaped by the EC, will be related to RRI and will link with regional and local issues of interest. The project is coordinated by Ellinogermaniki Agogi Scholi Panagea Savva (EA) and has 20 partner institutions. The project aims to describe and implement at scale a process that will facilitate the transformation of schools to innovative ecosystems, acting as shared sites of science learning for which leaders, teachers, students and the local community share responsibility, over which they share authority, and from which they all benefit through the increase of their communities' science capital and the development of responsible citizenship.

- STEM activities

Smart Futures

This is a selection of various educational activities for schoolchildren and students that allow them to understand the meaning of STEM education[60]

SciFest

[59] http://castel.ie/openschools/
[60] https://www.smartfutures.ie/

The SciFest programme consists of a series of one-day STEM fairs for second-level students. The aim of the programme is to encourage an interest in, and love of, the STEM subjects.

Tech Week

It is a nationwide series of events, showcasing and celebrating Ireland's application on technology which provides a platform for students to learn, share ideas and create connections to enhance our future world.

The Festival of Curiosity

It is Dublin's annual international festival of science, arts, design & technology. With brand new digital, virtual and blended formats for people of all ages to explore and discover science, arts, design and technology in playful new ways so we can stay safe while staying curious.

STEM in the Midlands

Accenture STEM professionals visited schools in the Midlands and presented STEM materials as well as explaining what Accenture has to offer. As a board member, one of the Accenture professionals is involved in the planning and direction of the organisation.

CoderDojo

In 2016, Accenture set up its' first CoderDojo coding club for a group of energetic young people, with a team of enthusiastic mentors from The Dock. Accenture continues to run the club for beginners to advanced learners, aged 7-17, through CoderDojo, in our Accenture offices in Dublin. It was created a coding club in Accenture, The Dock, during school term. CoderDojo offers a number of topics for kids to get involved in, like Scratch, Lightbot and Robotics. They learned how to code, develop websites, create apps, games and so much more in a fun, social and collaborative environment. It was also supported the other initiatives creating a wider awareness of STEM and coding alongside CoderDojo.

Girls Only TY Week

This is a weeklong Transition Year work experience programme, for girls only, with the aim of encouraging them to think about choosing STEM subjects for Leaving Certificate and studying STEM career in College. 15 Female TY Students attended. After the week finished all girls who attended agreed that they would consider a career in STEM for the future and would now consider STEM subjects for the Leaving Certificate. We are also considering emphasizing STEM more in our mixed TY weeks, given the success of this theme with the girls only week.

CWIT and Teen Turn

Teen-Turn is a non-profit organization run completely by volunteers. This organization strives to give teenage girls from disadvantaged areas/DEIS schools, the ability to explore technology and STEM as a whole and hopefully in turn choose to take it on at leaving cert level and 3rd level. Connecting Women in Technology (CWIT) is a network of technology companies working towards the common goal of attracting, retaining and promoting females in the technology sector. Teen Turn had connected with CWIT in the lead up to the first Technovation Challenge in Ireland (Jan – Apr 2018). CWIT Education Chair brought the programme to the member companies. As this aligned very closely with Accenture's goals of promoting STEM, we promoted it internally and recruited volunteers. We also participated in the Project Squad Sep – Nov/Dec 2018. At the start of 2019, I (Jill Egan) took on the role of leading the initiative across all CWIT member companies.

Intel Ireland Balloon Rocket Launch

Intel Ireland reached out to 16 local primary schools with the aim of engaging third class students in an appropriately levelled science and engineering lesson, using inexpensive and widely available materials to demonstrate a scientific principle and the fundamentals of experimentation in an accessible and interesting way.

Intel Ireland Mini-Scientist

Intel engaged with schools in the locality and also encouraged employee volunteers to encourage the competition in schools where they had an existing relationship. Schools are invited to complete an online registration form for entry (www.intel.ie/miniscientist), participating schools divide students into teams of 4 to work on projects relating to STEM and are then invited to host an exhibition of

the projects at the school, with Intel providing the adjudicators and prizes. Winning projects from each school progress to regional and then a national final.

Introducing Students to Coding – Google CS First

A 6-week programme, led by volunteers from Google, to give 4th class students (ages 9-10) at an all-girls primary school (with DEIS status) their first taste of learning how to code. Staff from the Google office volunteered 1 hour per week to go to the school and support the students through structured lessons on CS First - Google's free curriculum to teach coding with Scratch, a block-based programming language.

Ericsson INFUSE

The Ericsson Athlone INvesting in FUture Software Engineers or INFUSE is a range of initiatives that focus on creating enthusiasm and interest around Science and Math's. The INFUSE program believes that interacting with the students at a young age avoids the negative stereotypes of the career, especially for future female engineers.

Fujitsu–Schools Business Partnership Programme

Since 2011, Fujitsu Ireland and St. Joseph's School, Rush have partnered together as part of Business in the Community Ireland's (BITCI) Schools' Business Partnership Programme. This programme aims to tackle the retention rate in post primary schools and gives young students an insight into the careers and options available in the STEM industry. Each year, four internships offer for students who have excelled throughout the programme. They come in for one week in the summer to work on meaningful tasks and projects across our business. In order to secure the internship, a class of 5th year students was equipped with a CV and Interview skills session in the school. These are life skills which will greatly benefit students in the long term. Then they were invited to Fujitsu for a site visit which includes a welcome speech from our CEO Tony O'Malley, a tour of the building and a careers speed networking session with our employees. Following the site visit, students apply for the internship with the CV and cover letter which we helped them to create in the workshop. They are then called to interview, and four candidates are selected for the internships.

STEM Teacher training

The quality of teaching of STEM subjects in schools has a direct bearing on the quality of learner experience and achievement. Thus, any approach that aims to improve STEM education in Ireland schools must treat STEM teacher education as a key priority.

The importance of initial teacher education (ITE) in STEM lies in challenging and deepening student teachers 'beliefs about the learning process, in developing their understanding of the nature of the STEM subjects and familiarizing them with a range of teaching approaches. Teacher knowledge is usually viewed as having three strands: subject matter knowledge (SMK), pedagogical knowledge (PK) and pedagogical content knowledge (PCK) (Shulman, 1987). SMK concerns knowledge of content (e.g., knowledge of mathematical or scientific concepts, mathematical or scientific reasoning etc.). PK relates to knowledge of pedagogy and is generally subject independent (e.g. sociological or psychological aspects of education). PCK is the interplay between content and pedagogy, that is, the link between knowing something and facilitating others to learn it. It is expected that, as pre-service teachers progress through their preparatory programmes, these different forms of knowledge become more tightly interconnected.

This Term of Reference looks at STEM engagement at an earlier stage, when teachers are preparing to enter primary or post-primary service. Measures taken at this level of ITE will build STEM capacity in education in Ireland in the long term.

There are two routes to registration as a primary school teacher in Ireland: the concurrent route, which involves completing an undergraduate degree course in primary ITE, and the consecutive route, which involves completing an undergraduate degree and a postgraduate programme of ITE.

In both entry routes, pre-service teachers are expected to engage in Foundation Studies, Professional Studies and School Placement (Teaching Council, 2011a). As part of professional studies, students begin to develop their PCK of all subjects of the Primary School Curriculum, including STEM subjects. Furthermore, the courses are directed towards pupils in classes from Junior Infants to Sixth class.

Essential Leaving Cert grades to qualify for ITE are a Grade C3 in Higher Level in Irish, Grade C3 Ordinary Level or D3 Higher Level in English and Grade D3 (either

Ordinary or Higher Level) in Mathematics. The Teaching Council has provided advice to the DES on Leaving Cert grades for entry into ITE programmes. This advice is currently under consideration by the DES.

Similarly, there are two models for post-primary teacher registration. One is a concurrent model of a degree qualification in post-primary ITE, which combines the study of one or more approved curricular subjects along with teacher education studies.

The other is a consecutive approach of first completing an undergraduate degree, which enables the holder to teach at least one approved curricular subject, and then completing a postgraduate programme of ITE geared towards the post-primary age range.

At present, a student entering initial primary teacher education needs a minimum of a Grade D3 (at either Ordinary or Higher Level) in Leaving Certificate mathematics. However, the majority of entrants to primary ITE programmes exceed this grade, and only a small minority present with the minimum grade required in mathematics.

While a high level of content knowledge is necessary, it is not sufficient for the effective teaching of mathematics and, in particular, PCK is now recognised as a 'decisive 'variable in student achievement in mathematics (Education Committee of the European Mathematical Society, 2012). In addition, one study has suggested that raising the minimum entry requirement in mathematics may not, in itself, yield a significant improvement of teaching (Corcoran, 2008). Nevertheless, the relatively low entry requirements for mathematics (primary teacher education) compared to the entry requirement grades needed for English, and Irish is, at the very least, problematic in the disciplinary prioritisation that it conveys to students. This balance needs to be redressed. Furthermore, greater support needs to be given to increasing discipline knowledge across STEM subjects at both primary and post-primary levels.

Because mathematics underpins all STEM subjects, there is a strong case for targeting improvements in mathematics teaching. Raising the entry levels (for primary teaching) in mathematics in a measured fashion would not only enhance the public and student perception of the importance of mathematics, but it would

also ensure a higher baseline of subject knowledge upon which to build during ITE. In this context, it is most important to emphasise that pre-service teachers should be supported in achieving an agreed level of knowledge of mathematics as they undergo ITE.

Government-supported Initiatives have been put in place to address literacy and numeracy during teacher preparation, but the need to augment science education has not been addressed sufficiently, particularly at primary level. The development of specialist courses/modules in science subjects and science education during primary and post-primary ITE would serve to increase the content on offer to pre-service teachers (such courses/modules are already offered in some HEIs).

In general, the low level of knowledge and insight that pre-service teachers possess in the physical sciences is a matter of deep concern. Low percentages of students entering ITE courses have studied Physics or Chemistry for the Leaving Certificate, while a high percentage of students have studied Biology (Murphy and Smith, 2012). Poor scientific content knowledge leads to a lack of confidence in teaching those subjects.

In Ireland, there has been a move in recent years towards the establishment of a general set of standards for teachers which includes the use of ICT in teaching and learning. Highlighting ICT as one of the key national priority areas and a significant aspect of student teachers 'developing professional skills, the Teaching Council lists ICT in Teaching and Learning as one of the mandatory elements of ITE (Teaching Council, 2011a). As ICT has the power to be transformative and lead to the design of new learning environments, its use needs to be embedded across course work in ITE.

School placement is an inherent component of all ITE programmes. While it usually takes place in either a primary or post-primary school (depending on the programme of study), some students of post-primary ITE programmes have a practicum in a senior primary setting. However, short placements with STEM-related industries during teacher preparation could also offer important experience and insights into the importance and practical applications of STEM. This would be an opportunity for industry to contribute to developing stronger STEM education in Ireland.

Continuing Professional Development

- STEM Teacher Internships[61]

This is a 12-week paid internship in a STEM role within industry (e.g. tech/pharma/finance) for pre-service primary and secondary level teachers. A pilot programme commenced in 2016 as a collaboration between DCU, Accenture and the 30% Club. Since then it has recruited over 20 companies to host STEM internships through the Connecting Women in Technology (CWIT), 30% Club and PharmaChemical Ireland networks. In 2019, 32 students completed internships across 19 host companies - bringing the total to 54 participating teachers to date. The pilot was created by DCU, 30% Club and Accenture as a practical way to address the low number of students, particularly girls, pursuing STEM subjects and careers, as consistently reported by Accenture's STEM reports. The participating teachers have since taken up teaching positions in schools and have incorporated these unique experiences in their subsequent teaching roles. They draw upon their experiences and transfer the knowledge and skills gained to their students and colleagues, to increase student interest and awareness of STEM roles and careers. The pilot programme was carried out with 5 students from DCU's BSc Science Education programme which qualifies teachers of Physics, Chemistry and Mathematics at second level. The interns completed a 12-week paid internship at Accenture during the summer months. The programme was then extended to Intel and AIB in 2017 and has since been extended to other companies – with 9 companies hosting in 2018 and 19 companies hosting in 2019. The target for 2020 is to extend the programme to offer 50 internship positions in summer 2020. Research, including Accenture 'Girls in STEM' reports in 2013 and 2015 showed that teachers are one of the biggest influencers in young people's lives and they have a powerful multiplier effect. This led to the pilot of STEM Teacher Internship programme. Subsequent STEM report from Accenture in 2017 and What Now for STEM report in 2019 further highlights the need to make STEM subjects engaging for all students from an early age and that giving teachers a first-hand experience of working in STEM industry has the potential to change students opinion on future careers in STEM. The impact on the participating teacher has been transformative - in terms of increasing their understanding of STEM roles and careers in industry, addressing stereotypes, developing the key skills required to be

[61] http://castel.ie/stem-teacher-internships/

successful in industry and the relevance of STEM subjects to real world applications. Positive feedback from companies is substantiated by the fact that all the companies who have hosted internships have offered to host again and increase the number of positions available in subsequent years. One of the key impacts of this programme is the development of education-industry relationships and closing the gap between STEM in schools and STEM in the workplace for students, teachers and parents.

- Professional development service for teachers[62]

The PDST is the country's largest single support service offering professional learning opportunities to teachers and school leaders in a range of pedagogical, curricular and educational areas. The PDST was established in September 2010 as a generic, integrated and cross-sectoral support service for schools. The establishment of the organisation was synonymous with the amalgamation and restructuring of a number of stand-alone services which now operate under the PDST providing their services to schools in the context of PDST's overall vision and mission. The work of the PDST contributes to school improvement by fostering reflective practice through the school self-evaluation process and through the ongoing development of teachers and school leaders through a range of CPD models. Amongst the priorities for the Department of Education and Skills (DES) for the coming years is the implementation of proposals to improve Literacy and Numeracy in both primary and post-primary schools. Other key priorities include supporting school leadership, school self-evaluation, assessment, ICT for teaching and learning, inclusion, health and wellbeing and post primary subjects and programmes. These priorities inform the work of PDST and are addressed through the work of individual teams across the organization.

PDST Primary Workplan for 2019/2020

The PDST will offer customized school support on application across all priority areas. This will include a model of sustained support for schools who will be selected according to completion of an online application making a case for such support according to identified needs and plans for improvement. Sustained support will involve various forms of deeper transformational modes of teacher professional learning aimed at building internal capacity and enabling schools to

[62] https://www.pdst.ie/

drive and embed change as independent communities of learners. Such modes will include coaching, lesson study, in- school professional learning communities and the development of middle leadership cultures.

Primary STEM 2019/2020

Seminars & webinars

Team Teaching for Inclusion in Mathematics, Lesson Study Shared Learning Day, Inquiry Based Approaches to Measures and STEM as Gaeilge, Number Sense Webinar, Play Based Approaches to Mathematics and Science Webinar.[63]

Maths Recovery

The PDST in conjunction with Maths Recovery Ireland will continue to provide CPD to selected DEIS schools in the Maths Recovery Programme. The Service Level Agreement between the PDST and MR Ireland for 2019 2020 stipulates that this will include the following: 8 days training for all Maths Recovery Associates; one Maths Recovery Teacher to be trained in 120 selected schools (on application); one class teacher to be trained in each of the 120 selected schools and also in schools already in the programme to a total of 400 schools (September 2019 to June 2020).

Primary STEM Sustained School Support

Models of Sustained support for Primary STEM; Lesson Study; Communities of Practice; Coaching and Mentoring (September 2019 to June 2020).

Primary STEM Summer Course

This new PDST Summer course will aim to promote a classroom culture of curiosity and investigation in STEM. This course is designed to give teachers inspiring practical STEM activities. Teachers will be facilitated to approach STEM in the primary classroom in an integrated manner. The range of relevant STEM curricular areas will be addressed by stimulating and rich inquiry-based tasks. Making connections to the Arts curriculum, integrating and combining creativity with a

[63] https://www.pdst.ie/numeracyteamteaching

STEM theme, this course presents an interdisciplinary approach to presenting STEM subjects (July/August 2020).

Digital Portfolios Pilot Project

This pilot study[64] aims to utilise a sustained support approach with 24 schools to explore how the usage of digital portfolios can support and enhance formative assessment practices in the primary school context. A collaborative cross-team approach will be employed here, building capacity, whereby 4 advisors from the Digital Technologies team will upskill 4 advisors from the STEM team in this area and then the 8 PDST advisors will together provide support to the 24 schools involved in this initiative (3 schools per advisor). PDST will draw from the success of the Post-Primary formative assessment through e-portfolio project (November 2019 - April 2020).

Once labs are online, faculty and students are freed from the equipment and scheduling constraints of the brick-and-mortar laboratory.

[64] https://www.pdsttechnologyineducation.ie/en/Training/Courses/Introduction-to-Digital-Portfolios-Primary.html

STEM-EDUCATION IN SWEDEN

Curriculum for the compulsory school, preschool class and school-age educare[65]

The curriculum for the compulsory school, preschool class and school-age educare contains five sections and has been adopted by the government. The first section, *Fundamental values and tasks of the school*, applies to the compulsory school, preschool class and school-age educare. The second section, *Overall goals and guidelines*, applies to the compulsory school and, apart from the content about grading, to the preschool class and school-age educare. The third section applies to the *preschool class*, the fourth section to *school-age educare* and the fifth section containing *syllabuses* applies to the compulsory school. It is important to read the different parts of the curriculum as a whole in order to understand the purpose of the education.

Curriculum for the compulsory school, preschool class and school-age educare (revised 2018)[66]. Page 296-303 in the following pdf-document is about the subject Technology: Curriculum for the compulsory school, preschool class and school-age educare (pdf)[67]. Read more about:The Swedish National Agency for Education[68]

Instead of the national policy of Sweden in the field of secondary and higher education, we present excerpts concerning Sweden from the "Do Well Science" – Manual for Innovative Pedagogy in STEM Contents[69] (An Erasmus+ project to increase secondary students' achievements in Science subjects).

In Sweden there is no specific policy regarding the development of STEM education but the diploma goals for the Natural Science programme (upper secondary school, high-school) may be regarded as STEM policy: "The Natural Science Programme is a higher education preparatory programme. With a diploma from the programme, students should have the knowledge needed for higher education studies primarily in the Natural Sciences, Mathematics and Technology, and in other areas. The education should develop students' knowledge about context in nature, about the conditions for life, about physical phenomena and events, and about chemical

65 https://liu.se/cetis/english/curriculum.shtml
66 https://www.skolverket.se/getFile?file=3984
67 https://www.skolverket.se/portletresource/4.6bfaca41169863e6a65d9f5/12.6bfaca41169863e6a65d9fe?file=3984
68 https://www.skolverket.se/andra-sprak-other-languages/english-engelska
69https://www.dowellscience.eu/project//download/Templates%20and%20tools/Manuals/Manual_English_Version.pdf

processes. In Biology, Physics and Chemistry, the surrounding world is described in models that are developed in interaction between experiment and theory. The education should also develop students' knowledge of Mathematics. Mathematics is a subject with its own distinctive character and is also an instrument whose concepts and symbolic language is used for models developed to understand and analyse relationships in other subject areas. The education should stimulate students' curiosity and creativity, and their ability to think analytically. Through the education, students should develop a scientific approach. This covers the ability to think critically, reason logically, solve problems, and make systematic observations. Students should thus be given the opportunity to develop the skill of assessing different types of sources, and the ability to distinguish among statements based on scientific and non-scientific grounds. Understanding of sciences is based on the interaction between theory and practical experience. Experiments, laboratory experiments, field studies and other comparable practical areas should thus be central elements in the education.

The education should contain a perspective from the history of ideas, which means that the ideas and theories of the sciences are studied as parts of a historical process. Students should be given the opportunity of developing their interest in science questions, and they should be able to benefit from current research findings in relevant areas. The education should give an understanding of how science and the development of society both affect and are affected by each other, and in particular highlight the role of science in questions concerning sustainable development. Students should also be given the opportunity to take part in ethical discussions of the role of science in society.

Language is a tool for communication, as well as for reflection and learning. The education should thus develop students' ability to argue and express themselves in advanced writing and speaking situations related to Science and Mathematics. Students should also be able to understand, read and write about, and discuss basic Science in English. In Science and Mathematics, data collection and calculations are mainly carried out using computers. The ability to search for, select, process and interpret information, and acquire knowledge of new technology is important for scientists and mathematicians. The education should thus provide good practice in using modern technology and equipment. The education should encourage students to take responsibility and cooperate, and further stimulate them into seeing

opportunities, trying to solve problems, taking initiatives and transforming ideas into practical actions".

Conclusion. Based on the diverse information, regarding structures, contents, aims and contexts produced in the different countries and presented in the previous paragraph, it may be difficult to present just and objective comparisons between the policies of the countries included. From another point of view, the resulting knowledge and skills of the individual students appears to be fairly similar. Thus, it may not be important to compare the content, or the structure of the goals presented in different documents or found in other sources but to try to evaluate the outcome of the education in each country. However, this is not the objective of this presentation. Still some questions remain: Why do we have these similarities in the outcome of the teaching regardless the differences in the curricula? The subject content is similar, at least in a wide perspective; although the main principles are learned through different examples, pedagogy, etc. is used. Focusing on STEM, there are some immediate similarities. The STEM concept is rarely used directly in the national context. This may partly be due to the acronym itself. The word "science" in English is "ңayka" (nauka) in Bulgarian, "Επιστήμη" (epistimi) in Greek, "scienza" in Italian and "vetenskap" in Swedish. Only in the Italian word the letter "s" is found in the beginning. Similarly, "engineering" is "инженерство" (inzhenerstvo), "μηχανική" (michaniki), "ingegneria", "ingenjorskonst". Here, none of the word begins with an "e". Further the four words may, as it is in Swedish, belong to different groups of words. Vetenskap or usually naturvetenskap refer primarily to the theoretical subjects' Biology, Chemistry and Physics. Teknik often refer to how to do in different situations but also to more technical activities as building or construction. Ingenjorskonst is usually the professional activity of construction, which may be used as a synonym to teknik. Matematik is in Swedish a subject at school similar to Biology etc. Thus, in Swedish STEM refers to (school) subjects or theoretical areas, how to act practical in different situations and a specific type of professions. As STEM includes all these disparate areas and activities, it is not a concept easily used outside the curricular school world.

In Sweden, the educational aims and content for all subjects is determined in a centralized way but by the Government after directions of the Parliament www.sweden.se/society/ education-in-sweden. The Swedish curriculum for compulsory school (year 1 to 9) also includes the pre-school class, the year before the first year of the primary school, and the recreation centre (pedagogic activities in the

early mornings and late afternoons, as most pupils belong to families where both parents are working the whole day. The curriculum of the last three years before university, gymnasium, includes not only preparatory programs for university studies but also programs with more practical training and thus embraces almost all Swedish older teens.

In Swedish curricula, seven areas of Mathematics are covered by the curriculum. A relevant area is: Teaching in Mathematics should give students the opportunity to develop their ability to: - interpret a realistic situation and design a mathematical model, as well as use and assess a model's properties and limitations. In the Swedish curricula the model formulation represents a similar view as that of the Italian curriculum but in a more strict or delimited mathematical sense. Although the large differences in their approaches and descriptions the teaching based on the four curricula may result in similar learning outcomes, even if there are some differences.

Mathematics curricula. The structure of the curricula in Mathematics differs among the countries and also the subject content. Here, as for the other subjects, we follow the actual text of the curricula not the syllabi for different courses. For example, many of the detailed specifications of knowledge and abilities in the Bulgarian curriculum are similar to the content of Swedish courses according to their syllabi. Thus, it is problematic to make comparisons exclusively out of the curricula. Further, the general structure of, e.g., the Swedish goals covers elementary mathematical courses in practical study programs (farming, carpentry, hairdressing, etc.) in which the content is on a basic level far from the objectives of, for example, the aims of the Italian curriculum which is quite similar to the syllabi of the more advanced courses in Sweden. Anyhow, the presentation of the general principles makes it possible to compare the basic mathematical ideas included in the different curricula.

The Swedish curriculum is less specific but shows differences and similarities to the others. There are seven areas in which the teaching in Mathematics aim at promoting the ability to: - use and describe mathematical concepts and their relationships; - use procedures and solve standard problems; - formulate, analyze and solve mathematical problems and evaluate strategies, methods and result; - interpret a real situation and create a mathematical model and further use and evaluate the properties and limitations of the model; - follow, direct and evaluate mathematical reasoning; - communicate mathematical reasoning orally, in writing and in action; - relate Mathematics to its importance and use in other subjects in professional, social and historical contexts. As the structure of the curricula, and also the description of

their contents differs, it may be difficult to make reliable comparisons among them. Each of the eight groups of concepts and methods in the Italian curriculum refer to or have similarities with at least two, usually three or more, of the Swedish goals. The Swedish goal about communication is the only one not directly corresponding to any of the Italian groups. On the other hand, the groups in Italian curriculum are process oriented and may be regarded as instructions to follow to increase the understanding of Mathematics while the Swedish curriculum more directly aims at the goals of the teaching. Similarly, the general principles of the Greek curriculum focus not only on mathematical thinking and skills but underlines the importance of students being able to use them in daily adult life. In that perspective, the Greek curriculum clearly relates to daily life. The Bulgarian curriculum, as presented here, may be regarded as dealing with strict mathematical Science but the detailed specifications of the abilities and knowledge, that the students are supposed to master at the end of their studies, are often related to everyday life. Thus, despite the differences among the constructions of the curricula, it is quite possible to make consistent interpretations of their aims concerning mathematical understanding. The ability to use Mathematics in a wider context seems to be more strongly supported in the Greek curriculum compared to, for example, the Bulgarian. This may lead to similarities among the abilities of students from different countries in their strict mathematical skills but to differences in their ability to use these professionally or in everyday life.

Physics curricula. The curricula in Physics differ among the countries mainly in structure but not so much in content. Teaching in the subject of Physics should give students the opportunities to develop the following: Knowledge of the concepts, models, theories and working methods of Physics, and also understanding their development.

Natural Science curricula. The Natural Science are divided into two different big areas, Biology and Chemistry. In Sweden, teaching in the subject of Biology should give students the opportunities to develop: - knowledge of the concepts, models, theories and working methods of Biology, and also an understanding of their development; - the ability to analyse and find answers to subject-related questions, and to identify, formulate and solve problems. The ability to reflect on and assess chosen strategies, methods and results; - the ability to plan, carry out, interpret and report field studies, experiments and observations, and also the ability to handle materials and equipment; - knowledge of the importance of Biology for the individual

and society; - the ability to use knowledge of Biology to communicate, and also to examine and use information.

The Swedish curriculum starts with the eligible skills of the students at the end of the studies and specifies the knowledge content (the concepts, models, theories and working methods of Biology) in the syllabi of the different courses. The learning outcome of these different types of curricula is similar as long as the studies aim at practical biological knowledge which they are able to apply in real life situations, which was a goal of the Italian teaching in Biology.

Teaching in the subject of Chemistry should give students the opportunities to develop: - knowledge of chemical concepts, models, theories and working methods, and understanding of their development; - the ability to analyze and find answers to subject-related questions, and to identify, formulate and solve problems. The ability to reflect on and assess chosen strategies, methods and results; - the ability to plan, carry out, interpret and report experiments and observations, and also the ability to handle chemicals and equipment; - knowledge of the importance of Chemistry for the individual and society; - the ability to use knowledge of Chemistry to communicate, and also to examine and use information. The Swedish curriculum appears as a mix of the others, with emphasis on knowledge of the subject in combination with practical skills, but also on the understanding and use of the subject content in practical life. There are differences in structure and content of the curricula, and their explicit goals, but the students probably will reach similar levels of their knowledge content, especially in regard to their possibility to participate successfully in higher studies. If there are differences these probably will show in everyday Chemistry, which often is hidden or obscure unless specifically trained on.

Regarding the students participating, in Bulgaria, Greece and Italy all students in high school study STEM subjects. In Sweden, the Natural Science programme has about 12,000 students, about 12% of total students. The technology programme with 10,000 students, round 10%, may also include courses to prepare for academic studies in Mathematics, Physics and Chemistry. In total about on fifth of Swedish teenagers are prepared to study STEM subjects on an academic level.

In Sweden, the STEM teacher qualification includes five to five and a half years of academic studies. The studies include subject studies of three and a half years, the core of education Science in one year, and a further half year of practical work at schools. The different courses may be spread out over several semesters which will

result in a mixture of theoretical, pedagogical and practical courses during the training. The subjects studied normally include two subjects, usually Biology/Chemistry, Biology/Mathematics, Biology/Natural Science (Chemistry, Physics, and Earth Science), Physics/Mathematics, Geography/Mathematics or Chemistry/Mathematics. One of these subjects is studied for two years, the other during one year and a half. The core of education Science includes the history of the school systems, the present school organisation, basic democratic and human rights, curriculum theory and didactics, theory and research, development, learning and special education, social relations, conflict handling and leadership, assessment and grading, and finally evaluation and development. The practical courses are often spread over time in the program to increase the teaching ability of the student and adapt the training to the personal requirements of the student.

As seen already above, there are several differences in the structure of these curricula as well as in their contents. Also, the aims or goals seem to differ, but mainly due to the different perspectives of the curricula. It is anyhow possible to acknowledge the possibility of similar results concerning the preparation for higher studies in the development of theoretical understanding and practical skills of the participating students. If there are differences in the resulting knowledge and practical skills of the different subjects, these may probably mainly appear in the practical everyday life of the student. It may be important to learn the lesson of the Greek curriculum and never forget to relate the subject content to everyday life whenever this is possible. School Science may be adequate in school situations, but learning should also be learning for life, not only for school. In combination, these curricula show the necessity of the teacher to use several ways of describing goals, to vary the way of teaching and use the individualities of the students. To facilitate this and widen the perspectives, every teacher should not only be accustomed to the curriculum and syllabi of the own country but also of these of others.

The Swedish teachers, since they mainly developed exercises in Biology, implemented the exercises almost exclusively in the Navigator mode, since it was the one most suited to the questions that they usually pose to the student and for which a draft with "Do Well Science" allows a different view that helps students in the skills they need to develop.

STEM in sweden universities

- KTH - Royal Institute of Technology (Swedish: Kungliga Tekniska högskolan), the Department of Learning in Engineering Sciences[70]: Learning in STEM. Learning in STEM (Science, Technology, Engineering and Mathematics) is one of four units at the Department of Learning,, belonging to the School of Industrial Engineering and Management (ITM) at KTH. The unit consists of three research groups: Engineering Education in Society, Higher Education Organisational Studies (HEOS) and Learning in Technology and Science Education (TN-didactics). In addition to our research and development, the unit has KTH-overall assignments and competence in engineering education.

  Research areas: Engineering Education in Society. The Engineering Education in Society research group aims to influence the strategic development of engineering education from a broad perspective. We aim to contribute to the development of the competencies relevant for Sweden to continue to develop as a leader in engineering education internationally. Our goal is to prepare and equip KTH and our partners for a rapidly changing society.

  The role of Engineering Education in society. We are studying how engineering education should develop as a discipline, pedagogically and socially to best meet the goals described in the university regulations. We are also looking forward to understanding what will be required in the future. Our goal is to help KTH and our partners to be prepared to facilitate rapid change.

  Our research also explores how we create a broad interest in engineering education and engineering in the school in general. This aims to help more young people from all walks of life choose a career in the engineering sector and to contribute to the strengthening of technological awareness in society.

  Our research reflects, challenges and solves problems that arise in an engineering education context. To do that, we use theoretical frameworks that are applicable for this purpose, and we can take advantage of several research paradigms depending on the problem. We use both qualitative and quantitative methods, also dependent on the issue.

  Research. The Engineering Council's expectations

  At present, there is no consistency between what the student and the university teacher expect from an engineering education. In order to achieve consensus on the development of engineering education, from student teams, universities and employers, we are now launching a new project that takes the lead in a qualitative

[70] https://www.kth.se/en/larande/stem/larande-i-stem-1.804298

study of different actors' views on the future of engineering. For this project, we are now looking for one to two doctoral students who are expected to start their studies in 2018.

- Nordic initiative for STEM education. *Future Nordic engineers: a powerful driving force in the global economy.* "The fourth Industrial revolution and the involved disruptive changes will have an impact on the employment landscape, business models in companies and the education systems. There is an emergence of new sector demands, new skills and competences, which calls for agile responses from both the private and public sector. Especially, the modernisation of the education systems is in focus. According to the World Economic Forum report: The future of Jobs, 65% of children entering primary school today will ultimately end up working in completely new job types that do not exist yet."

  Our research group participates as one of four universities in this project, the other universities are Aalborg University, Aalto University and Reykjavik University. KTH is also the coordinator of the project, funded by the Nordic Council of Ministers and the universities involved.

  How do students' attitudes and self-confidence develop for STEM? In order to provide opportunities to participate in technological development, it is important to understand how people perceive science and technology, both as engineering students and later in life. Several studies have been carried out in this field and in autumn 2018 we hope to recruit a postdoc who, together with other researchers, can develop research in this area.

  Courses at Learning in STEM[71]. Learning in STEM (Science, Technology, Engineering and Mathematics) offers courses for teachers from P-12 education and higher education. The unit also offers courses for doctoral students.

  Courses for educators and teachers. If you have a Bachelor's degree but do not have subject knowledge, KTH offers specific purpose education within 'Teacher Lyft II', a continuing education course. Programming for teachers, with focus on technology or mathematics education (7.5 ECTS credits): In-service technology for teachers in school years 1-3 (7.5 ECTS credits); In-service technology for teachers in school years 4-6 (7.5 ECTS credits); Technology for Teachers, grade F-6 (7.5 ECTS credits).

  Courses in higher education. Course offerings and course content are developed to follow SUHF's new recommendations for higher education. All courses can be

[71] https://www.kth.se/en/larande/stem/kurser-1.826546

included in the requirement of 15 credits of teaching at higher education for employment or promotion to staff at KTH.

Courses in teaching and learning in higher education for KTH employees and doctoral students, Postgraduate and Doctoral courses at learning.

What is a STEM Degree?[72] STEM degrees are Science, Technology, Engineering, and Mathematics programs. They all require using research and reasoning to solve problems. And, they could lead to diverse career paths in growing fields. Within each category, you'll find many kinds of STEM graduate degrees. For example, engineering students could study civil, electrical, or computer engineering. Science students could study everything from biology to veterinary and animal sciences. You could pursue goals that range from building bridges to keeping IT systems safe. No matter what path you pursue, STEM careers are key to a brighter future.

What Careers are in the STEM Field? STEM career paths are wide-ranging, and the industry as a whole is growing. Mathematics roles are growing the fastest, with 28% more jobs projected by 2026. 50,400 new jobs could be added in occupations that include Actuary and Operations Research Analyst. This is due to the growing importance of Big Data for businesses and government agencies.

Science career paths are also growing faster than average. Fields to watch include biomedical research, psychology, energy management, and environmental protection. An increased need for scientific expertise should lead to 10% growth across the board, by 2026.

Many engineering career paths are also growing. For instance, Civil Engineers could see 32,200 new jobs by 2026. This is due to the increasing obsolescence of U.S. infrastructure. So, engineers will be needed to update everything from roads to water treatment facilities. (Sources: https://www.bls.gov/ooh/math/home.htm, https://www.bls.gov/ooh/life-physical-and-social-science/home.htm, https://www.bls.gov/ooh/architecture-and-engineering/home.htm)

The Young Academy of Sweden Joins the Global STEM Alliance[73]

The Global STEM Alliance is an initiative aiming to promote the interest in key areas (Science, Technology, Engineering, Maths) that are related to several of the big challenges of our time, areas that currently experience diminished interest from students worldwide. The STEM Alliance was launched by the New York Academy of Sciences (NYAS). The Young Academy of Sweden has joined as Founding Mentoring

[72] https://www.gradschools.com/programs/math-science-engineering?countries=sweden
[73] https://www.sverigesungaakademi.se/en-GB/458.html

Partner, with the purpose to provide mentorship to students via an online platform that is being developed by NYAS and the IT-company CISCO Systems. The Academy Chair and CEO were present when the initiative was launched at the UN General Assembly in New York in 2014.

Jönköping University becomes member of International Centre for STEM education[74] 2018-12-04 The School of Education and Communication at Jönköping University has become an elected member of the International Centre for STEM education (ICSE), a consortium of 14 European universities that are collaborating to carry out research in STEM education.

In summer of 2018, the School of Education at Jönköping University became an elected member of ICSE. The ultimate aim of ICSE is to help improve STEM education across Europe through practice-related research and its transfer into practice. STEM is a term used to group together the academic disciplines of science, technology, engineering and mathematics.

"Through the membership in this prestigious consortiaum we have access to collaboration with some of the most successful international research institutes in the STEM education research arena," says Jesper Boesen, Associate Professor of Mathematics Didactics who is leading the collaboration on behalf of the School of Education and Communication.

Linköping University[75] (LiU) is a major university in Sweden, with the areas of medicine, education, engineering and economics as main profile. LiU runs teacher education programmes for the entire Swedish school system, from pre-school to adult education, and also programmes for after-school teachers and special needs pedagogy. The Faculty of Education has the main responsibility but departments from all faculties of the university are engaged in the teacher education.

LiU is the host of two national centres for professional development in the STEM area, the National Centre for Science and Technology Education (NATDID) and the National Centre for School Technology Education, CETIS. Both centres are appointed and financed by the Swedish government.

NATDID was founded in 2014 with the aim to support school development in science and technology on the national level through dissemination of current research in

[74] https://ju.se/en/about-us/press/news/news-archive/2018-12-04-ju-becomes-member-of-international-centre-for-stem-education.html
[75] http://stem-pd-net.eu/en/liu/

science and technology education. This is for example achieved through arranging conferences, network meetings and workshops. NATDID has also contracted NATDID-ambassadors (annat ord?) at eight universities in Sweden, who will network with teachers and participate in the writing of teacher specific research communication articles.

CETIS[76] was originally founded in 1993. The aim of the centre is to inspire, support and help teachers develop good, general, technological education to all Swedish pupils and students, in collaboration with teachers, teacher educators, representatives for the industry, and others. In Sweden, technology perspectives are included in the national curriculum for pre-school and all students study the subject Technology in compulsory school (grades 1-9). Some of the major arrangements by CETIS regional or national conferences for teachers in Technology on a biannual basis, network meetings for teacher educators and seminars for PhD-students in Technology education.

Linköping university, through Director Claes Klasander at CETIS, is the leading partner for intellectual output O7 in the STEM PD NET project: Policy briefings.

Swedish National Scientific Centers

- Centre for School Technology Education[77]. The Swedish National Centre for School Technology Education, CETIS, at Linköping University started in 1993. In 1996, the government made CETIS a national centre. The main aim of the centre is, in collaboration with teachers, teacher-trainers, and representatives for industry etc, to develop technology education in schools. CETIS works with a broad array of activities. One of our larger commitments is to arrange regional or national conferences for teachers in Technology on a biannual basis. We arrange network meetings for educators in teacher education concerned with Technology. Four times a year we publish a newsletter and send to all Swedish schools, for free. Once a year we run a two-day national research seminar for PhD-students in Technology education. We have an active website (www.cetis.se) and can be found on Facebook (CETISliu). We provide teachers with support material and teaching support. Collaboration with the DfE and NAE is central to us, as well as industry, labour unions, company organisations, museums etc. We cooperate with other national centres as well as similar international hubs, since international

[76] https://liu.se/cetis/english/index_eng.shtml
[77] https://liu.se/cetis/english/index_eng.shtm

overview and contacts are of great importance to us. We engage, and get engaged, in national competitions, EU applications, curricular activities, in-service training etc.

CETIS is situated at Linköping University, Campus Norrköping. The ultimate aim is to inspire, support and help teachers develop good, general, technological education to all Swedish pupils and students. For this purpose we often use the wide term "Technological bildung" which encapsulates most aspects of the pupil's growth towards deeper technological knowledge, awareness, skills, competencies, and literacy. Our vision is to provide a body of knowledge that combines theory and practice, integrating technological knowledge, philosophy and science with the humanities, and the social and natural sciences.

The Swedish national curriculum for the Technology school subject has changed over the last six decades, and so has its motives. It has broadened from a male orientated industrial subject at lower secondary school to a compulsory subject for all pupils at all ages. In the present curriculum for the compulsory school, technology is a core subject from year one to year nine (age groups 6-16). There are at least three good reasons for this:

- As a citizen in a living democracy we must try to understand and evaluate technology and technical systems. Many of today's important social issues concern technological choices.
- By allowing the pupils themselves to play with, try out and develop different technical solutions they will become familiar with the technology which surrounds them in everyday life.
- Our society is to a great degree dependent on our education of scientists and technologists in more and more areas of work, who are discerning and aware of important issues.
- Practical and investigative work is important, but the syllabus also emphasises that the scientific and social aspects must be present in teaching, together with historical and international perspectives.

- National Resource Center for Physics Education[78] (NRCF)

Sweden, along with many other countries, is facing a gradual decrease in the number of young people who choose to study science and engineering. With the

[78] http://www.fysik.org/english/

intention to bring about a change, five national resource centers for mathematics, physics, chemistry, biology and technology education have been established by the government and are located at five different universities with the purpose to reinforce the aim to be national centers and to spread the activities to all Sweden.

The National Resource Centre for Physics Education is aimed at being a resource for teachers from preschool to upper secondary school (high school). The aim is to inspire and stimulate the development of physics education and to give teachers the opportunity to further studies of physics.

NRCF's task is to give teachers the opportunity for further training and help to find inspiring resources for their physics teaching. We do this by giving courses and training days ourselves and in collaboration with others and developing materials, but also by collecting, reviewing, evaluating and disseminating information from others.

Together with the national resource centers for chemistry and biology, we organize NO biennials for F-9 teachers. We participate in other events, such as the School Forum, the Mathematics Biennale, CETIS, the Preschool Biennial and the Physics Society's Physics Days.

Our employees' competence spans many different areas in physics and didactics, and we have experience of teaching at all levels. We have good contacts with researchers and teachers at all Swedish universities with physics education, with teacher educators in science subjects and with teachers from many different schools across the country. We also have good international contacts in research and education.

Most material about NRCF is in Swedish, but some of these papers are published in English.[79]

- Centre for School Mathematics Education, Gothenburg University-NCM[80]

NCM's task is to support the development of mathematics education in preschool, in the compulsory and voluntary school system. It was established by a government decision in January 1999. NCM is one of several resource centers for various school subjects established over the past 20 years.

The center is located at the University of Gothenburg and is led by a director who, together with the center's employees, implements overall decisions.

[79] https://indico.cern.ch/event/257126/contributions/575996/attachments/451347/625815/nrcf_20juni.pdf
[80] http://ncm.gu.se/om-ncm

NCM's staff include people who have a background, or are active as teachers, teacher educators, researchers and mathematicians. They are responsible for and participate in various activities and projects such as publication of the journals Nämnaren and NOMAD; publication of literature for teacher education and teacher training; participation in and arrangement of seminars, courses and conferences; operation and development of several websites.

- KRC - Centre for School Chemistry Education, Stockholm University[81]

  The Chemistry Teachers' Resource Center, KRC, is a national resource center and an initiative of the Ministry of Education and Stockholm University, operating since 1 July 1994. KRC has close contacts with the Swedish Chemical Society and industry associations.

  KRC supports chemistry teachers throughout primary and secondary school with the aim of promoting a stimulating, interesting and current teaching. The support for chemistry teachers includes i.e. to prepare and give tips on experiments and other teaching materials, to give advice on safety issues and chemical issues, to initiate and carry out in-service training for school teachers, and to promote increased contacts between the school and the chemistry-based industry.

- National Resource Center for Biology and Biotechnology, Uppsala University[82]

  Bioresurs started in 2002 with a national assignment from the Ministry of Education and Uppsala University to support teachers who teach NO / biology throughout the school. The overall goal for Bioresurs is to contribute to teachers in preschool, school and adult education gaining increased competence and increased interest in biology and biotechnology.Through the efforts for teachers, students are given increased opportunities for a current and interesting teaching.

  The overall goal for Bioresurs is to contribute to teachers in preschool, school and adult education gaining increased competence and increased interest in biology and biotechnology. Here you will find subject resources and links to literature that can inspire you as a teacher. Here are also tips on where you can buy materials that may be needed in the teaching, as well as the safety rules that apply to laboratory work in the school. During the academic year, there is an opportunity for older students to compete in biology and for the younger students to participate in Bioresur's own Challenge.

[81] http://www.krc.su.se
[82] https://bioresurs.uu.se

- The Swedish National Centre for Science and Technology Education (NATDID)[83]. NATDID's task is to support school development at the national level in science and technology by disseminating results from current didactic research to those who are active in the school. The goal of this is for teachers to be able to put subject didactic research into practice and thereby let the school rest on a scientific basis. NATDID was established following a government decision in February 2014.

  The center is located at Linköping University and is led by a board consisting of representatives from both the school world and the university world. A director leads the centre's daily work together with a deputy director and a number of employees.

  One aspect of disseminating research is about the available channels for dissemination. Digital arenas are a meeting place with both a website and social media where teachers and researchers are and are active. It is important for NATDID to be where teachers and researchers are. At the same time, we also strongly believe in the personal meeting. Here, conferences, network meetings, workshops and inspirational lectures are some examples of how physical meetings could be carried out.

  An important part of NATDID's mission is to build networks for the target groups in the school, in teacher education and for relevant interest groups and organizations. This includes creating conditions for long-term relationships and dialogue with the target groups.

  NATDID is also tasked with coordinating the four existing resource centers in biology, physics, chemistry and technology in matters relating to research communication.

[83] https://liu.se/forskning/natdid

STEM-EDUCATION IN TURKEY

Ministry of National Education (MoNE), Turkey

The Ministry of National Education (MoNE) in Turkey manages one of the largest educational systems in Europe. Administrative legislation and supervision related to formal and non-formal education (except for higher education) are performed by Ministry of National Education.

Educational services at all levels are provided substantially (more than 90 %) by public education institutions, and for those institutions MoNE regulates the teacher employment and relocation and imposes the curriculum; timetables, textbooks used in the classroom, and explicitly use tests to monitor teaching practices in the classroom.

As an example of initiatives in the STEM area, MoNE's current curriculum encourages lower secondary school teachers of mathematics and science to collaborate and integrate their coursework with STEM education. MoNE also has a wide network of schools, relations with all of the stakeholders, and a sound network system including local, regional and national authorities.

There are for example 81 Provincial Educational Authorities which include District Educational Authorities, so it has the capacity for well-planned, coherent science and mathematics education within schools by supporting the development of local clusters for sharing advice and support on curriculum planning and subject leadership. MONE has the impact to work on collaborations between specialist science and engineering schools to deliver outstanding science and engineering education; to share expertise in the planning and delivery of STEM education in schools.

Making science work for the youth of Turkey[84]

[84] http://www.ingenious-science.eu/web/guest/country-focus-turkey

Stimulating and harnessing the scientific imagination of young people is the dream of Assistant Professor Murat Cakan. Although he teaches at the prestigious Istanbul Technical University (ITU), it's his second job as Director of the University Science Centre that really interested us.

Launched in 2007 to make scientific knowledge more accessible to young people, the Centre has enjoyed some success – but, says Murat, it should be enjoying a lot more. When inGenious recently interviewed Murat in Istanbul, we discussed the challenges of STEM education in Turkey and the steps that are being taken to overcome them.

"About 20 thousand pupils visit our Centre each year," observed Murat. "That's not enough, considering that 12 out of the 75 million Turkish people live in Istanbul. We aim to reach at least 200,000 visitors per year," he added.

- *How do you plan to achieve your target?*

"We try to attract youngsters by blending straight scientific facts with a fun approach: from optical illusions to theatre performances – and even birthday parties. The ITU has been in Istanbul since 1773 and we strongly believe it is our social responsibility to give young people new horizons through scientific knowledge. For instance, with the support of TÜBİTAK (Scientific and Technological Research Council of Turkey) we can invite underprivileged students for two-week visits."

- *What is the situation in the rest of the country?*

"It is a rapidly changing scenario. When we started back in 2007, there were only two or three science centres in Turkey. After only five years, we have reached ten. Now a new plan, unveiled by the government last year, will invest one billion Turkish lira (€428 million, US$555 million) to build a science centre in each of the 81 provinces by 2030."

- *Why is the Turkish government supporting science centres?*

"Science education in general is now a priority for us. At the beginning of 2012 the FATİH project was launched to bring smart boards and tablets to state schools."

"FATİH means literally "conquering" and makes me think of conquering pupils' scientific imagination… Turkey is a very young country and we simply cannot afford youth unemployment. This is why we invest on scientific and technology literacy, to bring youngsters closer to the attention of future employers," concluded Murat.

The FATİH project is promoted in collaboration with the Ministry of Education and the Ministry of Transport and Communications, and will distribute IT education solutions to 570,000 classrooms in 42,000 state schools across Turkey. More information about the project is available from the English-language newspaper, Zaman.

Whilst some of the initiatives promoted by its government are highly impressive, Turkey's growing economy faces a number of daunting obstacles if it is to meet its pressing need for a competitive labour force.

Reducing drop-out rates, increasing girls' education and enhancing STEM education are the main challenges ahead, according to Çiğdem Tongal of Sabanci University.

At an inGenious summer school meeting in Istanbul, she highlighted the recent rise in the age of compulsory education – from 8 to 12 years old – as an important first step in meeting these objectives. In the meeting, attended by teachers from across Europe, she also pointed out that working in partnership with stakeholders and industry, and improving the quality of professional training are also key to reducing education inequality.

In fact, Çiğdem's own Sabanci University has been playing a leading role in societal reform since 2003, with the Education Reform Initiative (ERI). This was launched within a network of public and private organisations, in collaboration with the UNICEF and the World Bank, with the objective of bridging the gap between public and private schools and ensuring quality education for all.

STEM in the universities of Turkey

- **Middle East Technical University (METU). Center for Science Technology Engineering and Mathematics Education**[85]

  Center for Science, Technology, Engineering, and Mathematic Education (BILTEMM) at Middle East Technical University, Ankara, Turkey, was recently established with the aim of advancing education in STEM fields. Through collaborative work of interdisciplinary community of faculty members, BILTEMM is committed to improving and enhancing opportunities for schools, educators, and students. The aims of BILTEMM include evaluating school curricula, developing

[85] https://biltemm.metu.edu.tr/en

new programs, advocating for diversity and access, and influencing relevant policy in education of STEM fields. BILTEMM activities target developing students' and teachers' 21st century skills and knowledge, enhancing their attitudes towards STEM fields, and contributing to the society by presenting solutions to the social and ecological problems through innovation in science, technology, engineering, and mathematics education.

Workshops for Teachers. BILTEMM teacher workshops are aimed to help teachers in STEM-related skills. Everyone can follow our web site and social media accounts for upcoming events.

Projects. The projects focus on developing new educational tools and curricula for learning in STEM fields, as well as developing and implementing professional development programs for teachers.

Design-make-learn. Supported by METU Research Fund, Engineering Design Education Training for Teachers is conducted in collaboration between BILTEMM and METU Center for Wind Energy (RUZGEM).

First step. Supported by the Science and Technological Research Council of Turkey (TUBITAK), this project aims at developing curriculum and materials to improve elementary students' math skills with real life applications.

MAKEITREAL Erasmus+ aims at addressing underachievement in STEAM education through real product design and making practices.

Amgen biotech experience project, conducted in collaboration between BILTEMM and TED University, aims to provide innovative professional development programs, materials, and equipment regarding molecular biology to middle school teachers.

- Izmir Yuksek Teknoloji Enstitusu (IYTE)

Education Application and Research Center STEM is Established for IYTE[86] on September 27, 2019. Collaborations in the field of education and Rector Prof. Dr. As a result of the initiatives of Yusuf Baran, the STEM, "İZMİR HIGH TECHNOLOGY INSTITUTE CHILDREN EDUCATION APPLICATION AND RESEARCH CENTER", which has passed from the planning process to the implementation phase and has been approved by YÖK, is established.

[86] https://iyte.edu.tr/haber/iyteye-egitim-uygulama-ve-arastirma-merkezi-stem-kuruluyor/

The project, which has been worked on for a while, is brought to life with the aim of supporting the development processes of students of all age groups, developing the sense of curiosity and questioning motives, which are the basic arguments of scientific research, artistic creativity and thought, with educational methods and techniques. The center will come to life in IYTE, where children will be able to learn by doing and living with the teaching methods and techniques specific to their educational fields.

The opening of a kindergarten approved by the Ministry of National Education, which was felt lacking in the campus in recent months and started education and started its activities, turned a long-awaited service into a contribution to İYTE and the environment. It was decided that IYTE will carry out a study in this context, based on the idea that universities should be environmentally friendly education centers, which was shaped after the initiative of Rector Baran. Thus, with the offer submitted to YÖK; The Center, which will operate by creating teaching environments and providing applied trainings, will also meet the need of the region and the country to raise qualified human resource potential.

The Center, whose aim is to follow educational studies in all fields with qualitative, quantitative and mixed method-based scales set forth by scientific research methods and psychology and to guide students in constructing their future with the results to be achieved, the Center will work as a university where students of all ages can develop their imagination and creativity. Established with the support of YÖK, "İZMİR INSTITUTE OF TECHNOLOGY CHILDREN EDUCATION APPLICATION AND RESEARCH CENTER" STEM, which will enable children to realize their potential and support them in shaping their future education environments, will also organize thematic workshops in different fields.

In the center, the foundations of which will be established with the support of İYTE faculty members and expert education staff; Modern century knowledge and skills such as coding, robotics, game design, fashion design, gastronomy, foreign language (s), digital agriculture and animal husbandry, data science, space sciences, archeology, swimming, tennis, basketball, indoor sports, painting, music Our children will be prepared for the future with the multidisciplinary trainings that can provide them with education.

With the Psychology Workshop; To keep the affective and cognitive motivation of children at the highest level, with the Educational Training Workshop for our

teachers who are the architects of our future; It aims to gain new skills in line with its interests and attitudes. Parent-Child Workshop will also support parents, and trainings will be given to ensure that the walls of families and their children are removed from time to time and seen as insurmountable. In addition, the Center, which aims to break grounds in its field with many additional units such as Children's R&D and Game Design Center, is coming to life as an important educational home that will make a name for the region.

- Hacettepe University[87]

  In the first half of the 21st century, it can be seen that especially developing countries are striving to educate students as individuals who ask questions, ask questions, identify problems, encourage innovative thinking, have an entrepreneurial spirit, have lifelong learning skills and are sensitive to society. Turkey's potential for research and technological development and improving social and economic development, especially at a young age, to compete with other countries to provide students with opportunities to develop these properties has become an inevitable requirement. The Hacettepe STEM & Maker Lab is not only national, but also has the aforementioned functions since 2009. It participates in various projects within the framework of the European Union Framework Programs with the aim of disseminating existing educational approaches in order to improve the qualifications of people at the international level. The team of the Hacettepe STEM & Maker Lab continues project work within the Horizon 2020 and Erasmus programs

  Hacettepe University (HU)[88] is a major state university in Turkey with over 28000 students and 3500 academic staff. The university has 13 faculties, 9 schools, 1 conservatory, 13 institutes and 35 research centres._The Faculty of Education is able to meet the challenge of contemporary education through its highly qualified academic staff, who are open to change and development and who also benefit from international experience and cooperation._The faculty has 16 programmes under five departments (Computer Education and Instructional Technology, Educational Sciences, Secondary Science and Mathematics Education, Foreign Language Education and Elementary Education).

[87] http://www.hstem.hacettepe.edu.tr/
[88] http://stem-pd-net.eu/en/hacettepe/

Hacettepe STEM & Maker Lab was established in 2009. H-STEM & Maker Lab has involved in several EC FP7 projects (e.g., S-TEAM, SAILS, MaScil) and Erasmus+ projects (STING, INSTEM, MASDIV and STEM PD Net). The team in the STEM PD project includes Prof. Dr. Gultekin Cakmakci and Prof. Buket Akkoyunlu.

STEM projects of Hacettepe University[89]:

- A Comprehensive Approach to STEM Teacher Education (STEM) / European Commission, Erasmus + / 2019-2021
- STEM & Makers Fest / US Embassy Ankara /2018-2019
- STEM European Centers for Professional Development Network (STEM PD Net) / European Commission, Erasmus + / 2016-2019
- Innovation in STEM Teacher Training for Gender Balance / European Commission, Erasmus + / 2015-2017 (3 years)
- Request for Education in Science, Technology, Engineering and Mathematics (INSTEM) / European Commission, LLP / 2013-2015

- Istanbul Aydin University. Workshop on Integration of STEM Education into Curriculum[90]. The Integration of STEM Education to the Curriculum Workshop, where the integration of STEM education into the curriculum, competence and capacity was discussed, and various solutions are presented, was held on May 5, 2017 at Istanbul Aydın University with the participation of academicians, experts, administrators and teachers.

  The data obtained in the Workshop on Integration of STEM Education into the Curriculum, which was held with a study group of 19 people, was evaluated using the descriptive analysis technique. Workshop data were evaluated on a session basis. In the first session, the problems arising in the integration of STEM education into the curriculum were determined according to the participant groups. The second session was held in two stages. In the first phase of the second session, the problems arising in the integration of STEM education into the curriculum were prioritized by the participants; in the second phase of the second session, the problems that emerged and prioritized in the integration of STEM education into the curriculum were re-prioritized by the researchers. In the third session, the suggestions made by the participants to the problems that emerged and prioritized in the integration of STEM education into the curriculum were

[89] http://www.hstem.hacettepe.edu.tr/tr/menu/projeler-3
[90] https://www.aydin.edu.tr/haberler/Pages/STEM-raporu-2018.aspx

addressed, and these suggestions were evaluated according to the following themes and appropriate solutions were proposed:

- Teacher Competencies
- Professional Development Trainings
- Awareness Raising
- Physical and Social Infrastructure
- Education Policies
- Quantification and consideration
- Curriculum Development
- Application in School
- Scientific Method
- Stakeholder Cooperation
- School Management

In the conclusions and suggestions section, the results obtained are explained in a summary form, the problems and solution suggestions of the participants were discussed in a broad framework, and final recommendations were made. The organizers of Workshop hope that these suggestions are taken into consideration by all stakeholders and that education policies are created accordingly.

STEM Teacher Certificate Program Applications[91]. Istanbul Aydın University STEM Center prepared a program to train STEM Teachers. With this certificate program carried out in cooperation with IAU Continuing Education Center, the teachers can to gain the STEM education competence by providing them with STEM education. STEM Teacher Certificate will be awarded to those who complete the program and are successful in the evaluations. This certificate program is paid and all teachers can apply. Over 500 teachers have been certified in 24 programs to date.

STEM Teacher Certificate Program will be held on 28-29 November 1-2 December 2020 at Istanbul Aydın University Florya Campus STEM Lab. Duration of Training: 40 Hours. The key to being a productive, competitive and creative society is integrating science and mathematics education with technology and engineering. In this context, Turkey's first STEM Teacher Certificate Program renewed by the Ministry of Education to teachers according to the school curriculum to teach competency in

[91] https://www.aydin.edu.tr/tr-tr/arastirma/arastirmamerkezleri/sem/psikoloji-egitimleri/Pages/STEM-Öğretmeni-Sertifika-Programı.aspx#

implementing STEM education. This certificate is internationally valid. Certificate is accepted for private school teachers.

Program Content: What is the STEM Approach? Scientific Research Design. Innovation and Creativity Workshop. Project and Problem Based STEM Activities Applications. Engineering Design Workshops. STEM Lesson Plan Preparation Workshop. STEM Lesson Plan Preparation and Implementation Workshop. STEM Lesson Plan Preparation, Application and Evaluation Workshop.

Turkey's first STEMlaboratory: Istanbul Aydın University STEM Laboratory[92] is the first STEM Laboratory in Turkey. Promoting STEM (Science, Technology, Engineering and Math) education was established in February 2015 with the cooperation of the US State Department and Istanbul Aydın University within the scope of the project among economically disadvantaged youth, especially among girls. Robotics, maker, coding and so on. trainings are carried out for teachers and students in the IAU STEM LAB. IAU STEM LAB is designed to be an example to schools in Turkey based on the integration of science, technology, engineering and mathematics. The schools are supported by the establishment of STEM Lab, STEM education to teachers and students.

Trainings for teachers and students on STEM, robotics, maker, coding etc. are carried out in IAU STEM LAB. IAU STEM LAB science, technology, engineering and math based on the integration of Turkey will be an example to schools is designed in such a way.

STEM Labs are set up to schools, teachers and students and supported in STEM education. The trainings carried out in STEM LAB to date are as follows: 1)Turkey's first STEM Teacher Certification Program (edited 25 times in 40 hours and about 500 teachers participated in the program); 2) K12 students are provided with STEM, maker, robotics and programming training; 3) STEM, maker, robotics and programming trainings are provided for gifted / talented students; 4) STEM, maker, robotics, programming trainings are provided for the schools and their teachers, where consultancy services are provided. (More than 1000 teachers have been given STEM education in STEM Lab and schools); 5) STEM teaching course, design, maker, robotics and programming trainings are provided for undergraduate students of Faculty of Education; 6) STEM Education project for Industry 4.0 in Vocational Technical High Schools accepted by TÜSİAD was carried out; 7) World STEM Festival

[92] https://www.aydin.edu.tr/tr-tr/akademik/fakulteler/egitim/Pages/STEM-Laboratuvar%C4%B1.aspx

project supported by TÜBİTAK was realized; 8) World STEM Education Conference, organized by IAU.

First STEM course in education faculties: STEM teaching course

One of the courses that will be taught for the integration of STEM disciplines is science, technology, engineering and mathematics (STEM). The course is offered as an elective course at the Faculty of Education of a Private University in the Spring Semester 2015-2016. The duration of the course is three hours, the credit is three and the ECTS is four. The duration of the course is planned to be 14 weeks. The course aims to provide students with basic knowledge and skills related to science-technology- engineering and mathematics (STEM) education at undergraduate level.

STEM school[93]

The STEM School was established in 2015 by the Research and Application Center of Educational Sciences and Technologies of Istanbul Aydın University.
STEM School was established to increase the competence of teachers and students in STEM fields (science, technology, engineering and mathematics) and to support the transformation of schools into STEM schools.
Trainings for the STEM School include integrated STEM, robotics, maker and programming. Counseling about STEM education is given to schools. STEM School programs are still in progress.

STEM projects of İstanbul Aydın University

"Promoting STEM education among economically disadvantaged youth, especially among girls" project / US Department of State / 2014-2016.

By İstanbul Aydın University' review of the literature and best practices on STEM and the obtained data, in order to promote the interest of disadvantaged students, especially girls about STEM, the project "Promoting STEM education among economically disadvantaged youth, especially among girls" was started and it was accepted in August 2014 and funded by the US Department of State.

The Project at which Assist. Prof. Dr. Devrim Akgündüz was the Project Manager and Academic Coordinator of the Center for Research and Application of Educational Sciences and Technologies, and Dean of the Education Faculty Prof. Dr. Hamide Ertepinar was Scientific Advisory, and Assist. Prof. Dr. Ayşegül Kınık is

[93] www.stemokulu.com

the lecturer from Education Faculty, was the Science and Technology Coordinator, was carried out between 1 October 2014 and 31 July 2016.

BAUSTEM Center at Bahçeşehir University, Istanbul[94]

BAUSTEM Center at Bahçeşehir University, Istanbul is a research and development center specializing in STEM teachers' education at the in-service level. Three faculty members, fellows and research assistants work at the center. As part of the externally funded Integrated Teaching Project (ITP) at BAUSTEM, several programs have been developed for the last three years for classroom, science and mathematics teachers. All programs emphasize equity, interdisciplinarity, rigor, and relevance in STEM learning and teaching. Over 5,000 teachers from Turkey, Caucasia, Southern Europe and Canada have benefitted from the hybrid (online and face-to-face) programs of Center.

Yildiz Teknik University[95] STEM teacher education.

As part of this training, participants will be provided with theoretical and practical training in STEM education, which aims to provide analytical and design-oriented thinking skills, create solutions to everyday life problems using an interdisciplinary perspective, 21st century skills, STEM fields (science, technology , engineering and mathematics) from an interdisciplinary point of view. and they will make many applications related to this education. Upon completion of the training, participants who will have specialized knowledge and skills in STEM education, are aware of the use of this education in various disciplines and the use of the STEM approach in education, will be able to teach and apply STEM education, and will be able to provide STEM education.

Elementary school teachers, middle and high school teachers from all branches, teacher candidates, university students from all faculties, parents and anyone interested in STEM education can participate. There are no preconditions for participation. Successful trainees will be issued a STEM TRAINER EDUCATION certificate. With this certificate, STEM Education courses and courses can be taken in kindergartens, private schools and colleges, as well as private courses.

The Curriculum imcludes the following modules: STEM Education and Philosophy, Historical Development of STEM Education, Conceptual and Theoretical Foundations

[94] https://support.golabz.eu/support/teacher-training-institutions/baustem-center-bahcesehir-university
[95] https://sem.yildiz.edu.tr/sertifikali-egitim-programlari/stem-egiticinin-egitimi.html

of STEM Education, Engineering Design Process & Application Examples, STEM Education Practices with materials from daily life, Sample STEM-based lesson plan review, STEM Education plan, scenario and activity presentations, STEM Education Applications with Building Sets, Measurement and Evaluation in STEM Education.

Turkish STEM Alliance[96] founded in 2015, is an independent body of network for promoting public engagement with Science, Technology, Engineering and Mathematics (STEM). It unites STEM practitioners, researchers, policy makers and public to enhance the quality of STEM education and broaden participation in STEM. Turkish STEM Alliance consists of several different members from science centers, science museums, PD centers, NGOs, STEM centers, companies, research centers and public organizations.

International Stem Education Summit / Mektebim Schools[97]

In this project, which was brought to Turkey with the vision of making Turkey one of the best practices' centers in STEM fields, our aim is to make Turkey a role model in STEM education.

International K12 curriculum. This project was prepared with a vision to determine competencies and standards of STEM education from pre-school to high school in Turkey, to increase the quality of STEM education, and to improve students learning processes. The STEM curriculum is prepared in accordance with international standards in cooperation with UNESCO to ensure that students are equipped to meet the future needs of Turkey.

STEM teacher training program. The STEM Teacher Training program, which includes teaching and evaluating the international STEM curriculum developed in cooperation with UNESCO, consists of peer solidarity and learning platform, evaluation guides and tools.

STEM student assessment and evaluation program. STEM student assessment and evaluation program has been developed to ensure that the benefits of international STEM education are measurable and in compliance with STEM requirements.

STEM & Makers Fest / Expo[98]

STEM & Makers Fest / Expo[99] is a versatile event that allows people from 7 to 70 to

[96] https://www.stemcoalition.eu/members/turkish-stem-alliance
[97] https://www.mektebim.k12.tr/unesco/en/
[98] http://www.hstem.hacettepe.edu.tr/tr/menu/stem__makers_festexpo-21

interact with science and technology. The purpose of this event is; It is to motivate and keep the participants' interest in STEM fields alive with educational, engaging and exciting products and workshops.

More than 200,000 people have participated in this event[100], which has been held in Adıyaman, Ankara, Antalya, Diyarbakır, Gaziantep, Kocaeli, Konya, Malatya, Mersin and Van so far, and this city and the number of people are increasing day by day with their contributions.

International STEM Teachers Conference[101]

The 1st International STEM Teachers Conference was held at the Merter campus of Istanbul Ayvansaray University on June 13-14, 2019 along with the "1st International STEM Education Conference" this year. The 2nd International STEM Teachers' Conference "will be held in conjunction with the" 2nd International STEM Education Conference "on July 4-5, 2020 in Istanbul.

The International STEM Teachers' Conference is a platform that allows the exchange of sample STEM teaching materials. All activities that can be used in a formal, informal and informal setting can be presented at the conference. The conference organizers announce the postponement of the conference to July 3-4, 2021 due to COVID-19.[102]

TUBITAK - Scientific and Technological Research Council of Turkey

Prof. Aziz Sancar GIS Camp[103]s, April and Zonguldak, representing the seven regions of Turkey, in May months, Mersin, Ankara, Ardahan, Istanbul, I STEIN in Ankara and Istanbul provinces (Science, Technology, Engineering, Mathematics) was held with the theme. 63 female students selected among the students participating in the activities and 13 guidance teachers assigned by the Ministry of National Education attended the TÜBİTAK Konya Science Camp on 11-12 June, 2016. The second day of the event was mostly spent with activities in the field of STEM. The day started with four different fast-paced workshops: "My Connection Establishment", "Cryptology", "Music of Fruits" and "The World of Living". Then, the states of matter were explained to the students with a science show. In the afternoon, a movie named

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[99] https://stemandmakers.org
[100] https://www.youtube.com/watch?v=yzgEFjEZ_04
[101] http://www.hstem.hacettepe.edu.tr/tr/menu/2_uluslararasi_stem_ogretmenler_kon-7
[102] https://www.stempd.net/event/2-uluslararasi-stem-ogretmenler-konferansi/
[103] https://tubitak.gov.tr/tr/haber/prof-aziz-sancar-gis-tubitak-konya-bilim-kampi-yapildi

"Mysteries of the Invisible World" was watched at the planetarium. After the screening, students participating in the "Design Your Car" activity raced the cars they designed, and besides the fastest first six cars, the three most beautiful cars were determined with the scores of the instructors. The second day ended with a visit to the Mevlana Museum. During the event, our students' interviews with students were given by Prof. Dr. Aziz Sancar's thank you message and the introduction of Konya Science Center can be accessed at Bilimgenc.tubitak.gov.tr.

The first conference was held in Turkey Science and Technology Centers[104]. TUBITAK, the purpose of science and dissemination of technology and development in Turkey, bringing together stakeholders operating in the public and private sectors and stakeholders cooperating for the purpose to improve their relations with each other Konya Metropolitan Municipality and TUBITAK, Konya Science Center, May 17 to 18 in 2017 "Turkey Science and Technology Centers Conference" was carried out.

Deputy Minister of Science, Industry and Technology Assoc. Dr. Hasan Ali Çelik, President of TÜBİTAK Prof. Dr. A. Arif Ergin, Konya Governor Yakup Canbolat, Konya Metropolitan Municipality Mayor Tahir Akyürek, TÜBİTAK administrators, scientific centers, museums, academicians, private sector and public representatives.

Within the scope of the conference, where presentations were made on science center exhibition design and production processes, education areas, planetarium, STEM education applications, TÜBİTAK Science and Society support, science and technology centers and companies opened stands.

[104] https://tubitak.gov.tr/tr/haber/turkiye-bilim-ve-teknoloji-merkezleri-konferansinin-ilki-gerceklestirildi

STEM-EDUCATION IN THE RUSSIAN FEDERATION

Context

STEM education which is considered as "an interdisciplinary approach to learning where academic concepts are coupled with real-world lessons as students apply Science, Technology, Engineering, and Mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy[105], is engineering the future workforce all over the world.

It goes without saying that STEM qualifications and skills are necessary for current and future workforce in the Russian Federation due to political and economic pressures as well as improvement of knowledge delivery and employability skills development. Since the launch of the 1st soviet Sputnik, scientific, mathematical, and technological knowledge has been essential for keeping pace with technological developments. Skills related to STEM and ICT are crucial for sustainable economy in the 21st century, STEM performance drives innovation and job creation in leading industries. Nations see research, innovation and production of high-tech goods and services, military solutions, and consumer electronics as necessities for their economic progress and defense.

STEM-subjects are the basis for staff training of the scientific-technological elite for the innovative development of the country in the context of Scientific and Technological Development Strategy of the Russian Federation, as well as for the implementation of the national program "Digital Economy of the Russian Federation[106] and „National Technological Initiative"[107].

In this context, new requirements to curriculum development and syllabus design as well as implementation of new teaching methods determine continuous

[105] Tsupros, N., R. Kohler, and J. Hallinen, 2009. STEM education: A project to identify the missing components. Carnegie Mellon, Pennsylvania

[106] Паспорт национальной программы «Цифровая экономика Российской Федерации» http://static.government.ru/media/files/urKHm0gTPPnzJlaKw3M5cNLo6gczMkPF.pdf

[107] Постановление Правительства Российской Федерации от 18 апреля 2016 г. №317 «О реализации Национальной технологической инициативы» https://nti2035.ru/documents/docs/317.pdf

development of formal and non-formal/extracurriculum education practices in the following subject fields: Science, Technology, Engineering Creativity, Programming and Algorithms, Project Activities.

At the same time, little action has been undertaken on the national level to modify educational systems: we note that STEM as teaching and learning approach has not been implemented in schools yet. There is neither National STEM School Education Strategy / National STEM curriculum, nor regional STEM curriculums.

Furthermore, there is a lack of STEM-teachers and respective STEM-teachers training programs, insufficient skill level of STEM-teachers, a lack of modern professional development programs (teachers do not have the knowledge, skills and experiences, needed to provide integrated STEM education effectively + there is a lack of methodological approach to STEM education: Insufficient use of research, design and creative approach); STEM careers are not popular enough with young people + insufficient students' skill level in STEM subjects – according to Unified State Exam Statistics, 2017-2018-2019, Russia shows low popularity amongst High School graduates and low academic achievement in STEM subjects (about 50%)[108] – as well as low mathematics and science performances across PISA cycles (30th place)[109]. A new School-University-Industry vocational guidance and partnership model, aimed at engaging students in interactive extra-curriculum STEM activities and projects, is being implemented but has not been largely disseminated.

STEM-Related National Policies and Initiatives

However, over the past few years, STEM-related national policies and initiatives have been developed and implemented in the Russian Federation that, among other things, tend to meet the need to develop career and educational pathways that align with STEM. The "Need for STEM" trend in Russian educational policy is defined by the following strategic concepts, executive orders and national programs/projects:

- Executive Order on the Scientific and Technological Development Strategy of the Russian Federation[110].

[108] РИА Новости Рособрнадзор сравнил баллы ЕГЭ за последние несколько лет https://ria.ru/20190626/1555935617.html (26.06.2019)
[109] 2018 Results (Volume I): What Students Know and Can Do, PISA, OECD Publishing, Paris, https://doi.org/10.1787/5f07c754-en
[110] http://kremlin.ru/acts/bank/41449

The Strategy sets out the main objectives of Russia's scientific and technological development, the principles, priorities and measures for implementing the state policy in this sphere, as well as the expected results of the Strategy's implementation, namely Russia's sustainable, dynamic and balanced scientific and technological development in the long term. The goal of Russia's scientific and technological development is to ensure the country's independence and competitiveness providing for "Big challenges" by creating an efficient system for building up and using the nation's intellectual potential.

According to the Strategy, in the upcoming 10-15 years the priorities of scientific-technological development of the Russian Federation will be presented by will be those areas that will allow to obtain scientific and scientific-technical results and create technologies for innovative and sustainable development of Russia in the outer market, that will ensure the transition to digital, intelligent manufacturing technologies, robotic systems, new materials and design methods, Big data processing systems, Machine learning and AI, environmentally friendly and resource-saving energy, personalized medicine, high-tech healthcare, highly productive and environmentally agriculture, etc.

For the purpose of achieving the goal in scientific-technological development in relation with education and talent management, the strategy is held to imply a creation of opportunities for identifying talented youth and building a successful career in science, technology, innovation as well as the country's intellectual potential's development, counting the development of a modern system of scientific and technical creativity of children and youth.

- Priority National Project "Affordable Supplementary Education and Extracurricular Activities" (2016-2021).

The key purpose of the project is to bring within the reach supplementary education for children, including technical and natural sciences [111]. By 2021, 25% of secondary school students will have been involved in extracurricular educational activities in the field of Engineering & Natural Sciences.

The project provides for implementation of modern regional systems of supplementary education and extracurricular activities for children (inter alia from rural areas) in every constituent of the Russian Federation. These systems based

[111] Паспорт приоритетного проекта «Доступное дополнительное образование для детей» в редакции протокола от 30 ноября 2016 года №11 http://static.government.ru/media/files/MOoSmsOFZT2nIupFC25Iqkn7qZjkiqQK.pdf

on best practices ensure the implementation of modern and popular in the region supplementary general educational programs of various directions, including technical and natural-scientific ones. Such regional systems involve networking cooperation of educational organizations of various types, including colleges and universities, as well as scientific organizations, social communities and industries.

STEM-related initiatives and best practices

According to the project a model center for children's supplementary education is on-stream in every constituent of the Russian Federation, inter alia based on children's technology parks "Quantorium", as a core element of the system[112].

"Quantorium" children's technology parks network is being put in place in every constituent of the Russian Federation. These are spaces fitted with high-tech equipment, aimed at new highly qualified engineering staff training, development, testing and implementation of innovative technologies and ideas in supplementary education.

Quantoriums offer modern technology (PBL, EBL, EduScrum, etc.) and unique educational three-month programs - "Quantums" (16 to 72 hours) in accordance with the key areas of innovative development of the Russian Federation (Auto-Quantum, Aero-Quantum, Data-Quantum, IT-Quantum, VR/AR--Quantum, Bio-Quantum, Geo-Quantum, Nano-Quantum, Robo-Quantum, etc.) for students over the age of 10 years old who are interested in Engineering and Natural Sciences. Quantoriums ensure the involvement of different ages' children in solving real cases (trade tasks), design and research activities in high-tech industries. The programs are free.

Quantoriums enable students to develop necessary STEM skills as a combination of the following hard skills (3D modeling and prototyping, programming, data analysis, network and information security, computer networking, blockchain, AI, web architecture, research skills, NLP and image processing, operating skills, etc.) and soft skills (time management, critical and system thinking, leadership, communication, collaboration, teamwork and project management skills, working on large amounts of information, spatial thinking, data presentation).

[112] https://www.roskvantorium.ru/

At the time being 80 thousand children are engaged on an ongoing basis in "Quantorium" children's technology parks in 62 regions and about 600 thousand are involved in educational activities of the network.

In the capacity of students 'achievements accounting mechanisms, a system of competitive educational events (exhibitions, contests and team competitions) is implemented with feedback for educational organizations and families, aimed at increasing the children's motivation, discovering and developing abilities and early vocational orientation.

- National Project "Education" (2019-2024)[113].

One of the main tasks of the national project "Education" is to ensure the global competitiveness of Russian education, to make the Russian Federation one of the 10 leading countries in the world in terms of the quality of general education. Project activities are primarily aimed at implementing the following key areas of education system's development: updating the content, creating the necessary modern infrastructure, teaching staff training and continuing professional development (lifelong learning), as well as creating the most effective mechanisms of education management.

STEM-related goals and initiatives

Federal Project "Modern School". This project is aimed at introducing new methods of training and education, educational technologies that provide learners with the basic skills and abilities, increasing their learning motivation enhancement and involvement in the educational process (incl. in particular PBL, EBL, etc.), as well as implementation of a new concept of "Technology" as a school subject (2018)[114].

The new concept orientation towards the 21st century technological literacy, ICT, project and research skills, critical and creative thinking, digital tech, design & programming as well as vocational guidance and orientation (specifically in the context of NTI markets of the future) is of particular importance for the implementation of STEM education. Under this approach "Technology" as a school subject becomes an organizing core of entry into the world of technology,

[113] Паспорт национального проекта «Образование» https://ng.ach.gov.ru/index.php?option=com_dropfiles&task=frontfile.download&&id=105&catid=27

[114] Концепция преподавания предметной области «Технология» в образовательных организациях Российской Федерации, реализующих основные общеобразовательные программы https://docs.edu.gov.ru/document/c4d7feb359d9563f114aea8106c9a2aa/download/737/

including material, information, communication, cognitive and social technologies. Thanks to the improvement of teaching methods, the leading form of educational activity during the learning of the subject area "Technology" is Project-based learning. Project activity serves as the basis for the integration of academic subjects and is implemented in various formats. In every constituent of the Russian Federation the learning of "Technology" as a school subject is made possible based on highly equipped organizations, as well as "Quantorium" children's technology parks.

Also, within the framework of federal project in schools situated in rural areas and small towns more than 3 000 Centers for Digital Education, Natural Science and Humanities "Growing Point" have been created (by 2024 it is planned to open more than 16 thousand). Growing Points are intended to ensure access to quality education for formation among schoolchildren the most in-demand skills of the future, become centers of modern digital, science and humanities education, a space for the introduction of new content and educational technologies, multidisciplinary/crossdisciplinary education practices and PBL in teaching Mathematics and Computer Science, Technology, Health and Wellness as well as extracurricular STEM activities.

Federal Project "Success of Every Child". This project aims to achieve the goal of the national project to educate a harmoniously developed and socially responsible person in the context of historical, cultural traditions, spiritual and moral values of the peoples of the Russian Federation, as well as breakthrough trends in the new technological paradigm. This project is implemented primarily through the development of regional systems of supplementary education and extracurricular activities for children, which includes measures to create a competitive environment and increase the availability and quality of children's supplementary education. Federal project provides for the mechanisms' development of children's early vocational orientation individual education plan implementation in accordance with the selected professional competencies in the framework of the "Ticket to the Future"[115] and "Proektoria"[116], projects as well as informal STEM-related practices such as «Lessons of the Present»[117] etc.

[115] https://site.bilet.worldskills.ru/
[116] https://proektoria.online/
[117] https://sochisirius.ru/edu/uroki

The project fosters setting up a network of Regional Education Centers for Talented Children implementing “Sirius” model (incl. short-term intensive project & inquiry-based programs in the “Science” direction) in every constituent of the Russian Federation. Apart from this, “Quantorium” technology parks are supposed to appear in every locality numbering more than 60 thousand (altogether 245 “Quantorium” children’s technology parks in Russian Federation in 2024). Development of distance forms of supplementary education and the implementation of such projects as “Mobile Quantorium” (a car-based platform for workshops on 3D prototyping, VR simulation, UAV engineering etc. for schoolchildren), will allow to reach by 2024 at least 2 million schoolchildren with high-quality supplementary education, including those living in rural areas, small towns and inaccessible territories.

According to the results of the federal project, the enrollment of children in additional education will reach 80% by 2024, including at least 25% of children will be trained in supplementary general educational programs of Engineering and Natural Science.

Federal Project “Digital Educational Environment”. This project is to create, by 2024, a modern and secure digital educational environment that provides high quality and affordable education of all types and levels. In order to ensure the creation of a modern digital educational environment, it is planned to create by 2024 a network of 340 “IT-Clube” Digital education centers for children[118]. “IT-Clube” is a STEM environment for the formation of relevant IT skills in a child. The project implements popular educational programs developed together with partners - market and industry leaders, for children from 7 to 18 years old in the following areas: Mobile development (Java, Android, “Samsung IT-school” education program), Python programming («Яndex.Lyceum» education program), VR/AR-development, Cyberhigiene and Big Data (“Kribrum” education program), Fundamentals of Algorithmics and Logic («Algorithmika» education program), Robotics programming (“Lego Education” program). The programs are free.

STEM-related Collaborative Projects (Government/Business/University) and Best Practices of Non-Formal/Informal STEM Education

[118] айтикуб.рф

- NTI or National Technology Initiative (2014-2035)[119]. The National Technology Initiative is a long-term comprehensive program aimed at creating conditions for ensuring the leadership of Russian companies in new high-tech markets (EnergyNet, NeuroNet, SafeNet, AeroNet, MariNet, AutoNet etc.) that will determine the structure of the global economy in the next 15-20 years. The NTI includes a set of projects and programs aimed at integrating of Russia into the formation of standards for global markets for the future and the receipt by Russian companies in these markets of a significant share.

According to the Scientific and Technological Development Strategy of the Russian Federation the National Technology Initiative should become one of the main tools for transforming fundamental knowledge, exploratory research and applied research into products and services that contribute to the achievement of leadership of Russian companies in promising markets.

NTI STEM-related education projects and practices

The NTI Kruzhok Movement[120] is on the one hand an all-Russian community of technology enthusiasts, based on the principle of horizontal connections among people, ideas and resources. On the other hand, it is a system of *kruzhoks* (children-adult communities of makers, who alongside the professionals in the field deal with current technological challenges and try to solve current technological issues) and engineering extracurriculum activities that is expected to enable schoolchildren to take part in various projects and initiatives in the field of technical creativity (design school contests and festivals), gain expert knowledge and access the equipment in resource centers (FabLabs, children's technology parks, etc.).

The NTI Kruzhok Movement can be considered as an analogue of Makers' movement since it is based on the same principles such as: freedom, do-it-yourself, open-mindedness, learning by doing, etc. However, it is an exceptional educational phenomenon that is intended to build an ecosystem bringing together technology enthusiasts and makers, big companies, state corporations and educational institutions, connecting education, science and tech business and creating feasible formats of cooperation of all the NTI Kruzhok Movement

[119] https://nti2035.ru/

[120] https://team.kruzhok.org/en/

participants. The following are the main educational initiatives of the NTI Kruzhok Movement: the first team engineering competitions for schoolchildren and students NTI Contest, NTI lesson, “RUKAMI” project (ideas and technology festivals), Project Mentors Academy, project schools “Practices of the Future” etc.

The NTI Contest (Olympiad) [121] is a unique format of engineering competitions for schoolchildren of 8-11 grades (The NTI Contest Junior is held for ones of 5-7 grades) as well as HE students (a special “HE student” track) aimed at identifying and supporting talented children who are able to solve complex interdisciplinary problems. The contest is organized to help schoolchildren interested in engineering enter top engineering universities.

The Contest includes an online selection stage, during which participants solve tasks individually, a team online stage, and, lastly, an on-site final, during which teams work with engineering equipment and develop engineering solutions in promising areas.

The Contest takes place in 30 educational profiles related to the development of markets of the future such as “Autonomous transport systems”, “Big data and machine learning”, "Intelligent Energy Systems", "Communication systems and remote sensing of the Earth”, "Unmanned aircraft systems", "Intellectual robotic systems", "Engineering biological systems", etc.

The NTI Lesson event[122] is a “non-formal to formal” education STEM practice, which involves teachers conducting special vocational guidance lessons for schoolchildren of 7-11 grades in the areas of the National Technology Initiative on the content and teacher’s manual of the NTI Kruzhok Movement. Developed teaching/learning materials (interactive lectures, problem-based and game-based assignments, online-practice, feedback forms, etc.) intended for such STEM subjects as Mathematics and Computer Science, Physics, Technology, Geography, Biology, Chemistry; and cover the following topics and aspects: neurotechnology, AR, Big Data and Machine Learning, financial technology, robotics, energy, unmanned vehicles, composite materials, smart city, aerospace systems and satellites, IoT, geographical applications of space photography, urban studies, genomic editing, cognitive technologies, agrobiotechnology, nanotechnology.

[121] https://nti-contest.ru/

[122] http://nti-lesson.ru/

TLMs can also be used for extracurricular STEM activities. The objective of the NTI Lesson events is to show every schoolchild the importance of dealing with emerging technologies based on in-depth knowledge in STEM subject fields as well as to motivate and attract them to solve real-life technology problems participating in the NTI Contest, to help acquire and develop the skills needed to go through all the stages of the Contest and win.

Project Schools "Practices of the Future"[123]. One-day and multi-day hackathons, as well as off-site schools, where teenagers get fully immersed in work on real-life tasks are among the most effective formats of project activity by The NTI Kruzhok Movement. The aim of the project school is to establish a systematic transfer of new technologies to the educational sphere and to support the values of the NTI Kruzhok Movement in the community. Within such activities as hackathons and design schools, schoolchildren and students are involved into designing new practices of future that are related to solving urgent issues and challenges.

The following are the key focuses of the project: child-adult environment; comprehensive development of the education system in the region (training local tutors, involving regional universities, interacting with regional industries and businesses); thinking techniques and soft skills (situation analysis skills, working with a problem, task decomposition, goal setting and teamwork); industry experts (representatives of the NTI markets, start-ups and large corporations).The methodology is based on scientific and methodological materials and researches in partnership with High School of Economics, Moscow State University of Psychology and Education, Shiffers Institute etc. Examples of the most interesting "Practices of the Future" events (2019-2020) include: Faculty "Practices of the Future" within the "Island 10-22 Educational Intensive Program" (120 students, The NTI Contest participants and "Practices of the Future "hackathon winners developed projects in three areas: neurotechnology, energy and satellite imagery analysis); "Local Hack Day" hackathon (600 schoolchildren and students from all over Russia, consisting of 15 teams, developed solutions to solve the problems caused by Covid-19); The Skolkovo Junior Challenge (Large-Scale Project Competitions for schoolchildren of 8-11 grades in the areas of *Energotech*, *Biomed* and *Promtech*, organized jointly with the Skolkovo International Gymnasium, is held with the aim of developing

[123] https://practicingfutures.org/

students' research and entrepreneurial competencies, leadership skills, productive communication, skills to create and promote interdisciplinary projects).

"RUKAMI" project[124] This is a series of educational events of the NTI Kruzhok Movement to promote technical creativity among young people. Its goal is to create an effective environment for the development of ideas and talents of Russian schoolchildren and students. The project comprises two tracks for children and teenagers: All-Russian project contest "RUKAMI" and a series of "RUKAMI" Festivals.

The Contest is intended to identify the best practices and technical projects of children and youth. Everyone can take part in the competition, regardless of age, individually or as part of a group. Projects must be implemented using modern technologies, be prototypes or MVP and comply with one of the following tracks: Bio, Tech, Art, Fun, Make the World a Better Place.

Regional "RUKAMI" festivals are events to popularize modern technologies, engineering, extracurricular STEM-activities and maker practices in regions. In 2019, regional festivals were held in 10 cities across Russia; in 2020, 15 regional festivals are planned. International "RUKAMI" festival (Moscow) is the central event and unites of inventors, makers, technology enthusiasts and artists from all over the world, who present their projects in the field of engineering and technical creativity. In real time, festival guests participate in interactive master classes, art performances, and participate in laboratory work.

- **"Sirius" STEM-education Practices.** "Sirius" Educational Center for talented children in Sochi[125] was established in 2014 by educational foundation "Talent and Success" on the initiative of the President of the Russian Federation V. Putin. The main goal of the center is early identification, development and further support of gifted children showing talents in arts, sports, science, as well as the ones successful in technical engineering creativity.

STEM-related "Sirius" education practices

About 30 **educational programs in the field of "Science"** (Mathematics, Physics, Computer science, Chemistry, Biology, Agrobiology and Plant Genetics,

[124] https://team.kruzhok.org/iniciativy/post/festival-rukami
[125] https://sochisirius.ru

Biomedicine, “Start in Science”, “Introduction to the experiment”, and others) as well as multidisciplinary and Partner (“Mail.ru Group”, “Rostelecom”, “Rosneft”, “Roskosmos”, “Skolkovo”, “Yandex”, etc.) project programs for schoolchildren of grades 6-11 take place in “Sirius” Educational Center every year. STEM-related project programs give schoolchildren an opportunity to use their knowledge, skills and creativity to solve real-life challenges and carry out hands-on experiments and projects on a range of topics (Space, AI, IT, Healthcare, Nanotechnology, Electronics etc.) developed in cooperation with major universities and companies[126].

Project Science and Technology Program “Big Challenges”[127]. The “Big Challenges” program is the most large-scale annual project program for schoolchildren in Russia, aimed at a full cycle innovative activity on priority scientific and technological areas. For three weeks of the program project teams of schoolchildren of 8-10 grades solve engineering and technology tasks presented by Russian tech companies and businesses, research institutes and leading universities. Apart from project activities, the students attend lectures and workshops by top scientists and experts, participate in masterclasses and operate high-tech equipment. The following are the main project/research areas of the “Big Challenges” program: Big Data, Artificial Intelligence, Cybersecurity, Autonomous Transport, Modern Energy, Smart City, Space Exploration and Technology, Agriculture Industry and Biotechnology, Cognitive Research, Genetics, Personalized Medicine, Nanotechnology, New materials.

All-Russian Competition of Scientific and Technological projects “Big Challenges”[128].

The competition is organized as a special event for schoolchildren selection for the annual “Big Challenges” program. Similar to the program, the competition takes place in the following directions: Big Data, Artificial Intelligence, Autonomous Transport, Space Exploration and Technology, Agriculture Industry Nanotechnology, etc. The regional stage of the competition takes place in more than 45 regions of the Russian Federation. Schoolchildren can also apply on-line if there is no relevant direction in their region.

[126] Educational Foundation “Talent and Success” / Educational Center “Sirius” / Report for the 2018/19 School Year - https://sochisirius.ru/uploads/f/SiriusAnnualReport2019_en.pdf
[127] Научно-технологическая проектная образовательная программа «Большие вызовы» https://sochisirius.ru/obuchenie/nauka/smena578/2893
[128] Всероссийский конкурс научно-технологических проектов “Большие вызовы” https://konkurs.sochisirius.ru

On the regional stage a mutual expertise of the projects is carried out which allows the experts to get acquainted with the projects from other regions and form an expert community. The main idea of the competition is to involve regional experts and companies in working with children, facilitate further work on projects due to the geographical proximity of schoolchildren and project managers, expand the pool of partners, mentors and teachers of the competition and educational programs[129].

Another example of non-formal STEM-related practices by "Sirius" Educational Center for talented children is **"The lessons of the present" Volunteer Project for School Science and Technology Studios**[130].

"The lessons of the present" project is aimed at organizing cooperation, joint project and research activities of schoolchildren and scientific leaders of the country, popularization of the Strategy for the Scientific and Technological Development of the Russian Federation ideas. The thematic palette of "The lessons of the present" is about responding to "Big challenges" in areas such as new materials, big data, Space Exploration and Technology, Agriculture Industry and Biotechnology, Modern Energy, Autonomous Transport, etc.

As part of the project, scientific-technological studios are being formed in schools. Schoolchildren of 8-10 grades from "The lessons of the present" studios participate in offline and online meetings, discussions with scientists, technology leaders and entrepreneurs, as well as develop projects and conduct research with them. The studio managers are usually "Sirius" Educational Center alumni.

The activities of the studios are divided into cycles. A cycle lasts for four weeks. Every month studio members / participants get acquainted with one of the leading scientific and technological areas and solve the problem that is set by a scientist or a company representing this area. All decisions are evaluated by an expert group and give feedback to the project participants. The studios open in September and close in May. Thus, the project goes through 9 educational cycles in one academic year.

The studios work on the basis of PBL and "flipped classroom" blended learning model using the online platform[131], the Sirius Educational Center Online Courses

[129] Educational Foundation "Talent and Success" / Educational Center "Sirius" / Report for the 2018/19 School Year - https://sochisirius.ru/uploads/f/SiriusAnnualReport2019_en.pdf
[130] https://sochisirius.ru/edu/uroki

service[132], and the Vkontakte social network[133] as a space for interaction of all project participants.

In 2019, there were 80 studios participating in 33 regions in Russia. The participants solved the problem from Yandex, they developed new skills for the "Alice" voice assistant. For "Roskosmos" studio members developed a program that automatically binds photographs taken from the ISS to a specific geographical area. They also improved the method of assessing the solubility of granular fertilizer for the "PhosAgro" company. "KAMAZ" proposed to develop a program for the assembly of a modern car.

Likewise, **Regional Education Centers for Talented Children** implementing "Sirius" model such as "Steps to Success" (Rostov-on-Don)[134], "Golden Ratio" (Ekaterinburg)[135], "Talent Academy"[136] (Saint-Petersburg), "Kazan open university of talents 2.0" (Kazan)[137] etc. develop and deliver project & inquiry-based educational programs and non-formal STEM-activities (summer camps, hackathons, project sessions, etc.) in cooperation with universities and regional industries/businesses.

- **All-Russian on-line educational project "Digital Lesson"**[138] is an example of successful "non-formal to formal" STEM education projects carried out within The National Program "Digital Economy of the Russian Federation"[139], federal project "Staff for Digital Economy"[140].

"Digital lesson" is an online course for schoolchildren of grades 1-11 initiated by the Ministry of Education, Ministry of Communications of the Russian Federation and the ANCO "Digital Economy" and developed in cooperation with top tech companies such as "Mail.ru group", "Sberbank", "1C", "Kaspersky Lab", "Yandex' as well as "Codvards" and "Algorithmika" online educational platforms. The project

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[131] https://online.sochisirius.ru/
[132] https://edu.sirius.online/
[133] vk.com
[134] Региональный центр выявления и поддержки одаренных детей «Ступени успеха» Ростовской области https://stupeni-uspeha.ru
[135] Нетиповая образовательная организация «Фонд поддержки талантливых детей и молодежи «Золотое сечение» https://zsfond.ru
[136] ГБНОУ «Академия талантов Санкт-Петербурга» https://academtalant.ru
[137] АНО «Казанский открытый университет талантов 2.0» https://utalents.ru
[138] Всероссийский образовательный проект в сфере цифровой экономики «Урок Цифры» https://урокцифры.рф
[139] Паспорт национальной программы «Цифровая экономика Российской Федерации» http://static.government.ru/media/files/urKHm0gTPPnzJlaKw3M5cNLo6gczMkPF.pdf
[140] http://static.government.ru/media/files/3b1AsVA1v3VziZip5VzAY8RTcLEbdCct.pdf

was initiated in 2016 as a Russian counterpart of the global movement “Hour of Code”[141].

Since 2019, the project designed to inspire STEM leaders of the future involves acquainting schoolchildren with the directions of the digital economy development (video lectures, webinars for teachers, teaching and learning materials) and their involvement in practical activities (gamification, online simulator activities for 3 groups of schoolchildren: 1-4, 5-7 and 8-11 grades) in the context of real tasks in the field of Programming, Big Data, Networking and Cloud technology, AI, Personal Assistants, Digital Security etc. Traditionally, from 1,500,000 to 3,500,000 schoolchildren take part in each lesson.

STEM Centers of the All-Russian Festival of Science 0+[142]**.** In 2015, Intel and All-Russian Festival of Science 0+ announced the regional expansion of a joint project involving industrial partners to create centers for scientific and technological activities for schoolchildren. By that time there existed about 155 STEM centers in Moscow, the Moscow region and the Volga Federal District. The STEM Centers project is focused on attracting students' interest in engineering and technical specialties, early career guidance, and aims to educate a new generation of inventors, innovators and entrepreneurs working on high-tech projects.

STEM Centers of the All-Russian Festival of Science 0+ is the network of research and engineering laboratories supporting scientific, technical and engineering components in extracurricular activities[143]. Laboratories implement educational programs based on Project-Based Learning and networking with industrial partners through network research projects, contests and competitions, project camps and summer schools such as Junior Skills Challenges, FIRST (FLL-Junior, FLL, FTC), «Scientists of the Future», «Baltic SEF», “NRJ camp”, “NANO camp”, “Smartcamp”, “Rosatomcamp”, etc.

The project participants are universities, scientific laboratories, children's supplementary education centers, schools meeting the following criteria: educational programs in the field of natural sciences, technology, programming or robotics for schoolchildren of 7-11 grades; specialists with scientific or technical expertise, ready to manage the project activities of children; necessary equipment;

[141] Глобальная инициатива «Час кода» https://hourofcode.com/ru
[142] http://stem.festivalnauki.ru/
[143] http://stem.festivalnauki.ru/pages/o-stem-centrah

motivational programs to maintain interest in research and engineering activities etc.

At the end of 2019, there are 226 STEM centers[144] in 40 regions in Russia. 17,000 schoolchildren in grades 7-11 were trained in STEM centers. Schoolchildren were trained in more than 200 educational programs. 750 projects were completed, 287 of them were presented at various conferences or competitions.

Skolkovo MAKERspace STEM Education Center for schoolchildren was opened in 2017 as a joint project of LEGO Education, Skolkovo Technopark, as well as LINTEH, TETRIX and Standart-21 companies, basic element of comprehensive lifelong learning programs for future engineers and researchers (kindergarden – school – university – industry/business). At the center, primary and secondary school students study engineering and information technologies: blockchain, internet of things, mobile robotics etc. The center's task is to develop children's interest in scientific and technical creativity, robotics and IT. Education in the STEM-center Skolkovo MAKERspace is carried out on the basis of robotic educational solutions Lego Education, TETRIX and SKART IOT, which are used in the course of professional training in the discipline "Engineer-designer of Internet of Things systems". The set includes an educational and methodological training module, designed for 72 hours; a universal mock-up stand "Smart House JS", a set for the study of neuro-biosignals Bitronics LAB, as well as a Lego EV3 set with SmartBRICKS sensors.

Robooky: STEM Engineering Creativity Programs for Children[145]. A good example of non-formal STEM education is represented by an international network (Russia, CIS countries, USA) of “Robooky” robotics and engineering schools that numbers 35 education centers, more than 11 000 students/course leavers and 130 winners of international STEM contests. The mission of “Robooky” is to help schoolchildren from 5 to 16 decide on their future profession (acquaintance with “professions of tomorrow”), develop skills in entrepreneurial skills and engineering / project thinking. STEM engineering creativity program consists of 13 modules, every two months the child studies a new subject field and profession: Aerospace Engineering, Civil Engineering, Robotics Lego WeDo and Mindstorms, Scratch

[144] http://stem.festivalnauki.ru/pages/katalog-organizaciy
[145] http://robooky.ru/

Programmimg, Marine Engineering, Industrial Engineering, Environmental Engineering, Arduino Basics, etc .

Individual and group lessons are held once a week based on Game-based and Project-based learning using own online platform and copyright teaching / learning materials and also include excursions to IT companies, children's participation in coding & engineering competitions.

Robooky, together with other STEM centers, organizes the annual World Robooky Competition in engineering and robotics for children from 5 to 16 years old. The Olympiad includes such competitions as: Goldberg miniCup, competitions with robots Lego EV3 and Wedo 2.0 Competitions, as well as the creative category "Medicine for the Planet".

- Practices of Formal STEM Education in Russia: the case of the private school “Khoroshevskaya Shkola” (“Khoroshkola”)[146]. Since the school was founded in 2017, the science education in “Khoroshkola” has been based on the concept of STEM education which implies project-based integration of science and technology. Student projects (design, research, laboratory) play a leading role in the educational process, generating information and capturing the necessary theoretical knowledge. Practical problems allow to include the 21st century skills directly in the process of studying the subject. The educational process is recorded, evaluated and supported by the digital environment and digital tools.

  The goal of Khoroshkola's natural science education is to develop the ability to independently solve various life tasks in a modern, rapidly changing, high-tech world, on the basis of research context, project-based approach; 21 century skills (4К); knowledge mastery and science process skills.

  Khoroshkola Science education cluster encompasses Physics, Chemistry, Biology, Physical geography / Earth Science and Astronomy. Schoolchildren of 5-9 grades study natural sciences within the framework of integrated subject field “Natural

[146] Ловягин С.А. Изучение естественных наук в логике STEM образования: концепция и практика Хорошколы // Сборник докладов IX Международной научно-практической конференции «Исследовательская деятельность учащихся в современном образовательном пространстве». Том 1 / Под ред. А.С. Обухова. М.: МОД «Исследователь»; Журнал «Исследователь/Researcher», 2018. – С. 166-172.

Science" (4-6 hours a week for laboratory work and 1 hour for individual work), participating in laboratory work with research elements, self-study hours, project work, demo-lectures, teacher-moderated discussions (the discussion of practical work results in large groups), lectures by representatives of hi-tech business and industry, hackathons (1-2 days project sessions); – field practices and excursions; - conferences, presentations and project defense.

The distribution of topics and sections by years of study follows the logic of intersubject connections on which the study of natural sciences in general is built. In grades 7-8, each of the natural science subjects is studied in the format of training 2-3 week modules, involving the study of one subject. The sequence of subjects throughout the year is built in the logic of intersubject connections (example: before studying the topic "Atmosphere" in geography, 7th grade students are engaged in physics for 2 weeks, mastering the concepts: Archimedean force, atmospheric pressure, thermal expansion, convection).

Problem-based science courses motivate children to deal with real-life practical issues, do laboratory works and projects in small groups (2-4 человека). They also design and develop equipment and installations, plan and carry out research and make individual reports.

Three methods of assessment are used: operational feedback, a high-quality formative assessment of each completed practical work, and criteria-based assessment (scoring) based on the results of the final work. The main form of assessment is formative assessment: students receive assignments not to test the availability of knowledge and skills, but to form them. The main form of the result is a report on laboratory work, which is the subject of a qualitative assessment (feedback), since it allows you to assess knowledge and understanding of the subject studied, as well as hard and soft skills demonstrated.

Khoroshkola's teachers combine the functions of a teacher-facilitator of group work, an expert who evaluates the work of students in accordance with a system of criteria, a scientist and an instructional designer - teachers independently and with the participation of professionals develop all teaching / learning materials, project tasks, tests and rubrics for assessment.

A specially designed educational environment plays a special role. The school has no division into chemistry, physics and biology classrooms. There are 4 large specialized spaces: 1) Megalab (900 m^2) is equipped with all the necessary

equipment for laboratory research, group discussion, educational work on projects in mini-groups, as well as lectures, presentations, conferences, viewing videos in 360°; 2) Experimentarium (250 m^2) allows doing practical works, design different devices and hold demonstrations; 3) FabLab (300 m^2) is a real maker space for any research / engineering project; 4) Robotics and Microelectronics lab (180 m^2)

STEM-Teacher Training Programs and Courses

The reviewed STEM-related national policies and initiatives, school-university-industry collaborative projects in the field of non-formal STEM education as well as particular cases of non-formal and formal STEM practices in Russia call for new types of modern Science, Technology, Mathematics, Primary School and Supplementary Education teachers. Such STEM teachers have to be aware of project-based learning, enquiry-based learning, gamification methodologies, experienced in designing integrated STEM curriculum, engaging students in real-life research and engineering projects in contexts that make connections between school, community, industry etc. They also have to be able to play the parts of instructional designer, educational project manager, classroom game designer, group facilitator as well as soft skills trainer.

The system of STEM teacher life-long learning in Russia hasn't been formed yet. However, there is a number of successful practices in the field such as MOOCS, summer schools and Master's degree programs.

- NTI Kruzhok Movement Project Mentors Academy[147] is a joint project of the Skolkovo Foundation, the Agency for Strategic Initiatives, the Skolkovo Open University (OpUS) and the NTI working group Kruzhok Association. The goal of the project is to create a system of mass training and certification for project/PBL mentors. To do this, online courses are created, and full-time intensive courses called Mentors Schools are held to train managers and mentors of project-based learning. It is also planned to create a «mentors' exchange» – a space for employing mentors for school and university student projects and teams.
- "How to become a mentor of project-based learning"[148] online course on "Lektorium" online education platform[149] is a two-month MOOK on organizing extracurricular project activities and PBL at schools, working with student project

[147] http://sk.ru/opus/p/academy.aspx
[148] http://project.lektorium.tv/tutor
[149] https://www.lektorium.tv

teams, managing projects in education for those who plan to participate in a Mentors School by Project Mentors Academy as well as for schoolteachers, supplementary education teachers and trainers, Quantorium tutors, FabLab project managers etc.

- "Lektorium" online course "From hackathon to project school"[150] comprises three modules devoted to different educational intensive formats: engineering competitions, hackathons and project schools. Each module deals with peculiarities of the format, the educational process organization and specific skills and responsibilities of PBL mentor.
- Master's degree program in Moscow City University[151] "Teaching Physics and STEM-education" is intended to train future teacher of Science and Engineering. Graduates of the program develop the necessary professional skills to solve the complex pedagogical task of providing an initiation in the engineering profession. The teacher of Science and Engineering, in addition to mastering modern educational technologies, also possesses engineering competencies, primarily the ability to plan and implement complex projects.

  The educational process is based on solving practical problems. Lectures are replaced by trainings, laboratory work and pedagogical practice. Part of the program is implemented in the format of master classes and pedagogical workshops, including at the sites of innovative educational organizations (technology parks of the Kurchatov Institute and the Moscow State Polytechnic University, Khoroshkola and School No. 1799). The research work of the master's degree student is focused on the development of teaching and learning materials.

  The Curriculum consists of four modules: 1. Research module. In this module, students carry out research and write their master's thesis. 2. Module "Education and Psychology", in which undergraduates learn to understand and use the age characteristics of a child and the patterns of situations of pedagogical interaction between a child and an adult. 3. Methodical module. In this module, the development of modern educational technologies and approaches based on the material of physics, technology, computer science takes place. 4. The technology module involves the study of educational robotics, electronics and programming

[150] https://www.lektorium.tv/hackathon
[151] https://en.mgpu.ru

for technology lessons, computer science and the implementation of additional educational programs (extracurricular activities).

STEM-EDUCATION IN KAZAKHSTAN

STEM Education policy in Kazakhstan

The active development of STEM education has also begun in Kazakhstan. This is confirmed by the designated transition to the updated content of school education in the context of STEM within the framework of the State Program for the Development of Education and Science for 2016-2019**152**. To implement the new educational policy, it is planned to include STEM elements in the curricula aimed at the development of new technologies, scientific innovations, and mathematical modeling. It was planned to implement:

- a new interdisciplinary and project-based approach to teaching that will allow students to strengthen their research, scientific and technological potential, develop skills for critical, innovative and creative thinking, problem solving, communication and teamwork.
- in the State Compulsory Standard of Primary Education, new enlarged-integrated educational areas “Mathematics and Informatics”, “Natural Science” and “Technology and Art” have appeared, which provide for the study of new academic subjects such as “Information and Communication Technologies”, “Natural Science” and “Artistic work". For students of primary and high school, new academic subjects "Graphics and Design", "Fundamentals of Entrepreneurship and Business" and elective courses, the so-called elective courses, have been introduced.

- The State program “Digital Kazakhstan”[153], approved on December 12, 2017, provides for the gradual introduction of the subject "Fundamentals of Programming" in secondary education in order to develop the creative abilities and critical thinking of the younger generation, starting from the 2nd grade. The programs (grades 5-11) will also be updated, primarily in terms of revising programming languages, taking into account the inclusion of STEM elements (robotics, virtual reality, 3D printing and others).

[152] http://adilet.zan.kz/rus/docs/U1600000205
[153] http://adilet.zan.kz/rus/docs/P1700000827

The government of the Republic was instructed to develop and adopt a separate program "Digital Kazakhstan", to develop in the country such promising industries as 3D printing, online commerce, mobile banking, digital services, including in healthcare and education, and others.

The task - “improving the quality of human capital” - is to make education the central link in the new model of economic growth. Therefore, modern curricula should be aimed at developing the critical thinking abilities of students and the skills of independent search for information, it is necessary to pay great attention to the formation of IT knowledge, financial literacy and the education of patriotism of youth.

- In accordance with the Strategic Development Plan of the Republic of Kazakhstan until 2025, approved by the Decree of the President of the Republic of Kazakhstan dated February 15, 2018 No. 636, STEM elements aimed at the development of new technologies, scientific innovations, mathematical modeling, programming, robotics and initial technological training. For this, additional education programs, extracurricular activities, scientific circles and extracurricular activities will also be organized, a network of children's technology parks and business incubators with all the necessary infrastructure and mechanisms for their maintenance will be created. In high school, a number of subjects will be taught in English[154].

- The State Program for the Development of Education and Science of the Republic of Kazakhstan for 2020 - 2025[155] was adopted by the Decree of the Government of the Republic of Kazakhstan dated December 27, 2019 No. 988. According to this program, the development of digital infrastructure of educational organizations (wireless communications, cloud technologies, microservers, computers and peripheral equipment, local network, broadband Internet access, etc.) will continue. As part of the World Bank's Secondary Education Modernization project, over 5,000 schools will be provided with 100,000 laptops and 20,000 printers. More than 2,500 schools with no internet connection or slow connection speeds will receive 1,200 data centers. As a result, the project “1 teacher – 1 computer” will be implemented to provide all teachers with computers. Schools will be equipped with subject classrooms for chemistry, biology, physics, STEM classrooms. Labor training rooms will be modernized.

[154] http://adilet.zan.kz/rus/docs/U1800000636
[155] http://adilet.zan.kz/rus/docs/P1900000988

STEM Education Statistics in Kazakhstan

Analysis of the quantitative data provided by the Education Departments of the regions and the city. Astana and Almaty showed that in the 2016-2017 academic year, 974 elective courses in various areas of STEM education are held in schools of the republic (according to the Altynsarin National Academy of Education)[156].

In particular, within the framework of elective courses, children are taught the Basics of Programming (51 courses), Robotics (733 courses), Computer Graphics and Design (103 courses), the Basics of Engineering (87 courses).

The number of elective courses in Robotics included in the working curricula is 75% of the total number of all elective courses in STEM education areas. At the same time, according to the Education Directorates, the number of schools that have included elective courses in robotics in their curricula ranges from 2% to 83% (of the total number of public day schools in 2016).

STEM centers at universities

- **Pedagogical STEM-park of Abai Kazakh National Pedagogical University**[157]

  On March 17, 2018, in the Abai Kazakh National Pedagogical University, as part of the implementation of the Address of President Nursultan Nazarbayev to the people of Kazakhstan "New development opportunities in the context of the fourth industrial revolution" and support of the State program "Digital Kazakhstan", an international Kazakh-Russian seminar "Pedagogical STEM Park" was held.

  The second seminar "Pedagogical STEM Park" is aimed at discussing ways to implement STEM education in a pedagogical university, and the immediate task is to create a STEM park (or STEM center) at the university, which would contribute to the development of digital education, training bachelors and undergraduates for additional specialty "Computer Science and Robotics", the introduction of an elective course for all natural science specialties in digital robotics and STEM-training and the discipline "Digital Technologies in Education" for all pedagogical specialties. The implementation of the tasks set will ensure the training of highly qualified personnel in digital technologies associated with the main elements of

[156] https://kaznpu.kz/docs/novosti/Bostanov_17_01_2020.pdf
[157] https://kaznpu.kz/ru/4124/news/

the fourth industrial revolution, such as automation, robotization, artificial intelligence, and the exchange of "big data".

Discussed issues: “Pedagogical STEM-park” – a new format of partnership between the education system and business. Integration of the STEM park into the educational process. Familiarization with the products of companies for STEM laboratories in digital robotics and mechatronics.

To implement the above proposals, a STEM training center was created, i.e. The pedagogical STEM-park of Abai Kazakh National Pedagogical University, which is the most important step for systematizing the training of students of a pedagogical university for teaching schoolchildren in robotics and performing research work in the field of robotics and developing a methodological system for teaching schoolchildren in the field of robotics.

In 2018, the Ministry of Education and Science of the Republic of Kazakhstan announced the launch of the project “Modernization of secondary education” For its implementation the government borrowed $ 75 million from the international bank for reconstruction and development. Within the framework of the project, a set of initiatives is planned to support the updated content of education, including the creation of robotics laboratories in 16 universities of the country, which included the Abai Kazakh National Pedagogical University.

On September 24, 2019, a class came to the Abai Kazakh National Pedagogical University, which includes 10 basic and 10 resource robotic kits Robotics Advanced Fischertechnik, 2 Robot track “Basic” kits, 10 kits for experiments and robotic projects Arduino, 3d Printer E12 Anet, 6 monoblocks, JI-K3020 CNC machine for cutting and processing materials, infrared soldering station ACHI IR-6500, soldering station Saike-852d++ with analog-digital control, microscope for soldering chips, digital oscilloscope UTD2052CL 50MHz and much more.

The STEM Pedagogical Park has implemented the following scientific and technical projects with high potential for the future STEM education:

No.	Name	Financial resources, tenge
1	System of automatic control of human wakefulness	1 500 000

2	A set of digital teaching and laboratory facilities for physics	1 779 500
3	Scientific and methodological foundations for the development of laboratory work in educational robotics and mechatronics	1 500 000
	Total	4 779 500

For the training of specialists in the field of “Robotics” the following works were performed:

- An educational program has been developed for the specialty "Electrical Engineering, Radio Electronics and Robotics" in the specialty "5B012000-Professional Training". Based on the developed educational program, MOP and RUP are drawn up for 2018/2019 and 2019/2020.
- Developed an educational program "Electrical Engineering, Electronics and Robotics" in the specialty "5B071600-Instrument Engineering" in the direction of professional activity "Mechatronics and Robotics". The necessary elective disciplines in basic and profiling modules have been selected. The qualification characteristic of bachelors of the specialty "5B071600-Instrument Engineering" is given. Based on the developed educational program, MOP and RUP are drawn up for 2018/2019 and 2019/2020.
- A work program for the discipline "Educational Robotics and Mechatronics" for technical and natural specialties for 3 credits has been developed, which includes the main topics of lectures and laboratory classes, assignments for Independent work of student, for Independent work of student with teacher and a map of educational and methodological provision.

- Nazarbayev University. In 2018 NU program on training school teachers in teaching STEM subjects in English proved compliance with international standards158. It was successfully evaluated by an international independent expert. The expert evaluated the program and gave a positive report. This assessment recognized the high quality of the educational program and revealed

[158] https://nu.edu.kz/news/nu-program-training-school-teachers-teaching-stem-subjects-english-language-proved-compliance-international-standards

that it complied with international standards in terms of management, delivery, content, methodology, facilities and resources.

During 2017-2018, within the framework of the state policy on trilingual education, Nazarbayev University trained over five thousand urban and rural teachers of Chemistry, Physics, Biology and Computer Science. Training in these programs helped the teachers achieve the B2 level in English, which was necessary to successfully pass the international language examination. So since 1 September 2019, a number of Kazakhstani schools have been teaching Chemistry, Physics, Biology and Computer Science in English for grades 10 and 11.

- Eurasian National University [159]. In ENU named by L.N. Gumilyov the masters is training in the specialty "7M01525 STEM education" who are able to apply information technology with STEM elements in the field of educational activities, monitor and manage the educational process, who have the skills of research activities.

Conducting training seminars, forums

Various training seminars and STEM forums are held in the country.

- In January 2020 in Shchuchinsk (Akmola region) a training seminar “STEAM - education in the vocational education system” was held at the Higher Pedagogical College. The purpose of this event is to develop competencies based on the use of technology, modeling, art, mathematics, interdisciplinary and applied approaches, which are the main idea of STEAM-education.
- On March 17, 2018, at the Abai Kazakh National Pedagogical University, on the basis of the international scientific laboratory of problems of informatization of education and educational technologies, an international Kazakh-Russian seminar “Pedagogical STEM Park” was held. Seminar participants: Moscow State Pedagogical University, KSPU, ZAO “Didactic Systems”, Moscow, http://disys.ru. The participants of the seminar shared their experience of creating educational laboratories and a STEM park. STEM Pedagogical Park is a new format of partnership between the education system and business. To implement the above proposals, a STEM training center was created, i.e. Pedagogical STEM-park of KazNPU them. Abai, which is the most important step for the systematization of the preparation of students of a pedagogical

[159] https://univision.kz/edu-program/25232.html

university for teaching schoolchildren to robotics and the implementation of research work in the field of robotics and the development of a methodological system for teaching schoolchildren in the field of robotics. KazNPU has three laboratories: 1) Robotics laboratory 2) Measuring systems laboratory 3) Mechatronics laboratory. The STEM Pedagogical Park has implemented the following scientific and technical projects with high potential for future STEM education: System for automatic control of human wakefulness; A set of digital teaching laboratory facilities for physics; Scientific and methodological basis for the development of laboratory work in educational robotics and mechatronics

- Republican forum on STEM education “STEM innovations in education” On February 28, 2020 in the city of Nur-Sultan at the International School “Miras” the republican forum “STEM - innovations in education” was held. The purpose of the forum is to popularize STEM education among general education and specialized schools of the republic. More than 100 teachers and students took part in the republican forum. As part of the STEM forum, master classes were held on the implementation of STEM technologies: Astana IT University, Introduction to Web, STEM education and it is future in education, Microsoft Hacking STEM resources, Robot league. The forum hosted an exhibition of 27 STEM projects of students. Participation in the STEM forum forms the skills of project work in a team, the ability to create a practical solution based on academic knowledge, formalize and present your result. The children receive new knowledge and skills, are involved in research, which allows them to master in practice the skills of scientific work, which will be useful in their further education at universities.
- Methodical seminars "Orleu". On November 4, 2019, the trainers of "Orleu" - Taraz B. Makhadieva, S. Kurmanova, A. Beisenkulova, Zh. Kosherbayeva for primary school teachers on the basis of secondary school No. 36 in Taraz, organized and conducted a methodological seminar "Features of planning for an updated educational program in primary school "as part of the implementation of STEM education. The aim of the seminar is to develop skills of short-term planning among primary school teachers in the context of renewal of the content of education. During the workshop, the trainers gave teachers useful advice on short-term plans and provided methodological assistance in effective feedback. The seminar ended with an examination of the features of planning short-term plans, the effectiveness of formative

assessment and ways of developing the teacher's professional competence in organizing the educational process.

- On February 14 2018 a two-day regional training seminar on the topic: "STEM education: organization of practical activities" began at the branch of the National Center for Advanced Studies "Orleu". During the seminar, the participants considered the possibilities of using STEM education in practice, shared their experience, identified the difficulties that exist at this stage. In particular, the teachers expressed their support for the creation of an online platform for the introduction of the new system and offered a number of recommendations. So far, STEM education is offered for familiarization, but this year the initiators of its promotion in Aktobe plans to open STEM laboratories on the basis of three schools for constant practical use in the learning process, and awakening interest in research activities among schoolchildren.

STEM bodies, festivals and enrichment programs

- STEM Olympiad at Nazarbayev University [160]

On November 1-2, 2019, the first Republican STEM Olympiad "STEM – Innovations in Education" was held at Nazarbayev University. The main purpose of this event was to popularize STEM education in Kazakhstan among students in general and specialized schools, as well as search for talented children in such technical areas as engineering, programming, design robotics and 3D modeling.

STEM Olympiad is an innovative educational competition that incorporates all the latest achievements in the field of technical education. In order to increase the popularity of STEM fields, the Olympiad's organizers used the most recent scientific and technical knowledge to create the competition events, while at the same time focusing on real world applications and using a format attractive to school children. It is hoped that this event will contribute to the growing popularity of STEM fields in Kazakhstan so that young Kazakhstanis will develope an interest in technical disciplines.

The event was attended by students from all over Kazakhstan, including from schools of the capital city Nur-Sultan, the cities of Almaty, Pavlodar, Karaganda, as well as from the East Kazakhstan Region. The event was attended by leading

[160] https://nu.edu.kz/news/science-can-be-fun-stem-olympiad-at-nazarbayev-university

experts and speakers in the field of education, who shared their vision of the development and popularization of STEM education in Kazakhstan. The Olympiad was held under the auspices of Astana Innovations JSC by Nazarbayev University and STEM Academia LLP, with the support of the Astana Daryn Center for the Development of Giftedness and Psychological Support, GKKP Center for the Modernization of Education and ChU NURIS NU.

For two days, students from all over the republic competed in the ability to apply their knowledge in practice. For example, they had to build bridges from straws that can withstand a weight of 10 kg, build a vessel that can withstand up to 30 kg and float in an outdoor pool up to 20 meters, invent mechanisms to create safe cars, and so on.

- International festival of robotics, programming and innovative technologies "ROBOLAND2019" in Karaganda (since 2015) [161]

The annual international festival "RoboLand" is organized to promote the development of the creative activity of students, the formation of their engineering skills, the popularization of educational robotics and programming, the exchange of best practices, and the identification of the strongest teams.

According to the website of the International Robotics Festival, which is held annually, the number of teams representing Kazakhstani schools is noticeably increasing every year. For example, in 2015, teams from secondary schools of the Karaganda region, Nazarbayev Intellectual Schools in Karaganda and Kokshetau took part in the robotics championship held as part of the international festival. Teams competed for a spot in five nominations: *minisumo*, *kegelring*, *line following*, *maze and creative projects*. In 2016, teams from 12 regions of Kazakhstan, the city of Almaty and Astana participated in 14 nominations of the competition. 113 participants represented Nazarbayev Intellectual Schools. 392 teams from Kazakhstan and Russia took part in the 2017 competition.

- The VI International Festival of Robotics[162], Programming and Innovative Technologies "RoboLand 2020" was supposed to take place on 27-28 March 2020 in Karaganda, Sports Complex "Zhastar". The organizing committee of the VI International Festival of Robotics, Programming and Innovative Technologies

[161] http://roboland.kz/

[162] https://roboland.kz

"RoboLand 2020" announced the postponement of the event. The reason is the introduction of restrictions on mass international events in connection with the threat of the penetration and spread of coronavirus in the territory of the Republic of Kazakhstan; the exact time of the festival will be announced later.

- **The first festival for STEM teachers in Kazakhstan**[163]**.** In October 2018, the Republican School of Physics and Mathematics, with the support of the Chevron company, in partnership with Science on Stage Europe and the Foundation of the First President of the Republic of Kazakhstan – Elbasy, held the first festival in Kazakhstan for STEM teachers. The aim of the festival was to improve the quality of teaching STEM subjects and create a platform for teachers to share their ideas and innovations in teaching. The festival was attended by 25 teachers from different regions of Kazakhstan and 20 projects were presented in various categories, which were pre-selected. The best projects of the festival received the right to represent Kazakhstan at the European festival, which took place in November 2019 in the city of Cascais, Portugal.

  For the first time, STEM teachers from all regions of Kazakhstan have found a single platform for the exchange of knowledge, methods and projects, thereby developing students' interest in science and innovation. As a result of the festival, each teacher was able to enrich himself with new ideas, which he could apply already the next day in his lessons.

  The following projects won the competition:

  - *AirGarden* is based on the principle of using the knowledge of all STEM subjects in one separate project on the example of creating an aeroponic vertical structure for growing vegetables and greens.
  - Assistant robot - robot allows you to visualize the principle of programming algorithms and learn the basics of robotics.
  - “Modern Science Class” - the aim of the project is to popularize Pasco wireless sensors that allow you to quickly collect data and analyze it in the form of graphs. Thanks to sensors, the educational process is transferred outside the school and allows you to study the environment.
  - Creative plasticine - aimed at developing abstract thinking in mathematics lessons by visualizing complex geometric shapes and problems.

[163] https://inbusiness.kz/ru/last/v-astane-proshel-pervyj-v-kazahstane-festival-dlya-stem-uch

The festival consisted of two parts - thematic workshops and the event itself, during which teachers defended their projects in front of the jury. Workshops were conducted by teachers participating in the festival and by members of the jury. The projects were assessed according to the following criteria: the possibility of increasing the interest of students in the study of science; determination of a sustainable effect, the possibility of implementing the project in the daily life of the school; minimal funding costs and focus on solving specific problems.

In March 2018, Kazakhstan, represented by the RFMSh NJSC, entered the European STEM Teachers Association "Science on Stage Europe". "Science on Stage" is a non-profit association that provides a European platform for STEM teachers to exchange teaching ideas and methodologies. Since its launch in 2000, "Science on Stage" has reached nearly 100,000 teachers in over 30 countries.

- The first city festival of STEM education "Deinde 4.0"[164] was held in Kostanay. 214 schoolchildren demonstrated their abilities. The festival "Deinde 4.0" was held at the school-gymnasium №3. It was held in five areas: "Paper Plane", "STEM Problem", "Robotics", "Pinkod", "Video".

International cooperation in the field of STEM education[165]

There is a positive experience of international cooperation. For example, since 2014, the five-year "Newton-Al-Farabi" Partnership Program of Great Britain166 and Kazakhstan has been implemented with a total budget of £ 20 million. The goal of the Program is interaction between the two countries in strengthening scientific and innovative potential, exchanging personnel and creating joint research centers.

Thus, our country is moving in the same direction as developed countries. STEM education is the bridge between studies and careers. His concept prepares children for a technologically advanced world. Professionals of the future require comprehensive training and knowledge from a wide variety of educational fields in science, engineering, technology and mathematics.

- ERG (Eurasian Resources Group) grants. Social projects in Kazakhstan aimed at developing innovative teaching methods and improving the quality of life of people are sometimes grandiose in scale. Eurasian Resources Group (ERG) invests

[164] https://top-news.kz/pervyj-gorodskoj-festival-stem-obrazovanija-deinde-4-0-sostojalsja-v-kostanae
[165] otbasym.kz/news/obrazovanie/2018-05-18/stem-obrazovanie-v-mire-i-kazahstane
[166] https://www.britishcouncil.kz/ru/newton-al-farabi

heavily in the development of Kazakhstan. Since 2001, ERG's total social investment has amounted to 226 billion tenge.

In particular, ERG is a key partner in the implementation and expansion of STEM activities in Kazakhstan. STEM based on colleges and schools includes the study and implementation of innovative technologies (science, technology, engineering, math). There are already 12 such laboratories in Kazakhstan, worth more than 80 million tenge.

"Today, STEM laboratories, with the support of including ERG, have been opened in 5 percent of schools in Kazakhstan. In order to feel the significant effect of the introduction of these laboratories, at least 20 percent, or 1,500 schools must be equipped. For 2020, we want to equip all these 1,500 schools and create, so to speak, a critical mass of schoolchildren who move STEM learning and bring the best changes to their society, "says Magzhan Kistaubaev, director of development at STEM Academia[167].

STEM In Schools of Kazakhstan

- **Nazarbayev Intellectual Schools (NIS).** The curriculum of NIS includes STEM elements aimed at the development of new technologies, scientific innovations, mathematical modeling, programming and robotics. Already today mathematics, statistics and informatics are actively used even in the humanitarian sphere[168].

Development of robotics at NIS

NIS supporting technically gifted and talented children, developing creative thinking and stimulating students' interest in the field of innovation and high technology, makes a significant contribution to the development of educational robotics in the Republic of Kazakhstan. Since 2014, NIS has been the national organizer of the Olympiads in robotics according to the rules of the World Robot Olympiad (WRO) in Kazakhstan. Every year, NIS conducts qualifying regional and republican stages of the Olympiad, according to the results of which a national team of Kazakhstan in robotics is formed to participate in the international stage of the WRO.

[167] https://stem-academia.com/
[168] http://www.nis.edu.kz/ru/projects/Robotics/

In 2014, NIS for the first time held a robotics Olympiad according to the WRO rules, which was attended by 90 students of the Intellectual Schools from 15 regions of the country. The winners of this Olympiad in November 2014 took part in the international stage of the WRO (Sochi, Russia), where, according to the results, they took the III place in the creative category, having developed a prototype of a robot that can be used to rotate space stations in space to obtain solar energy. In 2015, the Republican Olympiad in robotics was held in Astana with the participation of 152 students.

In 2016, NIS organized and conducted regional and republican stages of the Olympiad in robotics with the participation of the following participants: 401 students of the Intellectual Schools and 84 students of general education schools (Regional stage); 140 students of the Intellectual Schools and 44 students of general education schools (Republican stage). In December of the same year, the winners of this Olympiad took part in WRO-2016 (New Delhi, India) and won the Creativity Award nomination by creating a robotic orbital station for the destruction of space debris in near-earth orbit.

On April 29, 2017 on the basis of the Nazarbayev Intellectual Schools of Astana (IB), Almaty, Aktobe, Atyrau, Kokshetau, Karaganda, Kostanay, Kyzylorda, Pavlodar, Petropavlovsk, Taldykorgan, Taraz, Ust-Kamenogorsk, Uralsk, Shymkent (chemical and biological direction) and the regional stage of the Olympiad in robotics was held within the framework of the World Robot Olympiad 2017 rules. The regional stage was held for one day in the following categories: "Basic", "Creative", "Free" (Kegelring, Sumo robots, Trajectory - movement along the line) and "Football of robots ". 1210 students took part in this stage of the competition, including 326 students of Nazarbayev Intellectual and 884 students of secondary schools from 8 to 19 years old. As a result of the regional stage of the Olympiad, 300 students (150 teams) received admission to participate in the Republican stage.

On 3-4 July 2017, on the basis of the Congress Center of the International Specialized Exhibition "EXPO 2017", Republican competitions in robotics (hereinafter referred to as the Competitions) were held. The competitions were held under the auspices of the World Robot Olympiad 2017 (WRO 2017) in the following categories: "Basic", "Creative" and "Football of Robots". The Competition was attended by 300 teams from 16 regions of the country. One team of the Republic of Uzbekistan participated as a special guest.

These competitions became a qualifying stage before preparing for participation in the WRO. From among the winners, a list of participants in the training camp was formed, held from 7 to 14 September 2017 on the basis of the Nazarbayev Intellectual School of Physics and Mathematics direction in Uralsk. As a result of the training camp, the composition of the national team was determined from among 15 students of the Intellectual Schools. Astana, Almaty, Taldykorgan, Uralsk, Kokshetau, Kostanay, Petropavlovsk, which took part in WRO-2017.

From November 8 to 13, 2017, the national team took part in WRO-2017 in San Jose (Republic of Costa Rica), taking 4th place in the creative category with a realized prototype of a firefighter robot for preventing and extinguishing forest fires.

In January 2017, two teams of the Intellectual School of Physics and Mathematics in Almaty took part in the IX All-Russian Robotic Festival in Moscow and took I and II places in the VEX EDR category. In April 2017, they took part in the international competition VEX Robotics Competition World Championship-2017, Luisville (USA), where they took the 36th place out of 80 teams in the team competition.

In July 2017, the combined team of the Intellectual Schools of Almaty took part in the Inaugural First Competition "First Global Challenge" in Washington (USA), where it took 8th place out of 163 teams.

Also, for the purpose of professional development of teachers of informatics and popularization of the development of robotics in secondary schools of the Republic of Kazakhstan in 2015, the AEO developed an elective course program "Robotics" and organized refresher courses for 2999 teachers of informatics of secondary schools of the country[169].

- Republican School of Physics and Mathematics (RPMSh)[170] is a member of the international consortium of STEM schools, fully meeting the goals and objectives of this direction. In middle and high school, students acquire deeper knowledge in the field of robotics, building 3D models in CAD environments. They study such programming languages as Python, C ++, learn to work with controllers like Arduino.

[169] http://www.nis.edu.kz/ru/projects/Robotics/
[170] https://almaty.fizmat.kz/o-shkole/novosti-i-meropriyatiya/

STEM training courses[171]

On May 28-30, 2020, the Republican School of Physics and Mathematics, with the support of Chevron, organizes online programming courses for teachers of natural sciences and engineering disciplines. No special knowledge required. During the 2019-2020 academic year, more than 500 teachers learned how to apply information technology in the teaching of science. The teachers mastered the basic skills of working with automation systems on the Arduino platform, got acquainted with the methods of constructing an interactive lesson, and also assembled their own programmable installations for demonstration in the lesson.

The course content includes: Modern methods and technologies of teaching physics; Organization of research projects using Internet resources; Solving educational problems using programming; Electronics and microcontrollers in design activities; Innovative processes in education: domestic and foreign experience.

The Republican School of Physics and Mathematics has developed a program that will teach teachers across Kazakhstan to teach in a new way – exciting, interesting, effective[172]. RPMSh has launched free trainings for teachers of physics, mathematics, computer science, biology, chemistry and geography from other schools. More than 560 teachers have already passed them. The peculiarity of the program is that it teaches STEM teachers to integrate their subjects with each other and to actively engage children in science.

“Now any teacher from any school can take trainings with us and improve their skill level. We want to share the experience and pedagogical competencies accumulated during the existence of the Republican Physics and Mathematics School. After all, being open and willing to cooperate is a new trend in education. We follow this trend and support all kinds of knowledge sharing initiatives.

For half a century of existence, our school has become the flagship of STEM education for gifted children. It was created their own methodology, released a whole galaxy of scientists, entrepreneurs, as well as statesmen, known not only in our country, but also abroad”, said Yerlan Uteulin, Deputy Chairman of the Board of the RPMSh.

[171] https://almaty.fizmat.kz/news/kursy-povysheniya-kvalifikacii-dlya-uchi-2/
[172] https://almaty.fizmat.kz/news/kak-prokachat-uchiteley-metod-ot-rfm/#

The uniqueness of the STEM approach is that all subjects in it are closely interrelated. Let's say a student is faced with the task of launching a space rocket, building a bridge, refining oil, or assembling a robot. And this cannot be done without broad knowledge in various fields of physics, chemistry, mathematics and programming. Therefore, STEM integrates them into a single learning scheme, when there are "projects" and not subjects. In such an educational environment, children acquire knowledge and immediately learn to use it. This is the approach that will be disseminated by the teachers who participate in the program.

In May, more than 60 teachers from different villages and cities passed online trainings. The continuing education program for teachers, like many STEM programs, is supported by Chevron. After the quarantine is lifted, RPMSh trainers will begin to travel to the regions and conduct training for local teachers.

- British schools Haileybury[173] are independent British schools based on English educational standards and have branches in the UK and Kazakhstan. Haileybury Kazakhstan schools are located in Astana and Almaty and differ slightly in training programs - in Astana, students receive an International Baccalaureate (IB) diploma upon graduation, and in Almaty, they graduate with an A-level diploma. A-level and IB are university entrance preparation programs that are recognized by universities around the world. The main difference between the programs is that students study several specialized subjects in depth. Typically, the program takes the last two years of school.

  New technologies are also being actively introduced in schools - students have access to computer labs and robots, and in the future they plan to open a STEM center here - a laboratory of new technologies with improved electronics and robotics. Here they are actively introducing new methods of studying sciences, inviting practitioners to work and in every possible way motivating students to create their own projects.

  At Haileybury, STEM disciplines are central[174]. And this is not only traditional physics, mathematics or chemistry - students learn programming and are engaged in robotics at a serious level. In the classroom, teachers use special laboratory and educational equipment, 3D printers, and LEGO robotic sets. In addition, Haileybury hosts its own STEM Olympiad every year. Hundreds of

[173] https://the-steppe.com/razvitie/haileybury-chto-proishodit-za-kulisami-vedushchey-britanskoy-shkoly-v-kazahstane
[174] https://peremena.media/stem-v-odnoi-iz-luchshih-shkol-kazakhstana/

applications come from the strongest schoolchildren in the country, but only the best candidates make it to the final stage, who receive an invitation to further compete for a one hundred percent grant under the International Baccalaureate (IB) program. After all, encouraging young engineers and scientists is an important mission of Haileybury Schools.

- STEM center school[175] (STEM Academia)

STEM center is a school for children aged 5 to 15 years, where 4 areas are studied simultaneously: engineering, programming, robotics and 3D modeling. The founders of the company are students of the Bolashak program at Pennsylvania State University in the USA. The American education system pushed students to create such a school. They wanted to bring to Kazakhstan what they saw there. At the moment, the team of teachers includes either students who are now studying in technical specialties of NU and ENU or people who have already completed higher education in technical specialties. The main criterion for hiring is not the availability of pedagogical education, but the ability to transfer one's own knowledge. The person must be a specialist in AutoDesk, programming, engineering. Because there are people who understand physics, but do not know how to apply it in practice.

STEM center is represented in 16 regions of Kazakhstan, headquartered in Astana. Moreover, STEM is the first exporter of knowledge. It is located in four regions of Russia – Krasnodar Territory, Barnaul, Krasnoyarsk, Volgograd, The center is also represented in Lithuania and the UAE.

Educational program

The first step is to introduce children to *Engineering*. For this, a separate office has been allocated, which is fully equipped with the materials necessary for work. There is wood, environmental plastic, drill, saw, screwdrivers and all those tools that real engineers use to build a real object. Children must work in gloves and special glasses under the supervision of a teacher. The purpose of this direction is to show children how the world works and teach them to understand it. After all, creating something with their own hands, they lose the barrier to research.

After children master Engineering, they move on to *Programming*. Everyone knows about the importance of knowledge of basic programming skills, so the

[175] https://the-tech.kz/articles/what-is-stem/

second step in the STEM center is designated as it. Here children are taught not only to be able to do, but to understand how to do it. Programming is taught in three languages: Scratch, C ++ and Python. They are considered the basics of any programming. Scratch is a program designed specifically for children at MIT, C ++ is one of the main programming languages and Python is a higher level.

The third step is *Robotics*. Robotics goes through two modules. These are Lego Robotics and Arduino. After the children master Arduino, they move on to 3D modeling.

3D modeling is also in two directions. Autodesk and SolidWorks. At first, children learn to work on programs, then they do on a simulator in a 3D solution, and then they print what they have modeled.

- Miras International School (The Branch of Nursultan Nazarbayev Educational Foundation)[176]

  Miras school started the STEM educational approach in 2014 to provide various and multidisciplinary opportunities for students to experience first-hand practical experience through a variety of activities and in-school practical projects within STEM. To acknowledge creativity, students expand and upgrade their skills, and exercise the role of young scientists to fulfil the 21st-century skills for further education.

  The approach of school in education reflects in the technological, environmental and social importance of STEM in everyday life. In 2018-19, Miras school started a comprehensive STEM approach by promoting project-based learning throughout the whole school starting from pre-school to high school. During the current academic year, Miras school celebrated the first STEM festival where more than 20 schools, together with students of school participated and shared their STEM practices and knowledge gained through their experience. Also, Miras school is actively promoting teachers of all subjects to be trained to support STEM education.

- In 2018. A vivid example of the introduction of modern trends in the education system is Secondary School No. 33 of the Rodina village[177] of the Tselinograd district of the Akmola region, which has been successfully working for a year

[176] https://miras-astana.kz/pages/eng/stem.html
[177] https://lenta.inform.kz/ru/steam-obrazovanie-vnedryaet-sel-skaya-shkola-v-akmolinskoy-oblasti_a3459352

already within the framework of the scientific grant project “Formation and development of entrepreneurial STEAM education in rural schools in Kazakhstan”.

The participants of the project told the correspondent of MIA "Kazinform" about the nuances of their work and internship at Brunel University of Great Britain. Secondary school No. 33 of the Rodina village of the Tselinograd district of the Akmola region has been an experimental site for a year now and has been working within the framework of a scientific grant project aimed at developing the STEAM direction in education. During 2018 alone, the school was attended by foreign experts, invited teachers from the NIS of the city of Kokshetau, employees of the National Academy of Education named after I. S. Altynsarin, scientists from Nazarbayev University, representatives of Haileybury School Astana. Summer language school “You can STEAM it” was held this summer. But the most significant event for the rural school was the internship of the project research team at Brunel University in the UK.

- Caravan of Knowledge[178] interactive educational project dedicated to advancing STEM areas. The project is run with the support of “Chevron Munaigas Inc.” In Kazakhstan and a team of Kazakhstan professionals in the field of education and digitalization.

  The project is being implemented in 17 provinces and 3 cities of national importance by the following areas:

  - Is there STEM beyond school?
  - STEM and in demand skills in the profession of the future
  - Effective pedagogy: STEM teaching tools at school
  - STEM for everyone: how to teach a child with special needs?
  - Educational strategies: what is the path of Kazakh school?
  - Management in education: principles of effective school management
  - The role of STEM in the general education program

  The project invites teachers and parents; researchers and experts; young students; school administrators and district leaders; municipal, provincial

[178] https://caravanofknowledge.com/en

departments of education-public service bodies, etc. to participate in a variety of face to face and on-line activities, namely: sessions with leading local and foreign experts, interviews and surveys, round tables, literature reviews, etc. The final product of the project will be represented as research (in Kazakh, Russian and English), in the classic version and infographic format and strategic proposals for the project stakeholders.

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