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Project BOTSTEM

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INTELLECTUAL OUTPUT O3.A1

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HKR – Kristianstad, Sweden.

Contents

Disclaimer

List of Acronyms

STEM	Science, Technology, Engineering, Mathematics
DoW	Document of Work
O3	Intellectual Output 3
EU	European Union
ROSE	Relevance of Science Education
EECERj	European Early Childhood Education Research journal
EECERA	European Early Childhood Education Research Association
JES	Journal of Emergent Science
EJSTEME	European Journal of STEM Education
SSCI	Social Sciences Citation Index
ASE	The Association for Science Education
ESERA	European Science Education Research Association
CORDIS	Community Research and Development Information Service

1. EXECTIVE SUMMARY

STEM programmes are receiving increasing attention since they are considered efficient for developing scientific literacy for citizens and for increasing the number of young people choosing to study scientific-technological disciplines at the end of their compulsory schooling and choose scientific vocations (EU 2015). Decision makers are becoming interested in incorporating STEM approaches in formal education, also for early years. This document contains a description of STEM practices designed to encourage scientific vocations for early-years education in Europe. The practices have been found through thorough searches of scientific journals, and descriptions of ongoing and finalised projects supported by the EC. This strategy has been chosen instead of the proposed DELPHI study because the published journal articles are accepted and quality guaranteed and when the selected European practices are described and discussed in relation to the botSTEM framework (Greca, et al. 2020), and the partners, aspects of cultural adaptation and key challenges are addressed.

Furthermore, three central European journals for early-years education have been analysed to get a measure of the frequencies of articles pertinent to existing practices to encourage scientific vocations, i.e.

- European Early Childhood Education Research Journal (EECERJ) – general early-years education
- Journal of Emergent Science (JES) – early-years science education
- European Journal of STEM Education (EJSTEME) – early-years STEM education

The European Commission has supported a large number of European projects in recent years and a thorough scan of projects addressing the issue of encouraging pathways to scientific vocations is reported and discussed din relation to recommendations for designing practices aimed to encourage scientific vocations already at early childhood education.

Estimated Dates: 1/2020 - 3/2020

Activity leading organisation: HKR (UBU)
Participating organisations: All

2. INTRODUCTION

The Intellectual Output (IO3) is addressed to generate knowledge about practices designed to encourage scientific vocations for early-years education in Europe. This report describes the process of searching for descriptions of practices developed and implemented to that end. The selected examples from European contexts are described and discussed in relation to the theoretical framework of the botSTEM project.

3. The botSTEM Framework

The ideas shaping the botSTEM framework (Greca et al., 2020) have been organized in a didactical model that makes use of inquiry teaching and engineering-design methodologies. Both methodologies imply a certain number of steps and research suggests that young children can follow both, although some adjustments must be made. Inquiry teaching and engineering design are about questions, but, as Chalufour & Worth (2004) note, it is difficult for children to ask questions about something they have neither seen, nor touched, nor experienced. These authors propose that it is very important for young children first to engage, notice, wonder and question. That is, to be given time to play in a scientifically stimulating environment. It is therefore considered necessary to create these rich environments to stimulate children's questions. As many of the emergent questions may not be investigated, the role of the teacher is to scaffold the process and focus observation and clarify questions.

The botSTEM model consists of three phases, each designed to encompass more than one STEM discipline. Thus, in the first phase, teachers propose an engineering-based real-world problem, based on children's observations and questions that serves as a context to teach science-related content matter. During the second phase students perform a guided inquiry (Martin-Hansen 2002) in which, among other tasks, the students conduct different experiments using scientific practices and technology, in order to apprehend the knowledge necessary to solve the initial problem. The third and final phase (the problem resolution) requires the design or implementation of a technological solution for the initial problem. In this way, students begin to explore engineering design, linking engineering and science, as proposed in NRC (2012). As appears in Figure 1, simplified steps are proposed in both methodologies. In the case of inquiry, propose hypothesis, experiment, evaluate, share and discuss. Since it is proposed to work with both methodologies, the conclusion step from the inquiry phase is an input of the engineering design methodology. The steps of the engineering design methodology are similar, including a compare and complete step, since a relevant aspect of the engineering design methodology is to compare the different solutions (in terms of efficiency, sustainability, beauty, etc). Nevertheless, the teacher can make these steps more complex, depending on the children's responsiveness. Collaboration among children and with the teachers should be actively promoted during the use of both methodologies.

Maths concepts (such as classification, order, units, symmetries, introduction to display results graphically, among others) are used explicitly in all the phases. Similarly happens with technology. Besides the use of tools to take data, to analyse it and to present results, technology can be used to express children's scientific explanation models, for example by means of the 'Stop Motion' (Fridberg et al. 2017).

Related to computational thinking, a scaffolding process is proposed: begin with simple robots (that can be programmed physically), followed by the introduction to block-based coding (like *Scratch*©, that can be used for presentations, simple modelling, etc.) and ending with physical computing (like BBC microbit). Also, robotics and programming are integrated in two different ways: as auxiliary to a science real-world problem that guides the activities, or central when the problem is directly related with robotics. In the first case, for example, robots can be used to consolidate the new knowledge, letting children program a robot to "find" answers or using simple programming tools for modelling the phenomena. In the second case, activities such as the design of a domotic garden (or 'smart garden') are useful for guiding all the STEM project.

Figure 1 outlines the botSTEM model. This combined use of both methodologies, framed in a rich environment, fosters the development of scientific and mathematical knowledge, programming skills and technological abilities.

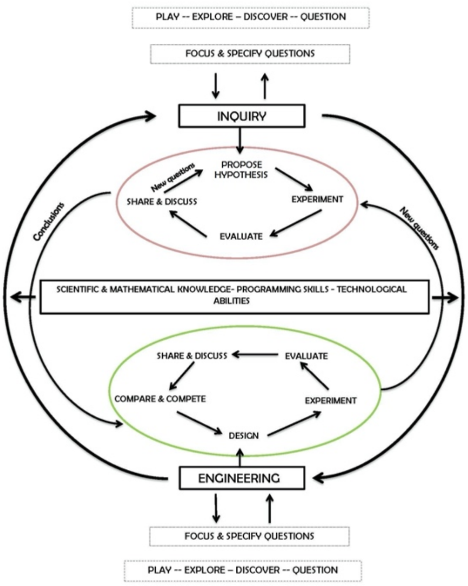

Figure 1. Botstem didactical model developed for introducing integrated STEM education at elementary grades (Greca et al. 2020). Inspired by Chalufour & Worth (2004)'s cycle of inquiry.

The intention of the framework and the developed activities using this model is to encourage integrated STEM education and robotics for early years, with a gender inclusive pedagogy that makes use of inquiry, engineering design methodology, collaborative work and robotics focusing on STEM content that relates to big ideas in science. This didactical perspective is expected to promote young children's future choices of STEM education and vocation for.

4. Practices designed to encourage scientific vocations – search methodology

In a first step, three databases were used for search in this literature review: Summon, ERIC and Google Scholar. The following keywords were determined among the researchers in the project, used and combined: STEM longitudinal, STEM education vocation, Early years STEM motivation, Early childhood education STEM motivation, Early childhood education STEM activities retention, STEM women career, STEM persistence girls, STEM enrolment girls, STEM enrolment, Integrated STEM vocation and STEM vocation early childhood longitudinal girls motivation persistence enrolment. For each search, about 60 abstracts were scanned. In the selection, articles published between 2010 and 2020 by European research groups, presenting results of STEM vocation from implementations, were chosen. Papers with theoretical discussions were excluded. Altogether these inclusion criteria resulted in only 3 hits, presented below. It was clear from the literature review that most research highlighting what stimulates STEM vocation is made in US and this could indicate a gap in research areas focused in Europe.

In the next step of the literature review, three European scientific journals were selected: *European Early Childhood Education Research, Journal of Emergent Science, Journal* and *European Journal of STEM Education*. The search methodology for these journals is described below. A discrepancy was found between the search hits in the databases compared to in the three journals. The explanation for this can be found in the key words in the selected articles from the three European journals. These did not match the search words used for the literature search in the databases but were instead: STEM, careers, engineering, science capital, research, pedagogy, drama, inquiry skills, learner identity, working scientifically, professional learning, primary science and technology, teacher mentors, collaborative enquiry, informal learning, family environment, children's media, parent survey, STEM career, promoting interest, STEM club, STEM retention, secondary education, integrated STEM, systematic review, instructional practices.

5. Practices – search results

5.1 Journal articles – search results

León et al. (2015) describes how the mechanisms and processes promoting math achievement are linked to students' autonomous motivation and deep-processing, the latter including critical and reflective thinking. Students with autonomous motivation engage in learning motivated by their own interest and not by external pressure. This intrinsic motivation is in turn connected to teachers providing meaningful rationales, acknowledging students' feelings, using non-controlling language and offering choices, as shown by León et al. (2015) and others (Su & Reeves 2010). Experiencing some degree of meaningful choice and a sense of psychological freedom is key to enhancing student's autonomous motivation (León et al 2015).

van den Hurk et al. (2019) has published a systematic review of empirical studies in which effectiveness of STEM-related interventions are assessed. The authors discuss the difficulties in determining whether the positive effects are in fact caused by the interventions but describe interesting findings from the literature. Two of the studies in the review were aimed at altering the social context around female students (Stoeger et al., 2016; Stout, Dasgupta, Hunsinger, &

McManus, 2011) by providing them with female mentors, that is, role models. This had a positive effect on the female students' interest in STEM. Other studies in the review highlighted how the instructional approach in the STEM classroom is favouring boys. For example, girls are more likely to use cooperative techniques to learn and this strategy is rare in STEM classrooms (Kelly, 2016; Wang & Degol, 2013). The strategy of letting the children work in small groups could possibly be beneficial to especially girls' interest in STEM. Other fruitful and motivational implementations described in the review are the use of more ICT (Kara & Yesilyurt 2008) or more hands-on experiences inside and outside the classroom (Lee & Erdogan, 2007; Prokop et al. 2007), and informing parents about STEM (Harackiewicz, Rozek, Hulleman, and Hyde 2012). In summary, it seems that programmes focusing on knowledge, ability, motivation and feelings of belonging could increase the interest and persistence in STEM education (van den Hurt et al. 2019).

Luttenberger's et al. (2019) made use of a questionnaire to ask female German university STEM students what they believed had encouraged their interest in STEM, with questions like "Were there specific school activities based around STEM, such as school visits or special projects?". Interestingly, and somewhat counterintuitively, school support was described as a negative contribution to intrinsic and extrinsic motivations. The authors speculate that a reason might be that these kinds of school activities perhaps carry the message that STEM subjects are not interesting per se, but need special encouragement in order to be regarded as attractive, especially for girls. They relate this finding to Bhanot and Jovanovic (2005) who showed for mathematics that parental support often carries these kinds of "hidden" messages. The results indicate how special activities and encouragement provided by teachers might backfire and discourage rather than encourage motivation.

5.2 Frequencies of articles about practices in three selected journals

The aim of the literature review is to identify research on how to promote scientific vocations on an EU level. Three scientific journals were selected: *European Early Childhood Education Research, Journal of Emergent Science, European Journal of STEM Education.*

a) European Early Childhood Education Research Journal

(https://www.tandfonline.com/loi/recr20#.Vyxp5VUrLRY)

The EECERJ, the Journal of EECERA, is one of the most prestigious early childhood journals in the world. It is one of only four early years journals indexed by the Institute for Scientific Information. The ISI is highly selective of the journals in the citation databases and indices it maintains. EECERJ is located in the Social Sciences Citation Index (SSCI). EECERJ is peer reviewed, scholarly and is particular interested in research which has application

b) Journal of Emergent Science

(https://www.ase.org.uk/resources/journal-of-emergent-science)

The Journal of Emergent Science is a professional research e-journal published by the Emergent Science Network in collaboration with ASE. The journal focuses on science (including health, technology and engineering) for young children from birth to 8 years of age.

c) European Journal of STEM Education
(http://www.lectitopublishing.nl/european-journal-of-stem-education/volume-4/issue-1)

The European Journal of STEM Education is an academic international journal that publishes original research related to STEM education. The aim is to contribute to scholarly understanding of teaching and learning practices and policies in the area of STEM, as well as to contribute to the improvement of educational practices. Articles may focus on formal and in-school education, from early childhood and pre-school education to well into university and vocational schooling and to continuous professional development. They may also focus on learning in informal and out-of-school settings and on co-operation with the community, science centres, businesses, or other organizations.

The review of these journals aims to identify articles containing research in the area of science education related to future vocation. The mere identification will give a notion of the perceived importance of research among the research community represented by these journals. Research articles identified as relevant will be analysed in order to extract good practices and suggested guidelines on how to promote scientific vocations.

d) The selection of journals
Journals selected are arguably representable for the European community of research into early childhood and science. The major organizations within the field of science and education in early years are ESERA and EECERA. Both organizations are represented by the Journal of Emergent Science and European Early Childhood Education Research Journal respectively. The third journal chosen is specifically focused on STEM. There is also a strategy for choosing these journals based on the expected contents represented by the different journals. European Early Childhood Education Research Journal has a long tradition and a broad scope in dealing with education research in early childhood. Journal of Emergent Science is more focused on the subject of science and the European Journal of STEM Education is specially dealing with the subject of STEM. There is an idea of funnelling down the searching process towards a more specific focus on STEM and early childhood.

e) Method
The first step performed was to identify research relevant to science vocation. The timespan for searching relevant articles was set to the period of 2010 – 2020. The first issue of The Journal of Emergent Science was published in June 2011. The first issue of the European Journal of STEM Education was published in March 2016 and the European Early Childhood Education Research Journal started in 1993 but the first article in our review is dated to march 2010.

Number of articles reviewed are in total 601 originating from the three different journals as shown in table 1 below.

Table 1. Investigated journals.

Name of journal	Number of reviewed articles
European Early Childhood Education Research Journal	469
Journal of Emergent Science	86
European Journal of STEM Education	46
Total:	601

In order to establish which articles that contained research about science vocation the following key words were used:

STEM
STEM (and)longitudinal

Vocation
STEM (and) Vocation

Career
STEM (and) Career
STEM (and) Women (and) Career

Motivation
STEM (and) Motivation
STEM (and) Motivation (and) Early years
STEM (and) Motivation (and) Early childhood
STEM (and) Motivation (and) Early childhood (and) education

Activities retention
Activities retention (and) Early Childhood
Activities retention (and) Early childhood (and) Education

Persistence
STEM (and) Persistence
STEM (and) Persistence (and) Girls

Enrolment
STEM (and) Enrolment
STEM (and) Enrolment (and) Girls

Integrated
STEM (and) Integrated
STEM (and) Integrated (and) Vocation

f) Results – European Early Childhood Education Research Journal

The journal is represented as a Taylor & Francis Online journal on the web. All the articles are searchable and hence the use of the search function for this review.

The result from searching for the keyword established in this review came out as follows:

Table 2. Response rate EECERj

Keyword	Response rate	Keyword	Response rate	Keyword	Response rate
STEM	53	Motivation	234	Enrolment	107
Vocation	6	Retention	79	Integrated	311
Career	78	Persistence	98		

By combining the major keyword with combinations of another keyword as described above the number of relevant hits were narrowed down. But even when analysing the different combinations of keyword, no relevant article was identified. There were a few articles containing relevant keyword but the content in the articles addressed professional development of staff personnel e.g Men in childcare services: From enrolment in training programs to job retention.

So, to conclude the extensive search for articles relevant for the literature review performed did not contribute to any input to existing best practices and guidelines on how to promote scientific vocations.

g) Results – Journal of Emergent Science

On a preliminary basis one article out of the 86 investigated seemed to match the criteria of encouraging scientific vocation. The article: *Raising STEM career aspirations through the primary years* (ISSUE 12) was identified through ocular inspection of the title.

For a more systematic review of the articles published in the journal a document containing title, abstract and keywords were compiled. The format of the journal on the web is that every issue is published as a cohesive pdf-file and thus are the separate articles not able to identify as a singular unit. There is no search function available on the journal's web page.

The result from searching for the keyword established in this review came out as follows:

Table 3. Response rate JES.

Keyword	Response rate	Keyword	Response rate	Keyword	Response rate
STEM	20	Motivation	6	Enrolment	0
Vocation	0	Retention	2	Integrated	2
Career	7	Persistence	0		

The most responses gave the keyword STEM. The 20 hits from the search activity emanated from three articles. One of these articles was added to the review results, *Using drama within a STEM context: Developing inquiry skills and appreciating what it is to be a scientist* (ISSUE 12)

The keyword Career gave 7 hits. One article was identified as relevant for our review: *The SSERC Primary Cluster Programme in Science and Technology – Impact on teaching and learning* (ISSUE 18). The other 6 hits emanated from the same article that already had been identified.

The keyword Motivation gave three articles but none of these were considered. The keyword Retention did not add any relevant article nor did the keyword Integrated.

To sum up there were three articles identified as being within the realm of this review:

- *Raising STEM career aspirations through the primary years* (ISSUE 12)
  Describes the impact on pupils of monthly contact with real scientists and engineers from a diverse range of careers, through a STEM assembly programme focusing on children by the age of 10.

- *Using drama within a STEM context: Developing inquiry skills and appreciating what it is to be a scientist* (ISSUE 12)
  Not specifically aiming at scientific vocation but represent an interesting approach to place 8 and 9-year-old children in specific types of 'roles' within a particular science context.

- *The SSERC Primary Cluster Programme in Science and Technology – Impact on teaching and learning* (ISSUE 18)
  Identifies key components of a national Career Long Professional Learning (CLPL) programme responsible for its effectiveness and concludes by reflecting on the implications of the findings for tackling the challenge of promoting science literacy and attainment.

The content of these articles was exposed to more advances analysis regarding the contents related to existing best practices and guidelines on how to promote scientific vocations. The result of this analysis will be reported further on in this review.

h) Results – European Journal of STEM Education

The journal is present on the web as a Lectito Journal. The first issue was published in 2016 and all articles are solitary and searchable on the publishing platform.

The result from searching for the keyword established in this review came out as follows:

Table 4. Response rate EJSTEME

Keyword	Response rate	Keyword	Response rate	Keyword	Response rate
STEM	10	Motivation	0	Enrolment	0
	0	Retention	1	Integrated	1
Career	2	Persistence	0		

All the 14 articles identified were analysed for content. From this analysis the following articles were added to the basis for further identification of existing best practices and guidelines on how to promote scientific vocations:

- *STEM Media in the Family Context: The Effect of STEM Career and Media Use on Preschoolers' Science and Math Skills*
  Describes whether parent attitudes towards STEM media and having a family member with a STEM career is related to children's science and math media use focusing on children between 3 – 5.5 years old.

- *Trinity Walton Club: What is its Potential for Promoting Interest in STEM?*
  Describes a Saturday afternoon club entitled "Trinity Walton Club" designed to promote interest in STEM aiming at young people.

- *Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education*
  Content more focused on formal teaching and older children but might give some insights to the problem area.

From the total of 601 articles 6 were considered to contain relevant information to contribute in describing existing best practices and guidelines on how to promote scientific vocations. The 6 articles were analysed and from the contents the following suggestions were made:

i) Results about the practices found in selected articles

Raising STEM career aspirations through the primary years, (Long, 2019) describes an initiative to present role-models to primary school pupils. The project presented is a monthly whole-school STEM Assembly series presenting a variety of engineers and scientists. Contributors comprising a variety of careers included a Formula 1 race engineer, a Bloodhound Education team, an orthopaedic surgeon, design engineer, biomedical scientist etc. presented their work on a monthly basis. Findings from the study of the project concludes that monthly STEM Assemblies can positively impact the career aspirations of pupils. The notion of meeting the engineers and scientists in real life rather than seeing them on TV is stated to be important. As one of the respondents from the study expressed the matter: "*…you get more about their personal lives by actually meeting them*" and "*…it's just for you*"

Using drama within a STEM context: Developing inquiry skills and appreciating what it is to be a scientist. (McGregor 2016)

This paper presents a project where various process drama techniques were used to purposely place 8 and 9 year-old children in specific types of 'roles' within a particular science context. The aim is to enable the children to appreciate what it might be like to *be* a scientist and to *do* some science. The focus of the activities is more on the scientific method. The children are expected to develop skills in asking relevant questions and using different types of scientific enquiries to answer them. To make systematic and careful observations, gathering, recording, classifying and presenting data in a variety of ways to help in answering questions and to use results to draw simple conclusions. The paper concludes that the use of dramatic inquiry could 'shift' children's identities from thinking that science was too hard and difficult to considering how they might succeed in science, and even wish to 'become' a scientist.

The SSERC Primary Cluster Programme in Science and Technology – Impact on teaching and learning (Crawford, Lowden et al. 2020)

This paper assessed the impact of a national Career Long Professional Learning (CLPL) programme, with a focus on promoting teachers' confidence and expertise in science and technology using practical skills as a vehicle. Surveys of >12000 pupils have shown, inter alia, that the programme encourages the preservation of positive pupil attitudes towards science. Doing experiments in class and going to the science museum or science centre were particularly popular. These findings indicate that learning science experientially may be fundamental in engaging young people with science and helping to maintain their enthusiasm for the subject. The paper suggests that the development and delivery of a professional learning package in relation to STEM, all early learning practitioners, primary and secondary teachers, technicians and community learning and development practitioners will have the opportunity to build their capacity to deliver effective STEM learning

STEM Media in the Family Context: The Effect of STEM Career and Media Use on Preschoolers' Science and Math Skills (Sheehan, Hightower, et al. 2020)

This paper investigated whether parent attitudes towards STEM media and having a family member with a STEM career is related to children's science and math media use, and whether these factors predict children's science and math skills. 296 American parents of children 3- to 5.5-years old and their attitudes toward STEM and their children's use of STEM television, computer games, and apps were surveyed. The paper indicates how results can direct research on the role of media in early STEM education. Exposure to STEM learning opportunities early in life is important because the development of STEM skills can further students' interest and educational attainment in STEM, as well as expand their career choices later in life. This paper indicates that parents may indirectly affect their child's exposure to STEM concepts by influencing how often their child is exposed to science and math television, apps, and computer games.

Trinity Walton Club: What is its Potential for Promoting Interest in STEM? (Prendergast, Murphy et al. 2018)

This paper presents a Saturday afternoon club entitled "Trinity Walton Club" (TWC) arranged by the Trinity College Dublin. This club attempted to 'bring STEM to life' through thought provoking content, real world problems, contextualised analogies and projects. The students in focus were from the year (eight grade) of post-primary education, typically aged 13/14 years old. The overarching aim of the initiative was to promote interest in STEM amongst young people and to further enhance their STEM knowledge and skills. It is clear from the data collected that students' confidence in their ability to do science or mathematics in school had improved as a result of their TWC experience. The TWC include problem based learning, experimentation, bringing numbers to life, programming, developing apps and building and controlling robots. All of these activities have the potential to stimulate and trigger participants' interest in STEM.

Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education (Thibaut, Ceuppens, et al. 2018)

This paper deals with the emerging approach that has the potential to improve students' motivation for STEM namely integrated STEM education. But there is a lack of consensus about instructional practices in integrated STEM. Based on the results of a systematic review of existing literature a framework containing five key principles is proposed: integration of STEM content, problem-centred learning, inquiry-based learning, design-based learning and cooperative learning. The object of this strategy is students in secondary education. But the papers have been selected since it is supposed to contribute with insights to the problem-area given that it contains a systematic review of literature.

In summary we find four major perspectives addressed in the papers. Role models are important, children need to meet with scientists and engineers in order to build some references on the concepts. Acting as a scientist and engineer is important in order to be able to relate to what scientists or engineers do. Teachers confidence in the subjects of science and engineering needs to be encouraged and supported in a lifelong learning context. Parents attitudes are important both in direct interactions with the children and in making science on TV and in other media appreciated and available to the children.

5.3 EUROPEAN PROJECTS RESEARCH

a) METHODOLOGY

In order to identify the European projects that have been developed in Europe about STEM education, the Community Research and Development Information Service (CORDIS) was consulted. This source provides the information about projects funded by the European Union's framework programmes for research and innovation throughout their factsheets, reports, deliverables, and publications. For this purpose, STEM Education, STEM Education vocation, STEM career and Science education for early childhood, were the keywords used for search in the repository of CORDIS. Initially, only 37 results were considered appropriate due to their apparent relationship with STEM education.

After this preliminary selection, the projects that started between 2010 and 2020, those that aim to boost interest in Science, Technology, Mathematics, Engineering and other related disciplines, as well as those that try to increase the number of STEM vocations were chosen. As a result, 21 projects were considered suitable for this discussion.

The information provided by CORDIS about the selected projects allowed us to know the strategies used to achieve the project's objectives and, in some of them, the recommendations identified as a result of their research work for the main stakeholders.

b) RESULTS

The following table shows the projects, their aims and strategies used/proposed, in bold letter the most relevant aspect of the strategies:

Table 6. Europeans projects.

Project	Aims	Strategies
CoM_n_Play-Science **(Ongoing project)**	Help Europe better understand the new ways in which non-formal and informal science learning is taking place through various coding, making, and play activities that young Europeans (children, adolescents and young adults) are nowadays increasingly engaged with, outside school and higher education science classrooms, beyond the formal boundaries of science education.	Identify, pool, analyse and empirically evaluate diverse existing **coding, making and play-based practices taking place outside formal science classrooms** which bear some promise for non-formal and informal science learning and their impact on formal science education, traditional non-formal and informal science learning interventions, young people as learners and citizens, as well as, on society.
https://comnplayscience.eu/project/		
ER4STEM	Turn curious young children into young adults passionate about science and technology with a hands-on use case: robots.	Refine, unify and enhance current European approaches to **STEM education through robotics** in one open operational and conceptual framework, promoting **competitions**.
https://cordis.europa.eu/project/id/665972		
MASCIL	Promote a widespread use of inquiry-based science teaching (IBST) in primary and secondary schools, making science more meaningful for young European students and motivating their interest in careers in STEM.	**Use of inquiry-based science teaching (IBST)** (training courses for teachers; innovative interactive e-learning platform; networking activities).
https://cordis.europa.eu/project/id/320693		
STIMEY	Educate, engage and increase the youth's interest in STEM education and careers.	Use of an **educational platform with multi-level components**, very interactive, joining a **radio** (with collaborative activities and events); an online **Educational Platform** will provide you with fun tools and elements to engage, entertain and educate our young people and a **Socially Assistive Robotic Artefacts.**
https://cordis.europa.eu/project/id/709515		
Next- Lab	Change the educational landscape of science and technology education in Europe on a very large scale.	Use of **Interactive online (virtual and remote) laboratories** combining instructions and inquiry while providing learning support.
https://cordis.europa.eu/project/id/731685/results		
Our Space our Future	Explore the practices and approaches that involve, excite and empower	A toolkit with a set of **tools and activities** to engage with students at early ages and

	school-aged students to feel space sciences are relevant to them**.**	show them how space impacts their daily life, even though we might not be aware of it.
https://ourspaceourfuture.eu/		
PERFORM	Investigate the effects of the use of innovative science education methods based on performing arts in fostering young peoples' motivations and engagement with science, technology, engineering, and mathematics (STEM).	**A creative, participatory educational process on STEM through the use of scenic arts** with secondary school students, their teachers and early career researchers, in order to contribute to foster girls' and boys' motivations towards science learning and strengthen the transversal competences they will need for STEM careers and jobs.
https://cordis.europa.eu/project/id/665826		
Hypathia	Communicate science to youth in a gender inclusive way in order to realise the full potential of girls and boys around Europe to follow STEM related careers.	-Disseminate a unique **modular toolkit of activities and guidelines for engaging teenagers in STEM in a gender-inclusive way and i**mplementation of the activities in schools.
http://www.expecteverything.eu/hypatia/		
SciChallenge	Develop novel concepts to actively integrate young boys and girls in science education using a contest-based approach to self-produced digital education materials from young people for young people.	A **Social Media Aware Platform for Contest-Based STEM Education** and Motivation of Young Students.
https://cordis.europa.eu/project/id/665868		
ECB-INGENIUOS	Increase young Europeans' interest in mathematics, science and technology (MST) education and careers, addressing two challenges: lack of interest in the subjects and the future skills gap.	**A strategic partnership between major industries and Ministries of Education to increase the objective of increasing the links between science education and careers through the c**reation of a repository of STEM methodologies and application of best practices in schools.
http://www.ingenious-science.eu/web/guest;jsessionid=2C72D2B78F14485D9C24DAE373AB97F3		
STEM4youth	Produce a comprehensive, multidisciplinary series of courses presenting key STEM discipline challenges to support young people, primarily high school students aged 14-19, formal and informal education**.**	**School courses in 7 STEM subjects** across the partner countries, with explanations **how core principles of that discipline happen in oureveryday life**, through **hands-on experiments or activities, games and critical thinking sessions,** and show how to use the skills gained in future professions.
http://www.stem4youth.eu/		
EDU-ARTIC	A cross-country adaptation of innovative practices in science education in Europe.	**Online webinar lessons** in virtual classrooms **with polar scientists; a "citizen science" environmental monitoring programme;** teacher trainings and workshops**; online "Polarpedia" portal;** a

		chance for students to win **a trip to an Arctic research station.**
https://edu-arctic.eu/		
SECURE	Provide relevant research data that can help policy makers to improve MST curricula and their implementation throughout the EU in order to prepare children from an early age on for future careers in MST, make MST more accessible and enjoyable for all children so that they will keep a vivid interest in science and technology, and understand the importance of their societal role.	
https://cordis.europa.eu/project/id/266640		
REESP	Boost the number of female students in engineering education and to keep as many majors as possible in such programmes of study.	**Develop student-centred, interactive, and pedagogically sound learning activities** that promote STEM among primary and second-level students, and change students' and the general public's perceptions of STEM disciplines and careers particularly **through the implementation of PBL methods.**
https://cordis.europa.eu/project/id/629388/es		
PHOTON	Create an innovative system that teaches children through entertainment by using their natural abilities for fast learning.	**Programming and logical thinking through entertainment andcompetition,** involving the usage of a **small robot that is fully integrated with a smartphone, tablet or computer** based on popular operating systems.
https://cordis.europa.eu/project/id/744429		
Creativelit tlescient	Better understanding, at the European level, of the potential available on the common ground that science and mathematics education in pre-school and early primary school can share with creativity.	**Guidelines, curricula and exemplary materials for relevant teacher training** in the various European contexts.
https://cordis.europa.eu/project/id/289081		
ALIS	Understand how pupils aged 3-11 years get involved in science within and outside school based on the reading of fictional picture books with the aim of giving teachers the means to develop integrated teaching systems (science and literature).	**'Realistic-fiction storybooks'** (Fictional storybooks) identifying relevant characteristics in terms of science didactic potentialities that can be read from 3 to 11 years old.
https://cordis.europa.eu/project/id/661134		
GirlsInScience. Ongoing project.	Reduce daily socialization reinforcing gender stereotypes in the school and family context.	**Video-feedback intervention aimed at reducing teachers' gendered classroom interactions in primary and secondary schools,** testing its effectiveness in reducing gender disparities in STEM in a randomized control trial (RCT).

https://cordis.europa.eu/project/id/726141		
STEAM	Provide a platform for bringing researchers and public together and motivate young people for a scientific career pathways, it also aims to emphasize on how scientific activities and developments can contribute for uniting European society at national and international level by raising awareness on the power of the science for social cohesion, dialogue and also individual development.	**European Researchers' Night.**
https://cordis.europa.eu/project/id/722929		
Science is for all of us		**European Researchers' Night.**
https://cordis.europa.eu/project/id/819006/results		
Science unites ALL		**European Researchers' Night.**
https://cordis.europa.eu/project/id/722956		

From these projects, several recommendations follow. We extracted the ones that seem more relevant for designing practices aimed to encourage scientific vocations at early childhood.

From **Our Space Our Future:**

1. **Get hands on with real science skills**: STEM engagement for greater impact is about developing a **positive science identity**, particularly when engaging marginalised groups in science. The key recommendation is to **keep the series of interventions practical, hands-on, varied and fun**, to nurture curiosity and stimulate new ways of thinking about science.
2. **Celebrate success and bring in the wider family and community**: Students become the **science communicators**, placed in positions of trust and responsibility within the partnership, with the opportunity to be creative, communicate their passions and become the 'agents of change' for audiences.
3. **Keep it careers-focused**: Our Space Our Future highlights both the breadth of careers from science and the relevance of science to many areas of everyday life. To fully integrate space science careers into the classroom requires time, knowledge and capacity which many teachers do not have, alongside logistical barriers such as limited availability of work placements or a lack of strong contacts with STEM industry ambassadors. Challenging perceptions and stereotypes by having female scientists and scientists of diverse race and backgrounds involved in workshops, or as leaders, nurtures the sense that a scientist can be 'someone like me' (4, 10).
4. **Challenge unconscious bias:** One of the most effective ways to challenge stereotypes is to **train teachers and raise awareness** for students of stereotyping and unconscious bias, and the many ways in which it impacts our daily lives.

From **PERFORM:**

1. Establish **networks and official channels of communication** to facilitate and encourage interactions between **Early career scientific researchers** (ECR) at higher education institutions, teachers in secondary schools, and science communicators.
2. Encourage and promote the use of **performance-based pedagogy** and activities that stimulate thinking about RRI issues involving trained ECRs in school outreach, fostering students' reflective engagement with STEM by **humanising**, **contextualising** and making more **participatory** the science learning process.

From **Hypathia:**

1. **Facilitate gender inclusion**. Be aware of a few significant concepts, as Gender/sex; gender stereotypes/skills; gender/science (when the gender variable is not taken into account by researchers: for example when medicines are not tested on both male and female).
2. **Suggestions for the implementation of activities:**

- Interacting with the group
  - Neutrality in assigning tasks and roles
  - Attribution of success and failure, overcoming stereotypical responses
  - Adopt a 'wait time' to encourage girls to speak in an environment of risk-taking boys who might respond faster than they do.
  - Interaction with the sexes to overcome the tendency to engage with male students more than with girls.
  - Unaware expressions of stereotypes.
- During discussion
  - Challenge learners to depart from their preferred interest and widen their engagement in science.
  - Consider if a forgoing explanation of the main concepts about gender and about terminology/concept connected could enrich the discussion.
  - While facilitating a discussion: Acknowledge that different learners have different kinds of prior knowledge that may be relevant in different ways.

3. Facilitate experimental situations, breaking the stereotypical perception of STEM.
4. Useful links about gender inclusion in the classroom.
5. Promote the meeting of female STEM professionals.

From **SECURE:**

1. Stimulate the interest for STEM subjects more efficiently from an early age onwards (3 y.o), with special attention for the crucial age of 10.
2. **Provide more challenges and more support for both high-flyers and low-achievers** based on a systematic approach and empowering curricula.
3. Primarily work is needed on the promotion of interest for STEM subjects for both boys and girls at early age (including kindergarten), being aware of gender-specific differences.
4. **Inquiry-based science education (IBSE) challenges learners, but still needs to be more structurally and consistently implemented in curricula and in practice**.

5. The **integrated use of ICT and multimedia** in teaching and learning requires special attention.
6. Actions should be undertaken to **design and promote formative and summative assessment tailored to classroom practices and innovative learning methods**.

From **Creative little scientists:**

1. **Use of approaches to planning at whole school** and class levels to maximize scope and flexibility to foster children's inquiries and to provide opportunities for play and exploration (across both preschool and primary phases of education).
2. **Use different forms of** supporting children's questioning, recognising questions implicit in children's explorations in order to support inquiry and creativity.
3. **Foster the role of social and affective dimensions of learning and their connection with cognitive dimensions** of learning such as engagement, evaluation skills and understandings related to the nature of science.
4. **Emphasise the important roles of play-based approaches, child–initiated activity and practical investigation in both preschool and early primary school.**
5. Give detailed attention to key features of problem solving and inquiry based learning and teaching particularly with regards to providing sufficient space and time in the curriculum for problem solving and inquiry to study areas in depth. Emphasise also the need for space and time for teachers to develop inquiry approaches and explore opportunities for creativity in learning and teaching in early science and mathematics.
6. **Promote the role of inquiry activities in supporting the children's understanding of science ideas and nature of science**. Give more attention to reflection and consideration of alternative ideas building on the social and collaborative features of learning and inquiry.
7. **Recognise the importance and roles of varied forms of representation**, including the use of ICT, in supporting children's learning processes.
8. **Encourage meaningful and authentic contexts for inquiry**, linked for example, to: events and experiences in everyday life; children's interests and concerns; questions emerging from cross-curricular projects or explorations; and issues in the wider environment beyond school.
9. **Create coherence in assessment between the aims and objectives of learning and priorities in assessment.** Foster the development of on-going assessment strategies and criteria for assessment to better reflect the emphasis on inquiry and creativity in the aims for science and mathematics in the early years. Assessment methods should be clearly linked to the multimodal approaches used in classroom practices.

Encourage dialogue with parents and the wider community concerning the aims of science and mathematics education in the early years including the development of skills, processes and attitudes associated with inquiry and their roles in developing not just factual knowledge but long term understanding of concepts.

6. Discussion of practices in relation to the promotion of scientific vocations

Discussion of found practices in relation to early-years education and the botSTEM framework. First of all we were surprised to see that published and established practices have been found to be much more rare in Europe compared to Australia and USA, which highlights the importance of this report. Even though Europe should be considered a multi-cultural part of the world, in relation to education we suggest based on the presented review the following suggestions:

- Role models are important (Stoeger et al., 2016; Stout, Dasgupta, Hunsinger, & McManus, 2011; Our Space, our future; Secure; Hypathia; Creative little scientists)
    - In order for young children to appreciate what it means to be a scientist or an engineer the children have to meet with them in person.
    - Encounters with female scientists are relevant for designing a gender inclusive approach.
- Acting as a scientist or an engineer is important (McGregor 2016 ; Prendergast, Murphy et al. (2018); Fridberg & Redfors, 2020; Our Space, our future; Alis; Hypathia; Creative little scientists; botSTEM)
    - By arranging projects to make children face real world problems that needs to be solved using hands-on activities included in inquiry based or engineering design cycles develops an understanding for the systematic actions performed by scientists. Drama and fictional story books are reported to be an effective way of staging such projects, as well as play-based approaches.
    - Robotics may also function as a motivation factor for exploring scientific concepts. In botSTEM preliminary results, teachers and children discuss, cooperate and physically try out skills in computational thinking with the focus of helping robots to overcome obstacles (Greca et al., 2020)
- Gender issues are important since early childhood (Fridberg & Redfors, 2020; Hypathia, SECURE; botSTEM)
    - Cooperative techniques for learning should be used in STEM classrooms to favour girls learning. This could be related to our botSTEM results where the Swedish teachers arranged the teaching situations in preschool so that children worked together and cooperated with interest when programming (Fridberg & Redfors, 2020).
    - Teachers and parents should challenge unconscious bias related to girls and STEM subjects, including robotics
- Promoting teachers' confidence and expertise in science and technology using practical skills is important. (Crawford, Lowden et al. 2020; Secure; Creative little scientists; Mascil)
    - Initiatives on Career Long Professional Learning (CLPL) programmes should be established giving teachers a chance to develop their own scientific and engineering skills. In botSTEM, a questionnaire answered by participating preschool teachers in Sweden and Spain showed increased confidence for STEM teaching among the participants.
- Parents' attitudes towards STEM and STEM-related media should be encouraged. (Harackiewicz, Rozek, Hulleman, & Hyde 2012; Creative little scientists)

    - Parents' attitudes towards STEM media can have an impact on children's perceptions of science and engineering. Parents may indirectly affect their child's exposure to STEM concepts by influencing how often their child is exposed to science and math television, apps, and computer games. From botSTEM results In Spain, parents expressed a positive attitude to their children's inquiry that continued at home, with the building of inclined planes from beds, etc.
- Experiencing some degree of meaningful choice and a sense of psychological freedom is important (botSTEM; Creative little scientists; Secure)
    - Although León et al. (2015) conducted their research with 14-year olds, our results from the botSTEM project point to the conclusion being valid also for younger children, robotics and STEM in general. Teachers nurturing of children's inner motivational resources by using as a didactic strategy to consider their own ideas and suggestions in the botSTEM activities engage the children in curious inquiry and discussions (Fridberg & Redfors, 2020).
    - Affective and social dimensions of learning and their connection with engagement and assessment should be considered.
    - High-flyers and low-achievers children need more support and challenge.

Special STEM activities and encouragement should be handled with care. The result by Luttenberger et al. (2019) shows how special activities and encouragement provided by teachers might backfire and discourage rather than encourage motivation. We view the finding as yet another reason for an early introduction of STEM and robotics to children. If children have a positive relation to STEM and see its content as a natural part of their everyday life, later and artificial 'special STEM programs' might not be necessary.

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