STEAM Tales

Co-funded by the European Union

Introductory Guide

Empowering girls through STEAM: cultivating curiosity and creating opportunities

Project Title

STEAM Tales (KA220-HE-23 -24-161399)

Work Package

WP2 - STEAM education impact and role models in primary schools

Date of delivery

April 2024

Leading partner

CESIE (Italy)

Contributing partners

MIND – Mittelhessisches Institut für Nachhaltigkeit und Diversität gGmbHNome (Germany, coordinator)

GoINNO Inštitut (Slovenia)

Universidade do Porto (Portugal)

SCS LogoPsyCom (Belgium)

Authors

CESIE (LEAD): Cecilie La Monica Grus

MIND: Katharina Haack

GoINNO: Nina Skrt Sivec

U.PORTO: Ana Cunha Ferreira, Carla Morais, Luciano Moreira

Logopsycom: Amandine Falcicchio, Tara Della Selva

STEAM Tales

Enhancing STEAM education through storytelling and hands-on learning

Introductory Guide

Empowering girls through STEAM: cultivating curiosity and creating opportunities

Co-funded by the European Union

Table of contents

Introduction

STEM disciplines (Science, Technology, Engineering, and Mathematics) are essential for solving the world's most pressing problems, from climate change to healthcare. Indeed, STEM skills are in high demand and STEM jobs are some of the fastest-growing and highest-paying in the global economy. Unfortunately, there is a deep-rooted **underrepresentation of women in STEM** professions and education, and in general a **lack of diversity** in STEM fields.

Despite progress in gender equity and growing awareness over the last decade, the underrepresentation of women in the Science, Technology, Engineering, and Mathematics (STEM) fields continues to persist. In 2023, the gender gap in STEM remained significant, with **women** making up **only 17% of the STEM workforce** in the European Union (Piloto, 2023).

This is undesirable from multiple viewpoints. Progress is only made on questions that scientists think to ask and these questions are strongly influenced by our **backgrounds** and **identities**. If we want science to address the whole natural world and problems that affect all sorts of people, then we need all sorts of people to be able to participate in science to be able to tackle all-concerting challenges (UnderstandingScience.org, 2022).

Supporting gender equality and diversity in STEM is therefore pivotal not only because everyone deserves to be able to pursue their curiosity and have an opportunity to **fulfil their potential**, but also because we all stand to benefit from science, informed and pushed forward by **diverse perspectives**. Moreover, STEM education helps develop critical thinking, problem-solving, and analytical skills which are essential for success in any field of work and life.

The gender gap in STEM has been attributed to several long-standing and deeply entrenched realities, including the persisting **stereotypes** and **lack of female role models**. Many still associate the STEM fields with masculine qualities and most of the STEM success stories represent male individuals, which leads to perpetuation of stereotypes that can discourage girls and women from pursuing STEM education and careers, and makes it harder for them to find role models and mentors in the field. (Piloto, 2023)

To encourage girls´ interest and participation in STEM, the **STEAM Tales project** will showcase positive female **role models** such as scientists, engineers, and mathematicians to help **deconstruct stereotypes**, and create learning opportunities for girls in an **inclusive learning environment**, and encouraging girls of all backgrounds to pursue STEM careers and fulfil their full potential in STEM.

Even though STEM education is becoming of central interest in European **education**, some teachers may encounter difficulties in encouraging pupils' interest in STEM subjects and explaining the importance of STEM fields to children. In fact, STEM subjects are often seen as highly theoretical and children typically start learning STEM too late in their school years. According to research, children recognise their STEM-related interests and occupations as early as in primary school, when they are just starting to build their own identities and making choices for their careers in the future (Archer et al., 2010). In addition, children who received a high-quality **STEM education in elementary school** and found science subjects fascinating and engaging were more likely to continue to study and explore science later (N.S.T. Association et al., 2018 in Norismiza, Kalsom, 2023).

To support the early introduction of STEAM concepts in an interest-stimulating way, this project promotes the use of **storytelling** as a method of presenting STEAM topics in a way that younger children (6 to 9 years old) can easily relate to. By adding **creative elements** and **hands-on experiments**, STEM education can be made more engaging and fun.

Chapter 1: Understanding the STEAM and Storytelling Approach

What is STEAM? (Science, Technology, Engineering, Arts, and Mathematics)

The National Science Foundation (NSF), a US agency dedicated to science and engineering education and research, coined the abbreviation SMET (science, mathematics, engineering, and technology) in the early 1990s. It was later changed to **STEM (science, technology, engineering, and mathematics)** for phonetic reasons. The goal of this approach was to enhance academic proficiency in these fields, elevating the workforce's quality, and improving the nation's competitiveness (Baptista, 2023). The improvement of the nation's workforce would allow the economy to develop and grow, and create professionals who would excel in their fields, leading to breakthroughs in the nation's science.

Since then, STEM has significantly gained momentum and is defined broadly by NSF, **encompassing not only the conventional categories of mathematics, natural sciences, engineering, computer, and information sciences, but also social sciences such as psychology, economics, sociology, and political sciences.** It has expanded on an international level and gradually through significant investment from government entities to attract young people to these fields, increase the literacy and improve the economic value of the country (Aguilera & Ortiz-Revilla, 2021; Breiner et al., 2012; Martín-Páez et al., 2019).

STEM education is conceptualised diversely due to scientific, academic, educational, and political context, as well as geographic location, and its limited theoretical foundation. The broad range of STEM educational definitions also varies in meaning, which indicates the early stage of development of STEM education (Aguilera & Ortiz-Revilla, 2021; Martín-Páez et al., 2019). Aguilera and Ortiz-Revilla (2021) identify that the **ambiguity in the STEM approach is significant**, but four definitions can be presented, at the moment:

1. **Resolution of problems** based on concepts and procedures from science and mathematics, which incorporates the strategies of engineering and the use of technology.
2. An **engineer-arts approach** that integrates two or more STEM areas and one or more curricular subjects.
3. Content from **two or more STEM domains**, framed within a real context connecting the subject matter with the daily life of the student
4. A **meta discipline** based on learning standards where the teaching has an integrated approach, the specific content of this discipline is not divided, and it uses dynamic and fluid instruction methods.

STEM literacy includes conceptual understanding and procedural skills, and for individuals to address STEM-related personal, social, and global issues. STEM literacy involves the integration of STEM disciplines; acquiring scientific, technological, engineering, and mathematical knowledge and using that knowledge to identify issues in daily and professional life**. The effect of STEM disciplines on our material, intellectual, and cultural world can be recognized by the development of the abilities associated with inquiry, design, and analysis that enable the creation of engaged, concerned, effective, and constructive citizens** (Aguilera & Ortiz-Revilla, 2021; Margot & Kettler, 2019; Perales & Aróstegui, 2021).

Due to the adoption of a **STEM approach**, a considerable number of pupils have received scientific training at school rather than artistic training, and this has an impact on pupils' learning because they are **biased into a less holistic view of the world** (Braund & Reiss, 2019). Georgette Yakman, an engineer and technology teacher proposed, in 2006, an even more open definition including the possibility of **integrating the STEM domains with other curricular subjects** such as **arts**, **language**, **history** and **humanities**, and the acronym **STEM** has evolved into **STEAM** to include arts in the educational model. It emerged as a new pedagogy during the Americans for the Arts National Policy Roundtable debate in 2007. This approach to curriculum integrates art with other areas (Singh, 2021; Stewart et al., 2019) and **aims to enhance learning through fostering creativity, critical thinking, innovation, collaboration, spatial divergent, and abstract thinking, openness to new experiences and curiosity**, as well as developing **interpersonal communication and writing skills simultaneously**. This approach is considered a well-rounded approach (Wannapiroon & Petsangsri, 2020).

The **STEAM approach** helps to create scientific training and knowledge with **personal meaning** and helps develop **self-motivation**. An integration of arts aims to give a more holistic view of day-to-day life (Aguilera & Ortiz-Revilla, 2021; Wannapiroon & Petsangsri, 2020).

Nevertheless, this acronym presents the same problem as the STEM acronym, the multiple meanings:

Yakman and Lee (2012) defined STEAM education as the **interpretation of science and technology through engineering and arts**, all based on **mathematical elements**;

Zamorano and collaborators (2019) defined STEAM as the **interdisciplinary integration of sciences, technology, engineering, the arts, and mathematics** for the resolution of the daily life problems of students.

The **STEAM approach** means incorporating **critical thinking** and **applied arts into real-world situations** and its goal is to develop true **innovations** that result from combining the minds of scientists and artists.

This integration addresses the demand to provide upcoming generations with a comprehensive education, developing individuals as science and technology experts, while also nurturing professionals in the arts, humanities, and social sciences. It is a disciplinary fusion expressed through **multidisciplinarity**, **interdisciplinarity**, and **transdisciplinarity**, three forms of cross-disciplinarity, and arts integration (Borda et al., 2020).

Here, it is important to define the terms from the **cross-disciplinarity**: multidisciplinarity, interdisciplinarity, and transdisciplinarity, in order to identify their similarities and differences: **multidisciplinarity** refers to the existence of different disciplines in the same space; **interdisciplinarity** refers to the existence of different disciplines in the same space and their dialogue and collaboration; and **transdisciplinarity** refers to the existence of different disciplines in the same space and their dialogue and collaboration in integrated learning (Choi & Pak, 2006).

With that in mind, **STEAM education involves combining scientific, technological, artistic, and humanistic skills, progressing from interdisciplinary to transdisciplinary integration**. This approach merges the divergent thinking and the convergent thinking (Aguilera & Ortiz-Revilla, 2021; Bevan et al., 2019; Braund & Reiss, 2019; Rosin et al., 2021).

STEM/STEAM education is characterised by the articulation of the areas (science, technology, engineering, arts, and mathematics), in an integrated way, at the interdisciplinary and transdisciplinary level; encouraging students to investigate these fields and pursue STEM professions; STEM/STEAM education focuses on real-world contexts and complex everyday problems. Aligned with these characteristics, innovative learning scenarios are utilised, incorporating methodologies to foster the development of transversal skills, like critical thinking, creativity, communication, and collaboration defined in the 2030 Agenda (Margot & Kettler, 2019).

Why STEAM Education Matters

STEAM education fosters transversal thinking, empowering individuals to create personal meaning in the face of challenges and questions, and motivating self-growth (Aguilera & Ortiz-Revilla, 2021). The objectives of STEAM education encompass advancing and developing STEAM literacy, fostering 21st century competencies among students, preparing a STEAM workforce, creating the ability to make connections between STEM disciplines, and generating interest and engagement in these fields (Margot & Kettler, 2019).

The 21st century is a century of skills and abilities. School is a response to societal, technological, and economic development. here is a set of key skills for the 21st century:

- **problem-solving ability,**
- **metacognition,**
- **creative thinking,**
- **self-efficacy,**
- **motivation,**
- **perseverance,**
- **conscientiousness.**

Therefore, the curriculum, content, and evaluation should evolve based on the required skills of the century. The field of education is constantly exploring new strategies to empower students with these skills and knowledge, and there is a growing emphasis on STEM/STEAM education promoting their literacy for its ability to build successful innovators and creators (Singh, 2021). STEAM education is crucial for nurturing the skills and competencies required by 21st century youth in the workforce. The development and implementation of STEAM education will prepare youth for the future and the development of the economy (Margot & Kettler, 2019; Singh, 2021).

STEAM education in primary schools

The implementation of a STEAM education approach facilitates the development of students' talents in science, technology, engineering, and mathematics.

It provides the necessary opportunities, support, and experiences for students to reach their full potential. This approach involves students working as professionals within the fields of science, technology, engineering, and mathematics to solve real-world problems that they are interested in. This leads to a deeper understanding of the content while tackling ill-defined problems (Margot & Kettler, 2019).

Zollman (2012) states that to contribute to STEM literacy for learning, we should consider the curriculum and the teacher. STEM should be seen as a discipline based on the integration of other disciplines; content and pedagogy must be blended in this approach; there is a **greater emphasis on supporting a student's learning**; student attitudes, beliefs, self-esteem, confidence, and motivation must be considered; a student's self-identity must be nurtured; and a student must be able to use STEM technologies autonomously and efficiently.

Although STEAM education is not the main approach of curricular programs in Germany, Italy, Portugal, Slovenia, and Belgium, it is indirectly included in education systems. The subjects and curriculum present an interdisciplinary approach, in general.

In Germany, Italy, Portugal, Slovenia, and Belgium, the formal education of primary school curricula include subjects that demonstrate close links with the various letters of the STEAM approach. An analysis of the curricula reveals a cross-curricular focus on interdisciplinary dynamics, critical thinking, abstract thinking, inquiry-based and problem-based learning, the development of transversal and life-long skills for active citizenship, understanding real-life experiences, the use of digital technologies, contextualization, experimentation, collaboration, and the articulation of knowledge to promote new learning.

In non-formal education, several activities have been developed to foster the use of the STEAM approach. For example:

- **Germany:** activities of student laboratories, STEM camps, student research centres, industry partnerships
- **Italy:** STEAM projects and laboratories like the "In2Steam" and the "STEM*Lab"
- **Portugal:** activities for curricular enrichment (AEC), activities of the educational teams of the Ciência Viva network centres, activities available at scientific museums, research centres, universities
- **Slovenia:** activities and workshops like the platform for teachers "steamcolab", "Technophobia is Not for Women" for promotion of science and technology to girls
- **Belgium:** activities available at scientific museums, workshops, and laboratories, and a week of STEAM activities for teachers organised by La Sciensothèque and the Ministry of Education.

However, some **problems** are identified: the lack of formation of the teachers, the lack of time, the lack of materials and the disinterest of the students, especially girls.

The Role of Transversal Skills: (4C's: communication, collaboration, critical thinking and creativity) in STEAM

When analysing the transversal competences defined by the 2030 Agenda by UNESCO (2017) and the assumptions of the STEAM approach, an overlap is identified, the 4 Cs: Communication, Critical Thinking, Creativity and Collaboration, to help build citizens better prepared for the challenges of today's world. These transversal competences are closely linked to the STEAM approach.

This integration aims to provide future generations with a more comprehensive education, preparing individuals better for the digital world we live in. **It combines multidisciplinary, interdisciplinary, transdisciplinary, cross-disciplinary, and artistic approaches.** This approach combines the divergent thinking of artistic disciplines with the convergent thinking that characterises STEM disciplines. It encourages individuals to connect their passions (Perales & Aróstegui, 2021; Singh, 2021; Taylor, 2016).

As transversal competences are crucial for living in today's society, it is important to promote the implementation of more STEAM initiatives. This will foster students' interest in these areas and better prepare future generations for the challenges of the modern world (Singh, 2021; Taylor, 2016).

Storytelling in STEAM education

Storytelling has been implemented as a strategy to **entertain** the children in the classroom and to **teach** the concepts of the different subjects. The potency of storytelling is linked to both **cognitive** and **affective-motivational factors**. The act of listening to stories can foster improved motivation and emotional engagement in students and exposing them to STEM stories enables them to recognise the pertinence of STEM and thereby increase their overall **engagement and interest in STEM subjects** (Barchas-Lichtenstein et al., 2023). Storytelling can be a useful strategy for illustrating scientific concepts. This is due to the memorable nature of stories, which can help to link theory to practise. Additionally, storytelling can provide opportunities for students to relate to different points of view.

As Boström (2006) argues, **storytelling is a narrative strategy** used in **context-based** and **problem-based learning** and the storyline method.

Rowcliffe (2004) demonstrated how **storytelling** can be used in **science education** to present scientific problems, explain complex processes, incorporate real-life scientific issues from everyday life, and include historical contexts to provide mental triggers that **support memory** or provide **entertainment** to make students **emotionally involved**.

Storytelling is an effective approach for students to develop their understanding of science due to the intrinsic nature of learning through storytelling. It directs attention, provokes emotions, and stimulates understanding (Gouvêa et al., 2019; Paiva et al., 2019).

Children develop **two modes** of thinking to make sense of the world: **the sociological mode**, which processes information by abstracting it from context; and **the narrative mode**, which is context dependent and relies on situation-based evidence. The narrative mode of thinking represents the default mode of human thought, providing structure to reality and serving as the underlying foundation for memory (Engel et al., 2018). In the context of science learning, presenting new information in the form of stories about science, scientists and scientific discoveries further supports a natural way of information processing for many students (Barchas-Lichtenstein et al., 2023).

A **narrative approach to science learning** provides benefits beyond the acquisition of new knowledge. Stories about science, scientists and scientific discoveries can have important positive affective impacts that inspire future subject specific learning. While more traditional communication of scientific ideas may be boiled down to a handful of facts or a timeline of discoveries, a **narrative approach allows for the true excitement of curiosity to shine through, fuelling children's own curiosity and interest in the process** (Gouvêa et al., 2019).

The introduction of stories in science education would increase the effectiveness of improving children's understanding of scientific concepts as well as promoting their positive attitudes towards science.

Nowadays, there are **three categories of storytelling in education**: **historical stories**, **imaginary stories** and **personification stories**.

- Historical stories consist of stories such as biographical narratives of scientists and their work to stimulate children's motivation and engagement in learning activities.
- **Imaginative stories** illustrate the sequence of events to directly address scientific concepts to promote children's understanding.
- **Personification stories** are stories that use certain story elements to describe scientific concepts by assigning personal characteristics to the complex concepts of a scientific field (Hu et al., 2021).

Storytelling is a successful approach in STEAM due to its unique ability to **connect human emotions and cognition**, making science education more human centric.

Composing stories to explain **abstract concepts** vividly and creating **memorable and interesting learning** experiences is a long and thoughtful process. For instance, a story in which we present a complex concept along with children's everyday life experiences makes them feel more **connected** and **enthusiastic** about the concept and better visualise the knowledge being shared (Gouvêa et al., 2019; Hu et al., 2021; Paiva et al., 2019).

Education faces many challenges and, with digitalisation and modernisation, increasingly demands new and greater creativity. To establish stronger connections between everyday phenomena and classroom activities, storytelling can and should be employed in a more holistic and effective process (Paiva et al., 2019).

Benefits of STEAM Learning for Girls

Gender equality and education are both recognised as fundamental requirements for achieving sustainable development on our planet. These issues are deemed so significant that they are listed within the 2030 Agenda, both as distinct goals and as catalysts to facilitate the accomplishment of the remaining objectives within the Agenda. UNESCO (2017) defined STEM education as a key foundation of the 2030 Agenda, playing an essential role in transforming our planet.

According to UNESCO (2017), **involving more girls in Science, Technology, Engineering, and Maths is an integral part of the social development process.** Women and girls are vital for implementing solutions to achieve "green" growth and enhance lives in society.

According to Cohen et al. (2021), STEM identity includes aspects of how individuals perceive, position and align with their conceptions of STEM based on their experiences with it, and identifies a link between students with a strong STEM identity and enrolment in STEM courses. Female students are underrepresented at the highest levels of STEM education and in the STEM workforce, and they tend to see themselves less as STEM people. Factors that contribute to the development of a STEM identity include encouraging role models, a supportive family environment, and positive learning experiences. **STEM experiences during the early formative years have been associated with identity development.** Beliefs about innate abilities emerge during the first years of life and are related to participation in STEM.

Since girl students' beliefs in their STEM-related abilities begin to fade at an early age, it is important to support girls with activities that are meaningful to them, both inside and outside the classroom. This is not only important for their empowerment but also for disrupting power structures (Cohen et al., 2021).

Chapter 2: Barriers Faced by Girls in STEAM

Gender equality is a basic human right (United Nations, 1948) that also stands as a cornerstone for fostering prosperous and modern economies characterized by sustainable, and inclusive growth. The idea behind gender equality goes beyond the concept of fairness; it's about **creating an environment where both men and women can contribute fully to various spheres of life**, including at home, in the workplace, and in public, leading to the enhancement of societies and economies as well as fulfilling individual potential and achieving personal wellbeing. The principle is also recognized as a universal basis of sustainable development in the UN Agenda 2030 (SDG5) which urges to eliminate gender disparities.

Despite progress in education, **gender differences persist globally**. In OECD countries, girls are generally achieving higher educational levels than their male counterparts, yet they continue to face challenges in participating in Science, Technology, Engineering, and Mathematics (STEM) studies resulting in an evident gender gap.

The aim of this chapter is to provide a picture of women's underrepresentation in the STEM field and shed some light to the **root causes of barriers faced by females in STEM** that lead to gender disbalance.

We will first start with a brief overview of STEM education and gender disparities in consortium countries

National context in partner countries

In 2022, there were almost **7.3 million female scientists** and **engineers** in the EU (41% of the workforce). Women working as **scientists and engineers** were, however, primarily employed in the **service sector**, comprising 46% (Eurostat, 2024)

Fig.1 Eurostat, 2024

Despite differences between European countries and regions, the gender gap is still evident in STEM education and fields.

Germany

In **Germany**, gender disparities persist in STEM education due to historical stereotypes and a lack of female role models, among others, discouraging women from pursuing STEM fields (Klemm, K., 2022, pp. 10-11). The MINT Nachwuchsbarometer 2023 report revealed that in dual STEM study programs only around 20% of participants are women. The situation is even worse in dual STEM apprenticeships where the percentage of women is only 12% (p. 18). According to Destatis - Federal Statistical Office of Germany (2023), during the winter semester of 2022/2023, females represented only a mere 32.4% of the total STEM student population enrolled in higher education institutions. When it comes to STEM professions, statistics also show that men outnumber women in STEM fields. In the third quarter of 2022, only 16% of all employees subject to social insurance contributions in STEM occupations were women (Anger et al., 2023, p.33).

Slovenia

In **Slovenia**, there is a relatively high proportion of female STEM graduates in comparison to other European countries, however, gender disparities in STEM education and professions still persist.

While **one in every three girls in Slovenia studies STEM** subjects, there is still a significant gender gap when compared to boys (Digital Skills and Jobs Platform of the European Union, 2022). Women are **particularly underrepresented at the tertiary level** in engineering, manufacturing, construction, and information and communication technologies (ICT), with only 23% of newly admitted students in engineering, manufacturing, and construction programmes being women, and 16% in ICT programmes (OECD, 2021). Gender stereotypes and unconscious bias continue to limit women's advancement in scientific and technical fields in Slovenia, particularly at the senior level (STA, 2020). In STEM professions, women are underrepresented especially in engineering, manufacturing, construction, and information and communication technology (Education and Training Monitor, 2020). Moreover, women with tertiary education earn 83% as much as men with comparable education (OECD, 2021).

Italy

In **Italy**, the proportion of upper secondary and post-secondary non-tertiary vocational graduates in the field of STEM is one of the highest among OECD and partner countries (OECD, Education GPS 2023).

However, data clearly show a gap between men's and women's participation rate in STEM higher education. Women make up more than half of tertiary graduates (58.4%), but only 8.8% have a STEM degree. Especially, the share of graduates in information and communication technologies is particularly low, at just 1.4% compared to the EU average of 3.9% (Education and Training Monitor, 2022). Even though the gender gap in Italian university programs seems to be experiencing a contraction, it is noticeable that the proportion of females is still lower than males. This scenario even worsens in professional environments, where another fraction of female STEM-graduates drops out from STEM jobs or accepts jobs for which they are overqualified due to difficulties connected to the need to care for their families. Considering that STEM degrees typically lead to higher-paying jobs, this gap in STEM degrees and careers adds persisting gender pay gap, which is the difference in average gross hourly earnings between women and men (Di Cagno, 2021).

Portugal

In **Portugal**, gender disparities exist in scientific and technological fields of interest and career aspirations among high-achieving students. The PISA 2018 - Portugal (Lourenço et al., 2019), highlights significant discrepancies, where one in two boys (48%) aim to pursue science and engineering professions compared to just one in seven girls (15%). This is a trend that is also observed in other countries, but not at such high levels, with around one in four boys aspiring to these careers (Fernandes et al., 2019; Lourenço et al., 2019). Nevertheless, it is noteworthy that most higher education students in Portugal are women (Farias, 2021), and the country has achieved significant progress towards gender equality in education. According to the International Labour Organization (ILO), in Portugal, 38% of STEM graduates are female. While 44% of those employed in STEM occupations in Portugal are women, this figure only represents 12% of the total workforce. Notably, upon conducting a thorough analysis of the STEM sector, Science and Maths professions may exhibit higher rates of feminization, while Engineering and Technology careers may have lower levels of female representation (ILOSTAT, 2020). The case-study conducted by Olmedo-Torre et al. (2018) show that women are still significantly underrepresented in engineering fields and that it may be more difficult for them to conciliate academic workload with other spheres of life than for male students.

Belgium

In **Belgium**, women outnumber men in three sectors of higher education: humanities and social sciences, health sciences and the arts. Conversely, they are underrepresented in science and technology (STEM) courses. According to Eurostat, the data for 2020 show that Belgium had a proportion of 22.8 male STEM graduates out of 1,000 and only 8.4 women out of 1,000 aged between 20 and 29 have a degree of this type. In Belgium, men are more likely than women to have digital skills. The proportion of men and women working as ICT specialists highlights a rather marked gender disparity. According to the results published in 2021, 8.6% of working men aged 16 to 74 are ICT specialists in Belgium. For women, this percentage falls to just 2.4%. In 2020, the six French-speaking universities in Belgium awarded 1,800 degrees in these fields, which represented only 23% of the 7,700 Master's degrees awarded that year. Women account for only about a third of STEM Master's graduates in the Wallonia-Brussels Federation. In the IT sector, they account for only 17% of all graduates.

As demonstrated, female underrepresentation in STEM education and profession is common within the consortium countries, where data related to STEM subjects are marked by substantial differences in career aspirations, with a higher percentage of boys aspiring to science and engineering professions compared to girls (Lourenço et al., 2019; Van Laetehm & Verstraete, 2018; Education and Training Monitor, 2022; Mint Nachwuchsbarometer 2023, OECD 2022). The evident underrepresentation of women in these fields further feeds the challenge of attaining gender balance in STEM professions.

Gender disparities in STEM fields

Women in western civilization were traditionally assigned the role of **managing domestic and family related duties**, while **men** were presumed to be **primary providers**. This brought more burdens on women in today's society as they need to consider the balance between family life and career more often than their male counterparts. (Corbett & Hill, 2015) According to a survey (Simard et al., 2008), **women** were more inclined to **postpone or even to renounce marriage and parenthood** due to work-related demands. In addition, in fields marked by extended working hours such as engineering and technology, women with children are more likely to **leave their employment**. For instance, in Italy, almost one in five women no longer works after the birth of a child, which is approximately 18% of all working women. Most leave because they cannot **balance work and caring for their children** (52%) (Bergamante & Mandrone, 2022). The long-standing research confirms that when **professional commitments clash with family responsibility**, it's predominantly women who are confronted with a situation demanding a difficult choice between their career and family commitments (Corbett & Hill, 2015).

For girls and young women growing up in such a cultural and societal setting, their perception of women's position may constitute a precondition to move away from the field of STEM. Indeed, as demonstrated above, statistical data from various European countries reveals a trend of **gender disparities** in specific academic disciplines, such as physics, mathematics, statistics, ICT studies, technology, and engineering. These fields show a significant underrepresentation of women, highlighting the unequal gender distribution in higher education (European Institute of Gender Equality, 2018).

In fact, the **gender disparities in STEM professions and studies** start much earlier in life. When confronting the recently issued OECD PISA 2022 data, it is evident that the underrepresentation of women and performance gap can be observed already in **school education**.

According to PISA 2022, **boys generally outperformed girls in mathematics** in most of OECD countries, including partner countries, with some peaks of significant outperformance in Italy. Girls also exhibit lower enrolment rates in technical and vocational programs and are less likely to pursue experiences in potential careers through internships compared to boys (OECD, 2022). Disparities in academic achievement between genders cannot be attributed to inherent abilities. Instead, **societal and cultural factors reinforce stereotypical attitudes and behaviours** associated with gender-related differences in student performance.

The PISA 2022 results also indicate that there has been **no variation in the gender gap over the past four years of analysis**. Indeed, despite a decline in overall student performance attributed to the COVID-19 pandemic, the decrease in performance has occurred both in boys and girls, resulting in the gender performance gap remaining unchanged compared to the previous values of 2018. Consequently, the performance of girls has continued to decrease, contributing to a widening of the gender gap. Within EU countries, the gap either remained constant or widened. Germany, Italy, and Portugal experienced a widening gap.

External barriers: discrimination and stereotypes

The underrepresentation of women in STEM education and professions has a damaging impact on diversity, equality, creativity, and innovation in the workforce. There are several factors that contribute to the gender gap in STEM fields. **Gender-based discrimination** and **stereotypes** that discourage girls and women from pursuing STEM education and careers are some of the most prominent.

It is generally believed that girls and women are more inclined to study **subjects related to people**, their care and education (Verdugo-Castro, 2022). However, it is important to underline that behind statistics that confirm this belief, there are reasons which influence, modify or determine the individual education and career choices, such as the **immediate environment**, including **family and societal expectations** (Botella et al., 2019).

Gender roles, patterns, and stereotypes embedded in family and societies influence the educational trajectories and career decisions of both boys and girls, as well as **teaching methods**, **social norms** and **personal beliefs** (Farias, 2021).

Barriers for girls´ full participation in STEM education and career can be thus of both **external and internal origin** as discrimination can also be implicitly constructed in individual's mindset, meaning that "much of our behavior is driven by stereotypes that operate automatically and, therefore, unconsciously" (Corbett & Hill, 2015, p. 38).

Gender discrimination is the pivotal phenomenon which has historically been the reason for women **underrepresentation in scientific academic careers**. Even today, throughout their education, girls and women face many barriers which impede their participation in STEM fields allowing them to achieve their potential (Ceci et al., 2014). One of the systemic root causes of the gender gap, can be found in the **education system and teaching approaches** widely applied. Some research (Gilligan, 1982; Belenky et al., 1986; Becker, 1995 in Bevan, 2001) suggest that girls have traditionally been **discriminated against in mathematics** because of their preferred **styles of learning**. It is argued that girls tend to be **'connected' thinkers** who require the exploration of context and interrelationships when encountering new mathematics. Head (1995 in Bevan 2001) has proposed that girls prefer **cooperative, supportive working environments whereas boys work well in competitive, pressurized environments**. Also, boys show greater adaptability to more traditional approaches to learning which require memorizing abstract, unambiguous facts and rules that have to be acquired quickly. On the other hand, girls do better than boys on sustained tasks that are open-ended, process-based, related to realistic situations, and that require pupils to think for themselves (Arnot et al., 1998 in Bevan, 2001).

In addition, gender stereotypes and biases are often **implicitly imprinted in the educational curriculum** (Corbett & Hill, 2015), and the **materials used within the educational system** reinforce the stereotype associating science primarily with men (Kerkhoven et al., 2016).

To bridge this gap, we need to focus on **adapting the teaching approaches** in Maths and other STEM subjects as well as **review and innovate teaching materials** to favor girls´ participation and encourage their interest in STEAM. Teachers need to be highly competent in explaining the importance of STEM to younger children, emphasising the practical use in contexts children are familiar with, and stimulating pupils' genuine curiosity about STEM subjects. Thus, the presentation of STEM disciplines as something highly theoretical must shift to a more tangible approach, making them more relatable for both girls and boys.

The impact of stereotypes on individuals is not only shaped by the **interactions within formal learning settings** but is also influenced by various factors spanning family and society expectations, and encouragement (Sullivan et al., 2015). **Gender stereotypes and biases** are intrinsically linked to **societal root causes**. Among the possible explanations, an example from the **engineering culture** can be demonstrated. In the field of engineering, logical thinking tends to be prioritised over critical thinking (Claris & Riley, 2012). For example, engineering students are rarely prompted to reflect on the reasons behind their actions, the **purpose** of their work, and the potential consequences of their decisions (Baillie & Levine, 2013), **disengaging** students in **ethical and social responsibilities** in both academic and workplace settings (Cech, 2014). This cultural aspect poses a particularly discouraging impact on women as they often express a preference for work that holds a clear social purpose (Konrad et al., 2000). As pointed out by Yoder, improved communication of the common goals in engineering and computing careers could potentially lead to increased interest from girls and women in pursuing these fields (Yoder, 2013).

Another common factor that leads to systematic discrimination is related to the belief that the scientific field is a masculine one. More specifically, women often contend with the **stereotype** of being warm and commonly face **discrimination** as traits necessary for a positive perception as a technical professional may contradict stereotypical expectations for women to be warm. Consequently, women in technical roles may find it challenging to establish strong professional identities and often feel the need to constantly prove themselves (Corbett & Hill, 2015).

Moreover, it is important to address the **concept of microinequities**, instances of **gender-biased behaviour** that individuals, especially women, may encounter by the time they start STEM education (Corbett & Hill, 2015). These instances manifest in various ways, including facial expressions, gestures, tone of voice, and discrete actions, such as assigning tasks like note-taking more frequently to women than to men (Bandura, 1997). Over time, the accumulation of these "soft" inequalities, known as microinequities, has the potential to impact the self-concept of students. This, in turn, may influence the career choices they make as they navigate their academic and professional paths (Corbett & Hill, 2015).

Internal barriers: self-perception and stereotype threat

Gender biases play a significant role in shaping not only how individuals perceive and interact with others but also in influencing their **self-perception** and actions. Starting from early childhood, people are exposed to **stereotypes** that unconsciously guide their choices and behaviours, directing them toward specific career paths while keeping them away from others. An example is the development of **implicit biases** already in first grade, where children associate maths predominantly with boys (Corbett & Hill, 2015). This can strongly impact later career choices, since the orientation to gender roles is especially relevant for occupational preferences on **ages six to eight** (Gottfredson, 1981).

The interplay between gender stereotypes and STEM education is strictly related to the concept of stereotype threat.

The stereotype threat – a term coined by the researchers Claude Steele and Joshua Aronson in 1995 (Steele & Aronson, 1995) – is a social phenomenon defined as the **perception of individuals' feelings about potentially confirming the negative stereotype associated with their respective social groups** (Cobertt and Hill, 2015).

Specifically, within the context of STEM, which has traditionally been associated as a masculine domain (Borsotti, 2018), **women** may find themselves **vulnerable to stereotype threat**, manifesting concerns and fear about potential **rejection** both in their academic and professional careers within this field. According to a study conducted by Murphy et al. (2007), when female STEM students perceive a significant **gender imbalance** in a scientific context, it negatively affects their **confidence**, **sense of belonging**, and willingness to **actively participate**, increasing the level of threat perceived compared to the group of women in a context of gender-balanced group of students. The repercussions of stereotype threat in the STEM sector are serious and multiple, leading to a significant lack of equal opportunities for girls and women which, despite their performance, may doubt their abilities and competences, and their self-confidence in general (Cheryan et al., 2017).

Lack of Female Role Models

Role models play a significant role in **shaping motivational processes**, providing guidance on goals and pathways to success (Lockwood & Kunda, 1997). Furthermore, role model interventions have proven effective in reducing concerns about representing one's group in a **stereotyped domain**, **mitigating the stereotype threat** (Dasgupta, 2011). Exposure to role models that one can identify with enhances career motivation, identification, performance on exams, perceived success, academic and career aspirations, and reduces implicit self-stereotyping (Ramsey et al., 2013). Conversely, **exposure to stereotypical male role models can lower women's interest**, belonging, and perceived success in STEM due to perceived dissimilarity (Cheryan et al., 2013).

Female role models have been identified as particularly effective in retaining female students in STEM (Cheryan & Plaut, 2010; Steele, 1997). The absence of positive female role models can contribute to the perception that STEM is not for girls.

Exposure to successful female role models counters negative stereotypes, demonstrating that individuals "like them" can thrive in the field (Hill et al., 2010).

To attract more girls to STEM classrooms, educators should actively develop materials showcasing images and profiles of female role models in the field, such as posters, flyers, and videos (Milgram, 2011). It is crucial for role models to convey that they have experienced challenges, making their achievements more relatable (Lin-Siegler et al., 2016).

Chapter 3: Empowering Educators for STEAM Learning

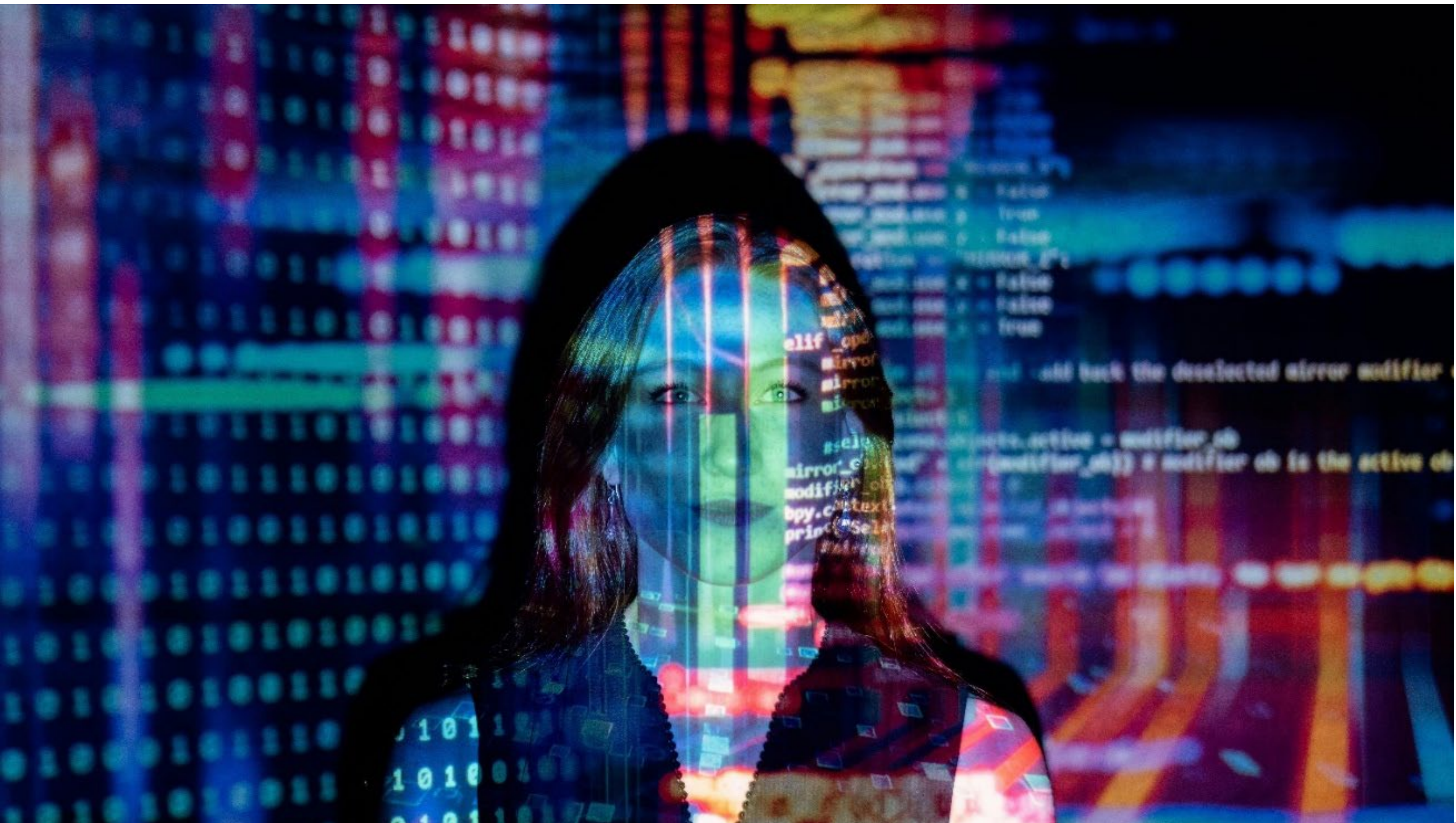
In the academic journey of STEAM education, **teachers go beyond traditional subjects, playing a pivotal role in developing students' character-building skills with broad, practical applications in the real world and life in general** (Bertrand & Namukasa, 2020). In this sense, this empowerment in the classroom is essential as it influences how students learn, fostering skills crucial for personal, academic, and future professional growth.

Development of the 21st century skills

As discussed above, cultivating **transferable skills**, often referred to as 21st-century skills (Taylor, 2016), is vital to empower STEAM education in the classroom.

This approach equips pupils with soft skills such as **collaboration**, effective **communication** (oral and written), **curiosity**, **critical thinking**, **perseverance**, and **adaptability** (Bertrand & Namukasa, 2020; Scott-Barret et al., 2023).

By doing so, STEAM education prepares pupils "to deal positively and productively with 21st-century global challenges that are impacting the economy, the natural environment, and our diverse cultural heritage" (Taylor, 2016, p. 86). This strategic development of skills is fundamental for navigating the complexities of the 21st century.



In the intricate landscape of scientific and technological fields, **educators play a pivotal role in nurturing an environment that fosters an inquisitive mindset and sharp critical thinking skills**. This is achieved by creating **opportunities for feedback, encouraging question-asking, and establishing a psychologically safe space**. Through these intentional measures, educators enable students not only to navigate but also to excel in the **complexities inherent in the STEAM disciplines** (Scott-Barret et al., 2023).

Collaboration stands out as another fundamental pillar emphasised in the literature on STEAM education (Bertrand & Namukasa, 2020). Educators play an important role in designing activities that promote **collaborative learning**, whether through group projects, challenges, or assignments. By providing opportunities for students to collaborate, educators actively contribute to the development of interpersonal skills – qualities indispensable for effective **teamwork**.

Facilitating **written and oral communication skills** also plays an important role (Bertrand & Namukasa, 2020; Huser et al., 2020). Teachers guide students in **documenting their making processes**, expressing their thoughts **verbally and in writing**, and effectively communicating their ideas. This emphasis on communication aligns with the broader goal of empowering students to articulate their thoughts and share their learning experiences (Bertrand & Namukasa, 2020).

Perseverance and adaptability are also crucial skills developed through STEAM education. Educators are encouraged to integrate **diverse teaching strategies**, such as the **incorporation of picture books, design-inquiry processes**, and **problem-solving activities** into their programs (Bertrand & Namukasa, 2020). This **multifaceted approach** not only exposes students to **assimilating STEAM principles** but also instils in them the **ability to embrace mistakes** and failures as integral components of the learning journey. Through these deliberate efforts, students not only demonstrate increased perseverance and resilience but also develop a profound understanding of the iterative nature of the creative and problem-solving processes (Scott-Barret et al., 2023).

To assess a successful development of pupils´ skills in STEAM education a **holistic approach assessment** (Huser, 2020) is needed. Educators are encouraged to move beyond traditional, standardised assessments and **incorporate authentic assessments** that mirror real-world tasks and expectations (Chiangpradit, 2023), and allow a more comprehensive understanding of students' academic growth and achievements. According to Huser (2020), through these assessments, teachers gain valuable insights into students' problem-solving strategies, interpersonal skills, and the application of content knowledge, contributing to a more significant understanding of their progress.

In conclusion, the role of educators in STEAM education extends beyond traditional teaching methodologies. It involves **fostering the development of transferable skills** that equip students for the complexities of the 21st century, implementing **appealing assessment practices** while creating a **dynamic and gender-inclusive learning environment**. Through intentional pedagogy and a commitment to holistic education, educators become **facilitators for empowering students** not only with subject-specific knowledge but also with the skills and mindset necessary for success in an ever-evolving world and, ultimately, make a meaningful impact on their community and the world.

Girls' participation in STEAM education

Despite significant progress in recent decades, the female proportion in STEAM remains disproportionately low compared to their male counterparts. A report by UNESCO (2017) underscores this imbalance stating that only a **mere 28% of the world's researchers today are women** and **only 17 women have won a Nobel Prize in physics, chemistry, or medicine** since Marie Curie in 1903, in contrast to 572 men. This disparity has a profound impact and consequences for both individuals and society, limiting opportunities for women and girls not only to develop their capabilities but also to realise their full potential and contribute to a workforce that does not reflect the diversity of the population. The consequences of the limited presence of girls in STEM fields are noteworthy.

Girls not only lose **opportunities to nurture their skills** but also contribute to a shortage of **diverse professionals** in vital sectors, impacting advancements in tackling global challenges such as climate change and healthcare (UNICEF, 2020).

Beegle et al. (2020) points out that girls are more likely to be **discouraged at a young age**, with societal norms directing boys toward activities that develop cognitive abilities essential for STEAM fields. Acknowledging these challenges, UNICEF (2020) asserts that early exposure of STEAM subjects, along with **proactive encouragement and active participation, is crucial for building the foundation of girls' skills and sustained interest**.

As demonstrated in the previous section, educators play a crucial role in creating such opportunities for girls. These opportunities enable girls not only to explore a variety of STEM disciplines, allowing them to discover their interests and passions, but also provide a spectrum of experiences that can contribute to breaking down stereotypes and expanding girls' perceptions of what is achievable in STEAM fields (Beegle et al., 2020).

Given these circumstances, it becomes imperative for educators to **actively engage girls in STEAM education**. To be able to enhance girls' engagement and encourage their active participation in STEAM education, teachers and educators need to be aware of challenges and target them with appropriate strategies and cultivate a more equitable and inclusive learning environment.

Gaps and obstacles to STEAM education

Teachers integrating the STEAM approach in primary school classes need to be able to recognize the existing **gaps** and **obstacles** to effectively prevent them from hindering the application of this approach.

One of the significant **challenges** often faced by educators is the **lack of resources and infrastructures**. Many schools struggle with **limited budgets**, leaving them unable to provide the necessary equipment, such as technological tools and software instrumental for some STEAM practices (Jacques, 2017). Therefore, educators who want to inspire and facilitate hands-on learning experiences and engaging lessons, often find themselves constrained by the **lack of essential tools and materials**. UNICEF (2017) highlighted that "the availability of equipment, materials and resources is essential to stimulate students' interest, and enhance learning, in STEM subjects" (p. 54).

Furthermore, the current **curricular frameworks** often lack the necessary structure to prepare educators to effectively deliver STEAM education. Traditional curricula tend to **separate subjects in silos**, failing to highlight the **interconnectedness of STEAM** disciplines and their real-world applications (Roehrig et al., 2021). This isolation can leave students feeling disconnected and unable to see the relevance of what they are learning.

Thus, curricula should be redesigned to be more **interdisciplinary** and **project-based**, emphasising **real-world applications** and thereby also fostering already described 21st century skills such as **critical thinking** and **problem-solving skills** (Tytler & Self, 2020).

An update in the curricular framework is, therefore, necessary. However, this shift will require collaboration between educators, curriculum developers, and subject matter experts to ensure that the revised curriculum remains aligned with learning objectives and empowers students to become active participants in their own learning.

In addition, **school textbooks** often reinforce gender stereotypes in STEAM by portraying male and female characters in traditional roles (UNESCO, 2017). The underrepresentation of female STEAM professionals and the use of language and images that depict women in stereotyped or subordinate positions can (also unintentionally) may discourage girls from pursuing STEM careers (for instance, male doctors but female nurses). Teachers, therefore, need to attentively consider materials they present to pupils and use in classes, opting for those promoting gender equality, showing that both girls and boys are interested in and succeed in mathematics, science, literature, history, and other disciplines; school subjects are gender-neutral. UNESCO provides a methodological guide on promoting gender equality through textbooks, including tools to evaluate gender representation textbooks (Brugeilles, Cromer 2009).

On top of these challenges, there are limited **professional development opportunities** or lack of depth and focus in those existing. This leads to lack of teachers´ and educators´ knowledge and confidence in integrating STEAM approach in lesson plans, and hesitation about navigating complex concepts, or trying specific software (Weng et al., 2020). Given the rapid advancements in scientific knowledge and technology and growing need for widely applied STEAM education, educators would greatly benefit from comprehensive and ongoing STEAM training (Dyer, 2017).

Finally, teachers need to be aware of **social and cultural barriers** that discourage girls and students from diverse backgrounds from participation and engagement in STEAM education and careers (see chapter 2). As a matter of fact, it is **the role of the educators to actively dismantle these barriers** and create **inclusive environments** that nurture their curiosity and encourage all pupils to reach their full potential.

One way to do so is by promoting female role models in STEM fields. By showcasing the diversity and achievements of women and individuals that represent a range of genders, backgrounds, and experiences, educators can inspire girls and help them envision themselves as future scientists, engineers, and innovators (Sullivan, 2019b). Additionally, to enhance the impact and establish a meaningful connection with female students, educators are also encouraged to **invite accomplished women scientists and engineers to visit the classroom** and engage with students directly (Sullivan, 2019b). This not only enriches the learning experience but also provides inspiring role models for girls pursuing STEM fields.

By acknowledging and actively mitigating these gaps and obstacles teachers and educators contribute significantly to a smoother integration of STEAM approach in classes and creating both inclusive and stimulating educational environments that not only motivates girls to actively participate but also empowers them to be part of this process.

Teachers' awareness and competencies in STEAM education

Competent STEAM educators appreciate the value of interdisciplinary approaches in cultivating a holistic comprehension of real-world challenges, as highlighted in initiatives from partner countries (e.g., "STEAM-IT", "GoSTEM", In2Steam, CHOICE). Therefore, effective STEAM education begins with teachers having a strong awareness of STEAM concepts and the skills necessary to interconnect them with other subjects and with real world problems.

Educators are instrumental in creating an **environment** that stimulates students' natural **curiosity** and in urging them to experiment with technology through play and discovery (Scott-Barrett et al., 2023).

Huser (2020) emphasises that for an educator to efficiently implement STEAM practices in the classroom competencies such as **interdisciplinary knowledge**, **pedagogical expertise**, **assessment literacy** and **inclusive practices** are required.

- **Interdisciplinary knowledge:** to make connections between different disciplines and seamlessly integrate them into their lessons. This allows students to see how the subject's knowledge complement each other and apply it to solve real-world problems (Roehrig et al., 2021).
- **Pedagogical expertise:** to implement effective teaching strategies such as inquiry-based learning, project-based learning, and technology integration to engage students and promote active learning. These strategies retain students' interest and encourage critical thinking, collaboration, and problem-solving skills (Scott-Barret et al., 2023).
- **Assessment literacy:** to assess student learning effectively, using a variety of formative and summative assessments that go beyond traditional testing methods (Huser, 2020). This allows educators to tailor their instruction to individual student needs and track progress over time.

- **Inclusive practices:** to create welcoming and inclusive learning environments that celebrate diversity and ensure all students have equitable opportunities to learn and succeed in STEAM. This involves addressing biases and stereotypes, providing non-formal instruction, and fostering a supportive classroom community (Sullivan, 2019b).

The role of school

However, even the most motivated and enlightened teachers need support from their institutions. In other words, not only individual teachers and educators but also schools are the key players in integration of STEAM education and girls´ engagement in it. Schools need to actively support educators in **gaining the required skills** and understanding of STEAM's importance. Therefore, schools are pivotal in offering teachers the necessary **training and resources** for the effective implementation of STEAM education. Such training and resources can address specific challenges faced by educators in different contexts. The professional development not only provides educators with essential content knowledge but also empowers them to deliver relevant and engaging instruction aligned with the evolving demands of the STEM-driven world in the classroom (Dyer, 2017).

Increasing professional opportunities on STEAM for educators is, therefore, crucial for boosting educators' **confidence in navigating complex concepts**, using specific tools and software, and seamlessly integrating **hands-on activities** into their teaching methods. On the other hand, schools also need to create a culture that encourages collaboration, risk-taking, and innovation in STEAM education. This can involve providing teachers with **adequate time and resources** to develop and implement STEAM activities, fostering a supportive learning community, and promoting gender equity.

In recognition of the pivotal role of teachers' awareness and competencies in STEAM education, educational institutions globally can implement **targeted professional development initiatives**, allocate **more funding to infrastructures and resources,** and **provide the time necessary for teachers´ preparation**. Empowering teachers ensures that they, in turn, empower students to excel in the dynamic and interconnected world of STEAM.

Free Online Resources for Teachers in the STEAM area

In the dynamic landscape of education, leveraging **free online resources** is a strategic approach for educators aiming to enhance their competencies in STEAM education. These resources offer valuable support, materials, and insights that contribute to effective teaching practices and the creation of engaging STEAM learning environments. Below we propose some examples of resources that serve as powerful tools, enhancing teaching practices and empowering primary school educators to create engaging STEAM learning environments for their students.

- **STEM Learning**

  STEM Learning is a resource hub for educators and individuals interested in STEAM. It provides a vast collection of free-to-access and quality-assured digital resources to support teaching and learning in STEM subjects, including primary and secondary education, cross-curricular activities, and professional development material. All resources are reviewed and approved by STEM Learning; a leading organisation dedicated to improving STEM education in the UK.

- **STEMfinity**

  STEMfinity is an online platform dedicated to providing free and readily available STEM resources for educators, students, and parents alike. It is a one-stop shop for anyone seeking to enhance their understanding and engagement in Science, Technology, Engineering, and Mathematics. What sets STEMfinity apart is its focus on quality and accessibility. All resources are carefully curated and reviewed by experts in the field, ensuring their educational value and alignment with learning objectives. Additionally, everything offered on the website is completely free, making it an invaluable resource for individuals and institutions with limited budgets.

- **NASA STEM Engagement**

  NASA provides a collection of free resources for educators through its STEM Engagement platform. Lesson plans, activities, and multimedia resources allow teachers to integrate real-world applications of STEM concepts into their classrooms. The platform covers a wide range of topics, from space exploration to robotics, fostering students' interest and understanding in various STEAM disciplines.

- **Khan Academy**

  Khan Academy offers a comprehensive range of free online courses in mathematics, science, programming, and more. The platform provides instructional videos, practice exercises, and progress tracking, allowing educators to supplement their classroom teachings with personalised and interactive resources.

- **PBS LearningMedia**

  PBS LearningMedia is an extensive digital library that offers free access to a wide range of educational resources. Educators can find STEAM-focused lesson plans, videos, and interactive activities designed to engage students and align with curriculum standards. The platform caters to various grade levels, ensuring flexibility for diverse educational needs.

- **TeachEngineering**

  TeachEngineering is a digital library that provides educators with a wealth of free, standards-aligned STEM lessons and hands-on activities. Developed by engineering faculty and educators, the platform supports the integration of engineering principles into traditional STEM subjects. Teachers can explore a variety of resources that promote experiential learning and problem-solving.

- **Google for Education**

  Google for Education offers a suite of free tools and resources for educators to enhance collaboration, creativity, and communication in the classroom. Google's Applied Digital Skills provides lesson plans that integrate technology into various subjects, promoting digital literacy and skill development. Additionally, Google Classroom facilitates streamlined communication and assignment management.

- **Scratch from MIT Media Lab**

  Scratch is a free programming language and online community developed by MIT Media Lab. It allows educators to introduce coding concepts in a creative and interactive way. Teachers can access a variety of free resources, including tutorials and project ideas, to engage students in coding and computational thinking.

- **National Geographic Education**

  National Geographic Education offers a range of free resources that connect STEAM subjects with real-world exploration and discovery. Educators can access lesson plans, maps, and multimedia content to integrate geography, science, and storytelling into their teaching practices.

- **Code.org**

  Code.org is a non-profit organisation that provides free coding resources for educators. The platform offers curriculum, online courses, and coding activities suitable for various grade levels. Teachers can equip students with essential coding skills while promoting computational thinking and problem-solving.

- **STEM Teaching Tools**

  STEM Teaching Tools, developed by the Institute for Science + Math Education, provides free resources to support effective STEM teaching practices. Educators can access instructional strategies, classroom scenarios, and toolkits that enhance the implementation of STEM education.

- **MSAP Center**

  The MSAP Center STEM Resources website provides educators with a comprehensive and user-friendly platform for exploring and integrating STEM into their curriculum. Categorised by subject matter and resource type, the site offers a diverse range of materials, including lesson plans, activities, games, videos, and quizzes. Notably, the website features a dedicated area for educators, allowing them to register for a free account and assign quizzes and games to students, electronically reviewing their results for assessment purposes. Additionally, the website offers resources specifically tailored for students, sparking their curiosity, and fostering their interest in STEM fields through interactive learning experiences.

- **IN2STEAM** project "Inspiring Next Generation of Girls through Inclusive STE(A)M Learning in Primary Education " - proposing STE(A)M learning applying art and design principles to science education through gender-inclusive methods. Resources include an online training curriculum and digital toolkit on STE(A)M learning for primary schools' teachers and trainers, and a behavioural assessment model guiding teachers in pedagogical methods on how to effectively measure behavioural change in pupils (in particular in girls) in primary school using the projects tested approach towards STE(A)M.

- **GeoGebra** - Free digital tools for class activities, graphing, geometry, collaborative whiteboard and more to make Maths and Geometry more fun and practical. It also offers ready-to-use maths resources for algebra, geometry, number sense, measurement, operations, statistics and probability across grades 4-8 to enhance student exploration and practice.

- **ESA – The European Space Agency Primary classroom resources** cover a wide range of curricular topics related to science, mathematics, technology, engineering and arts. Each classroom resource is composed of a teacher guide and student worksheets with practical activities.

Chapter 4: Cultivating Curiosity in Girls

Hands-On Learning and Experiment in School Setting

*"**Hands-on** (or kinesthetic) **learning** is where a student participates or carries out **physical activities relating to subject material** rather than listening to a lecture. Students learn by doing: engaging with the subject material to solve a problem or create something."* (TheThinkingKid, 2021) Furthermore, *"hands-on learning, also known as **experiential learning** or active learning, is an educational approach that emphasizes **direct engagement and practical experience** in the learning process. It involves active participation, manipulation of materials, and real-world application of knowledge and skills."* (ProctorEdu). While hands-on learning can be applied to all school subjects, like literature through writing poems or stories or history by recreating a certain historical event it is particularly appropriate for STEM subjects. It seems that their experimental, scientific, and transdisciplinary nature works particularly well with the hands-on learning (also known as HOL) approach.

The biggest difference between traditional teaching and learning through hands-on experiments is in the **involvement of students in the process**; the latter encourages or better say requires active participation; both from teachers and more importantly from students.

On the other hand, **traditional teaching** methods with the teacher talking and students listening or writing are known as **passive methods**. The differences in approaches result in different sets of skills that are gained during both pedagogical methods and levels of **in-depth connection** that is formed with the studied subject. When students actively manipulate the studied matter, they gain a **deeper understanding** of the concepts being taught, and they memorize the introduced subject better as opposed to listening to a teacher and taking notes about the subject. Studies have shown that when students passively sit and listen, they retain 20 percent of the presented information as opposed to 75 percent when they are allowed to practice what they have just learned (Moore, 2022).

In both, traditional and hands-on learning methods, **teachers play an important role**; the difference is in their dynamic with students. As said, within hands-on learning, students are actively involved in the process meanwhile, the teacher guides (if possible, unobtrusively) activities, and makes sure that exercises are age-appropriate and that the environment is safe and inclusive for all participants.

A **hands-on approach** to learning has many proven **benefits** for students who are engaged in this method. Amongst a wide range of skill sets this learning promotes (perseverance, adaptability, problem-solving to name a few), it also encourages the often mentioned 4 C's skills important for functioning in today's world: creativity, communication, collaboration, and critical thinking (Singh, 2021).

All of the above stated is equally important and beneficial for all students, regardless of their gender, ethnic background, or possible disabilities. Studies have shown that children who are introduced to STEM concepts at a younger age (below 11 years) are more likely to pursue STEM fields of study. This is especially important for girls who are underrepresented in the STEM field and if being introduced to hands-on learning in the early stages of their development, could help spark an interest in STEM subjects for the future its presence should be more encouraged in preschool and early school education. Good experience with STEM subjects in early years could potentially even lead to choosing a study program from the STEM field and consequently increase the representation of girls in the STEM workplace.

Other types of STEAM Learning

STEAM education is heavily based on hands-on learning but there are also other types of learning that correspond particularly well with what STEAM learning tries to promote. Firstly, there is **project-based learning (PBL)** which is not to be confused with school projects. In PBL students learn about the world by actively engaging in real-world and personally meaningful projects over time to change or overcome barriers that affect the real world (like climate change, healthcare, violence, …). PBL is *"a teaching method that brings learning to life, ignites student creativity and curiosity, and allows students to explore connections between school to the world around them."* (pi-top.com).

The second type of learning, that goes very well together with STEAM learning is **inquiry-based learning**. This type of learning tries to spark curiosity in students and encourage them to engage on a deep level. Instead of giving students answers, like in traditional teaching methods, they are encouraged to seek answers themselves and in doing so, a stronger and cohesive learning environment is created.

Both types of learning foster similar skills as STEAM learning, they are all student-oriented, process-driven, and rooted in the real world. These are all the reasons they work very well together and can benefit from each other.

At its core, STEAM learning combines science, technology, engineering, arts, and mathematics and this transdisciplinary combination of stated subjects can also be found in other, not just school environments. Students can come in touch with STEAM learning from home through different **tools** (toys, mobile apps), in after-school activities (STE(A)M clubs, STE(A)M camps, STE(A)M courses, …), in public places like libraries, makerspaces, museums, youth centres, and so on.

Considering the hugely popular use of screens among (not just young) people different **applications** and **programs** should be mentioned. Many applications are designed particularly for STEAM learning. To name a few for coding: ScratchJr, Daisy the Dinosaur, SpriteBox, Code Karts - all these applications combine simple coding with fun (dancing dinosaurs, cars moving and so on). Toontastic, Pencil 2D, Opentoonz, Blender, and many others are animation software suitable also for young children. Some of these applications and programs are marketed as specially designed for girls. Although this can be a good thing, it should be mentioned that one should be very careful when choosing apps described as such (designed for girls). This is an area that should be approached very carefully and cautiously in order not to further reproduce gender stereotypes but to help eliminate them and empower girls.

There are also many **toys** for younger children that one can use for STEAM learning. Some of them are designed with STEAM learning in mind and can be quite expensive (for instance toys for early code learning like Bee-Bot and Code-a-Pillar or different STEAM kits) while others are simpler toys that most children already have at home. If we take a closer look at what children learn when they play with LEGOS: while building bricks to build a house they learn basic engineering and maths concepts, while they play pretend with LEGO people, they use storytelling - and just like that, they unconsciously incorporate STEAM learning through play. It is similar with other more common toys like puzzles, bricks, cards, and board games; different STEAM areas are intuitively covered through play.

It is important to keep in mind gender stereotypes and be extra careful when choosing toys that girls will play with. Toys should not be divided into ones for boys and different ones for girls but should be gender neutral.

Encouraging questioning and explorations

Asking questions is an integral part of STEAM learning: what happens if I do this, why did this happen, how can I make this work, … If we want to strengthen critical thinking and problem-solving skills in students, **asking questions** and answering them should become counter piece of the learning process (Singh, 2021). But for students to feel comfortable asking all these questions and eliminating the fear of asking the wrong ones, the role of the teacher comes to light. Researchers stress the importance of teachers in creating a nurturing and supportive environment where students feel comfortable exploring uncertainty (Jirout et al., 2018).

Teachers must be able to support children's curiosity by regulating the level of challenge presented to the students and by helping to direct them toward relevant pieces of information, problems, and questions (Jirout et al., 2018). They should offer a safe environment, value diverse contributions, and support student confidence with **constructive feedback** (Scott-Barrett, 2023). For students to be curious they must be comfortable with greater amounts of uncertainty. It is that when they are comfortable, questioning and exploring can begin (Jirout et al., 2018).

Some ways for teachers to promote **comfort with uncertainty** are: to provide opportunities to **think**, **question**, **participate**, and **respond** – prompt students to generate questions, encourage students to think of alternative ideas, make connections between what students already know and what they do not, to name a few but it is also worth mentioning that teachers should always respond to questions positively, verbally and non-verbally (Jirout et al., 2018).

Another point that teachers should pay attention to is that they should take time and be patient when waiting for students to answer; some students need more time than others and this should be taken into consideration.

We can now take a look at more practical STEAM learning situations of how to spark curiosity and question-asking in children. One of the research projects that focused on practical examples of four STEAM learning programs in Canada (two in-school and two off-school) listed many different ways curiosity amongst students was encouraged during lessons. **Games, storytelling, playing with crafts material, and inquiring-type questions**; were all the ways that teachers used to help spark interest and curiosity at the beginning of the activity (Bertrand, Numikasa, 2020). One of the teachers who took part in the research said that by doing this *"you are activating kids' natural curiosity, their natural interest in figuring out how things work and how they can make things better."* (Bertrand, Numikasa, 2020, p. 46).

To conclude, we can see that teachers play a crucial role in fostering curiosity in students. There are many ways how this can be achieved, but in order to do so, teachers must be willing to actively participate in the learning process and provide a safe and inclusive environment.

Building problem-solving skills

Taking intellectual risks that happen through the exploration of uncertainty and acquiring new information (Jirout et al., 2018) brings us to another important character-building skill being encouraged through STEAM learning, which is problem-solving.

Research shows that STEAM learning compared to just STEM can reach more students and can provide content for authentic problem-solving (Roberts & Schnepp, 2020). Here are 10 characteristics of authentic activities that teachers can use when designing activities: **real-world tasks** rather than classroom-based tasks, **problems** that are not easily solved and are open to multiple interpretations, **complex tasks** requiring ongoing investigation, multiple perspectives, collaboration, reflection, interdisciplinary connection, integrated assessment that seamlessly integrated to the main task, polished products, multiple interpretations and outcomes (Herrington et al., 2002).

Failure is commonly associated with something bad, or negative. It is something usually not encouraged, especially in traditional school settings and through traditional teaching methods. On the other hand, failure plays an important role in STEAM learning, especially in the development of problem-solving skills. Because there is this big shift in the perception of failure in STEAM learning environment, the role of a teacher once again comes into focus.

Teachers should encourage failure as part of STEAM learning where trial and error are essential parts of the process (Milanovic et al., 2023), with the help of a teacher students should learn **to lose the fear of failing and learn how to benefit from it**.

If we take a look at the previous subchapter, we can see those greater levels of uncertainty (that are also encouraged in STEAM learning) lead to a greater challenge in resolving them which poses a risk of a greater chance of failure. Although gains in knowledge are greater than when resolving lower levels of uncertainty (Jirout et al., 2018).

To see how failure is important in building problem-solving skills, we can take a look at a **design-inquiring process**, where these six stages take place: **plan – design – make – test – redesign – repeat**. Through this process, students learn **persistence** and **adaptability** (Bertrand, Namukasa, 2020) but also **collaboration**, **exploring**, **analysing**, and **discussing** new ideas (Milanovic et al., 2023).

One of the instructors being interviewed as part of the research mentioned in the previous subchapter, about four different STEAM learning programs, said that they created a **learning environment** where failure and iteration were built into the lesson for students not to be afraid of **making mistakes** and **trying new things** (Bertrand & Namukasa, 2020). One of the teachers observed that students were sometimes not willing to try again even when something was not working, in response another teacher proposed that STEAM learning should: *"start in the younger years and this idea of building, designing and trying again, being resilient, knowing how many prototypes something takes before [you get the final product] in the real world … You are never going to get a final product without going through that messy process of try-fail-start again and repeat."* (Bertrand & Namukasa, 2020, p. 52).

When students are faced with for instance **hands-on learning** activity that involves **real-world challenges**, they integrate mental processes like analytical thinking, critical evaluation of the situation, and creative solutions. Through practical problem-solving students learn important skills that can be applied beyond the classroom (Main, 2023).

Promoting critical thinking

Another benefit of STEAM learning is the promotion of critical thinking in students. Through the process of STEAM learning, they strengthen their critical thinking skills which are skills that are very important in real-world contexts, not just in further education but also at home and in the workplace.

Researchers stress that STEAM education allows students to **think critically** on various issues. Students use a high level of thinking during the problem-solving process when they apply the content knowledge innovatively (Singh, 2021). Many of the above already mentioned skills that can be encouraged through STEAM learning are closely connected with critical thinking.

Questioning, exploring, making connections, analysing information, creative problem-solving, and collaborative learning; all these activities help **foster critical thinking.**

In STEAM activities students do not need to rely on memory as they do in traditional teaching methods but they learn by observing outcomes that come from their decisions (Moore, 2022), which is another way STEAM learning promotes critical thinking.

Let us again look at what teachers said about this topic in **four STEAM learning programs** that were analysed in the article. A teacher in one of the programs emphasized that she was not as concerned with the product as much as the process. She stated that one of the student learning objectives *"is critical thinking, so that they can make a plan . . . and critically analyse [their] plan to make sure that it is awesome and doable, so the design always comes before the building"* (Bertrand & Namukasa, 2020, p. 50). For the development of **critical thinking** skills success in the end result is not all that important, as opposed to the process that takes place in between (questioning, collaboration, detecting problems, searching for solutions, and so on). Through this process, all crucial skills are being exercised and knowledge on a deep level is being gained. This is the main difference between STEAM learning when compared to traditional teaching methods that are performance-oriented, where scores and grades are at the centre of student interest. Similar to the fear of failure mentioned in the previous subchapter, this is another thing that students must learn to overcome; to endorse the process not the end result. And just like with overcoming fear of failure, shifting from writing answers to asking questions, going from passively observing what teachers say or do to actively participating in the process, learning that there are multiple ways one can come to a solution as opposed to just one; once more, teachers play a crucial role. Teachers are the ones who can empower students and equip them with character-building skills for their future both in-school and out-of-school.

Chapter 5: Strategies for Empowering Girls in STEAM

As illustrated above, girls´ interest and engagement in STEAM education and later careers need to be encouraged from an early age. In this chapter, we will propose and discuss some strategies to empower girls both at **school and in the family environment**.

Inclusive curriculum design

The education systems across all European countries display distinctive features in their approaches, methodologies, and structures, and this diversity is also reflected in the approach they adopt when it comes to integrating STEAM in curricula. Despite differences, a common characteristic emerges across the partner countries – a shared **deficiency in adequately representing the invaluable experiences and contributions of women** in the field of STEM. This underrepresentation extends beyond gender to encompass people of diverse social, cultural or ethnic background, creating an additional layer of disparity within STEAM education. The narratives used in standard curricula often overlook the remarkable achievements and pivotal roles played by **individuals with diverse backgrounds**. The consequence is a missed opportunity for students to gain a comprehensive understanding of scientific advancements driven by individuals irrespective of their gender, ethnic origin, nationality, religion or other characteristics that make them different such as neurodiverse scientists or individuals with disabilities.

Innovative STEAM education **initiatives pushing towards more inclusivity** (not only regarding gender) have been implemented throughout Europe to provide a response to those realities. For example, **Finland**, a country that already provides **gender-neutral learning**, integrated **coding and computer science education** into its national curriculum to boost interest in STEM (Microsoft, 2017). However, such initiatives still encounter barriers in some countries both on country and institutional level (Alam et al., 2021). Firstly, the **gender barrier**, as fighting the deeply-rooted stereotypes surrounding women in STEAM requires a multi-level approach and a complete transformation of educational cultures. Secondly, a **socio-economic barrier** prevents students from low-income backgrounds and belonging to **ethnic minorities** from accessing quality STEAM education due to pervasive negative stereotypes. Finally, **structural barriers** linked to the lack of resources in the schools or the absence of proper training for teachers (Milanovic et al., 2023).

It will take some time to reach the objective of defining an **inclusive curriculum**, but those barriers are not insurmountable. As the initiatives multiply, they will progressively fall one after another. One possible solution that has been brought up to approach the issue of the STEAM curriculum is to create a **common European STEM education framework** (Alam et al., 2021).

The idea of a transversal, coordinated, supported and synchronised teaching and learning framework could provide a boost to the adoption of innovative and inclusive STEAM education, lead to long-term resource optimisation for each country, and encourage more people, especially girls, to choose STEAM career paths (Alam et al., 2021). An alternative **framework for STEAM curricula** was developed within a **EU project CHOICE**, indicating the areas in need of improvement and proposing new approaches to STEAM education.

But the main question is: **what elements should an inclusive curriculum focus on?** Of course, the answer is multidimensional. Here are some key aspects to be taken into account:

- **Gender inclusivity**: the curriculum counteracts gender stereotypes in STEAM fields where male representation was traditionally dominant. This involves encouraging girls to pursue interests in these areas and providing role models and materials that defy traditional gender norms. This approach should be valid for all subjects, for example by encouraging boys in reading and arts.
- **Cultural inclusivity**: the curriculum incorporates content that is culturally relevant and diverse, reflecting the various multicultural backgrounds of children in Europe. This might help engaging students who feel disconnected from the traditional approach due to a lack of representation of their culture.
- **Accessibility and adaptability**: the curriculum must be designed to be accessible to children with various needs, including those with disabilities or Specific Learning Disorders (SLDs). This might involve adapting teaching methods to accommodate different learning styles and choosing a hands-on approach as much as possible.
- **Collaborative learning**: the curriculum allows children with different strengths and weaknesses to support each other and learn collaboratively.
- **Professional development for teachers**: the curriculum should schedule for training on inclusive teaching practices, intercultural competence, and strategies for engaging all students.
- **Project-based learning**: the curriculum allows children to engage in hands-on, practical projects linking theory to real-world application that can be adapted to different skill levels and interests.
- **Creative learning**: the curriculum integrates creative opportunities to engage children who might not be as interested in traditional STEM subjects.

An **inclusive curriculum** would have multiple beneficial impacts on children, teachers, and on society in general as it enhances learning experiences by accommodating diverse styles, fostering a deeper **understanding of STEAM concepts**.

Moreover, the integration of Arts into STEM fields promotes **creativity** alongside **analytical thinking**, encouraging innovative **problem-solving** and broadening perspectives. Research indicates that inclusive practices enhance academic outcomes for all students.

According to a study carried by Rashida Robinson, an inclusive curriculum broadened the girls' perception of who can be a scientist and improved their confidence and belief in their ability to succeed in science (Robinson, 2021). Also, **students with special needs** benefit significantly from inclusive curricula, obtaining resources and strategies for success. STEAM education naturally develops critical thinking, and an inclusive approach extends these benefits across diverse student demographics.

Collaborative learning, a key feature of inclusive education, enhances social skills and empathy, breaking down gender and cultural stereotypes. Moreover, inclusive curricula prepare students for a diverse workforce, fostering early exposure to varied environments. When students see their interests reflected in education, engagement and motivation increase, addressing potential alienation in STEAM.

Lastly, the **societal impact** of inclusive education is significant, fostering a tolerant, open-minded society. Students educated in diverse settings are more likely to contribute positively to their communities, advocating for **equality and innovation**. In summary, an inclusive STEAM curriculum not only enhances individual education but also contributes to broader societal goals.

The role of parents

Many factors can have an impact on girls' interest in STEAM subjects: psychological factors, such as self-efficacy, peer influence, school environment, cultural norms, media representations, etc. Among those factors, **parents' support** and influence definitely come on top of the list.

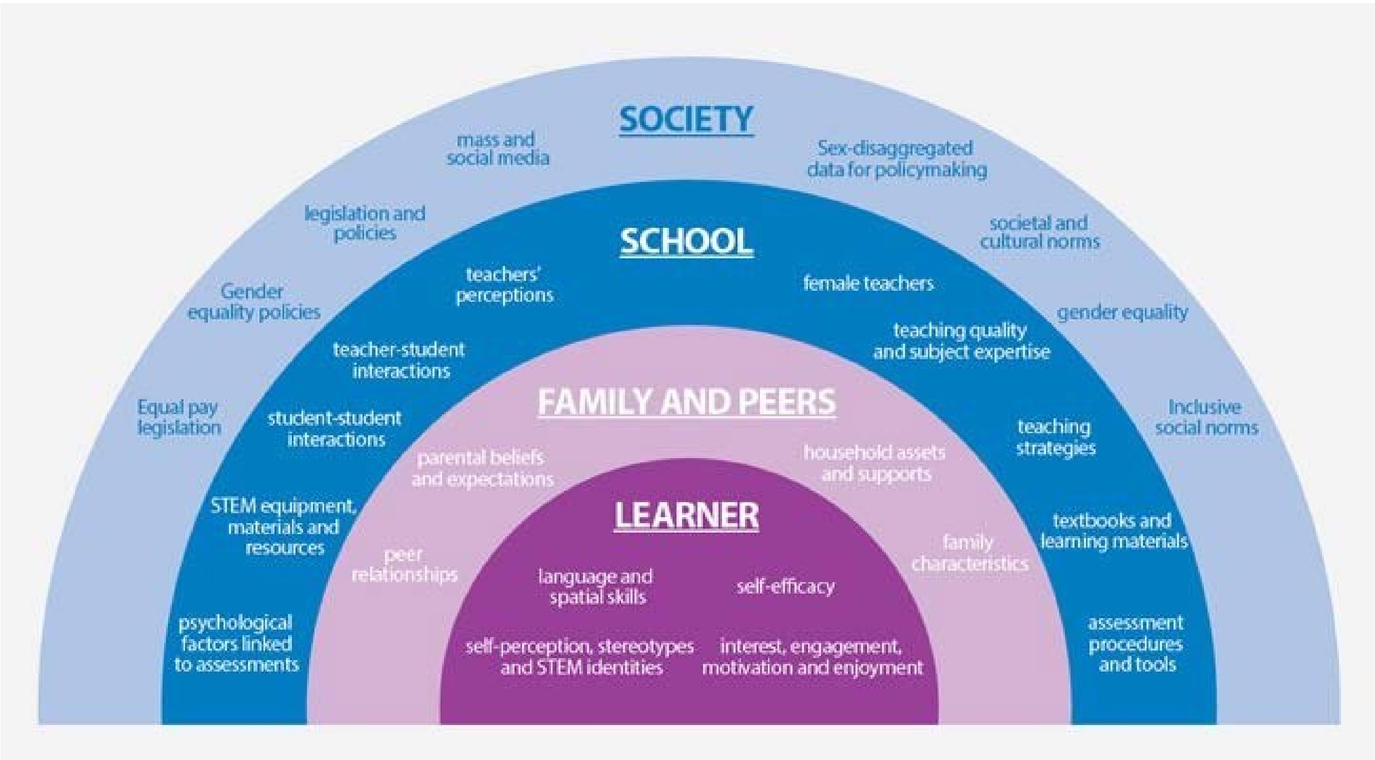


Fig. 2. Ecological framework of factors influencing girls' and women's participation, achievement and progression in STEM studies (UNESCO, 2017)

The beliefs, attitudes, values and content knowledge of STEM subjects of parents are referred to as "**scientific capital**" (McNally et al., 2022). The parents' scientific capital ultimately shapes their **children's participation**, achievement and progression in STEAM studies (Alam et al., 2021). Undeniably, the parents' education level and occupation as well as their socio-economic status influence children's interest in STEAM subjects. Studies have shown that the presence of a family member working in a STEM field, not only parents but also extended family members, contributes to increase the motivation to engage in STEAM activities (Johnson, 2019).

However, most **parents' beliefs are still very much influenced by gender stereotypes about girls' abilities in STEM**. Interestingly, it seems that those stereotypes have a greater influence on the future career choice of the children than the parents' education level or occupation (Alam et al., 2021).

The manifestation of such stereotypes in parental beliefs can lead to subtle biases, affecting the level of encouragement, resources and guidance provided to girls in their STEAM pursuits. Unconscious biases may influence parents to steer their daughters away from STEAM activities or unintentionally foster an environment that lacks the necessary support to encourage them to develop aspirations in those fields.

In this context, **what can be done by parents** to help overcome the stereotypes, contrast the biases and offer better opportunities to their daughters while contributing to bridge the STEAM gap? Here are some suggestions (Built by Me®, 2019; Kekelis, 2017):

- **Expose girls to female role models and monitor what they learn from the media**: it is crucial for girls to be exposed to stories featuring smart and independent female characters. Nowadays, an increasing number of books, cartoons and other media outlets opt for narratives that break gender stereotypes rather than perpetuating them.
- **Provide hands-on experiences**: avoid choosing gendered and gender-stereotypes perpetuating toys. Offer girls a variety of toys including tool sets, science kits or building blocks and let them choose what they like.
- **Consider extracurricular STEAM activities**: such activities allow for real-life experiences with STEAM and help them build self-confidence. According to various studies, girls who engage in extracurricular STEAM activities are more likely to pursue a career in STEAM later in their lives.

- **Encourage them, but also teach them to be comfortable with failure**: in order to build a favourable and relevant STEAM learning environment, it is also essential for girls to understand that failure is a part of the scientific process, since it relies on the trial-and-error method. Make sure to encourage them to try again and not to emphasise on their mistakes.

Finally, it must be stressed that encouraging girls into their interest in **STEAM does not mean developing parental pressure.** Some parents might have extremely high goals for their children to achieve and put excessive pressure on them, which can become counterproductive (Salvatierra & Cabello, 2022). Parental pressure can have many devastating effects on children (Moore, 2022), mainly on their mental health and self-esteem. Do not create a competitive atmosphere but rather cultivate girls' curiosity and interest in sciences.

The role of teachers and educators

From the teaching strategies they adopt to the interactions they have with pupils, **teachers and educators** have an extremely impactful role when it comes to influencing girls' participation in STEAM, They need to acknowledge their responsibility, cultivate and support the parents' efforts to engage girls in STEAM. Teachers can focus on the three following actions (Kekelis, 2017):

- **Invite** families to participate in STEAM activities, talk to parents about the importance of engaging girls in STEM.
- **Empower** parents to empower their children. Build relations with partners and welcome them to participate in learning with their daughters.
- **Coach** parents, provide them with resources and help them make connections to support their daughters.
- **Build equity in learning**. Look for settings that have a good balance between boys and girls, or that focus specifically on girls' learning.

Another idea could be **engaging parents as role models**. Search for women working in STEM among parents and invite them to join school activities.

Encouraging participation in STEAM extra-curricular activities

One of the elements mentioned above to address the gender gap in STEAM education is encouraging girls´ participation in STEAM activities. According to a survey conducted by Microsoft (2018) on 6.009 girls and young women in the United States, 75% of girls who take part in STEM clubs and activities understand the type of careers they can achieve thanks to their STEM knowledge, compared to 53% who do not engage in extracurricular activities. Furthermore, 77% of girls felt empowered by the hands-on STEM activities, against 34% for those who only engage in STEM at school (Microsoft, 2018).

These numbers highlight the fact that offering opportunities to **learn outside school** is important when the curriculum fails to equip girls with sufficient knowledge or experience. At the same time, students' participation in extracurricular activities such as science, technology, and engineering exhibitions, revealed that the more the engagement, the more girls showed a greater capacity to make informed decisions about their future and more positive attitudes towards science (Verdugo-Castro, 2022). In this regard, teachers play a pivotal role as agents of change in the educational process, creating, promoting and actively engaging pupils in extra-curricular activities.

Recently, there is a new trend growing in STEAM education where **all-girl clubs** are being created. It has been argued that such environments might not actually be the best initiative to encourage gender diversity in STEAM or that they are "unfair" towards boys. However, girls-only activities present certain benefits, such as creating **safe spaces for girls** to try out STEAM experiments, making girls feel personally invited to engage in STEAM, and offering opportunities for girls interested in STEAM to meet other girls that share similar interests. All-girl clubs can also be great places to discuss the life of women in STEM fields with young girls and invite female role models to speak with them (Gender4STEM, 2020).

While some schools already offer to their pupils the possibility of joining a STEAM club or participating in STEAM activities, not every child has access to a club or an activity devoted to STEAM subjects. To sum up, **what can parents and teachers do to improve this situation?** Together, they can take several actions, such as:

- **Advocating for STEAM education** and asking the school board for the inclusion of STEAM activities in the curriculum.
- **Create non formal STEAM activities** to compensate for the lack of formal activities. This can involve creating your own club and organising field trips to the local science museum or arrange workshops outside school hours.
- **Find content via online resources** to supplement traditional classroom learning. For instance, the resources of the **STEAM Tales** project will be available on the project website and will offer great additional activities to implement in class or at home.

An example of a free initiative that supports teachers in applying STEAM approach is the "**Rentrée des Sciences**" in Belgium organised by the **Scientothèque**, in partnership with the Minister of Education, the **Sciences et Enseignement initiative**, the **ESERO network** and the **Euro Space Center**. The initiative provides printable lesson plans that primary teachers can implement in class during a whole week. The objective is to provide the teachers with more entertaining activities to get them familiarised with a more hands-on approach and to boost the interest and motivation of all children, especially girls, in STEAM subjects.

As a teacher, stay informed about STEAM activities in your neighbourhood and do not hesitate to provide information about those to parents and encourage their interest.

Advocating for gender equality in STEAM

Teachers and **educators** have the power to shape the perceptions and the choices of children by creating an **inclusive learning environment** where all genders are equal.

As a teacher, it is crucial to show your pupils and their parents that you encourage gender equality in STEAM.

Studies show that young European girls become interested in STEAM subjects around the age of 11, but this interest significantly drops when they reach the age of 15 if they lack proper encouragement and support (Microsoft, 2017). This leaves a 4-year window for teachers and parents to **cultivate the girls' interest in STEAM** before they, sometimes reluctantly, decide on another career path because of pervasive gender stereotypes. 4 years is a rather short period, and that is precisely why it is imperative to spark their interest in STEAM from an early age.

This implies several attitudes to adopt, such as (Vivian et al., 2020):

- **Creating equitable opportunities** for all children regardless of their gender identity or their cultural background.
- **Addressing gender stereotypes** that limit girls' interest or confidence in STEAM fields and spread the message that anyone is capable of developing STEAM skills. Ask the pupils what they know about people working in STEAM and open the discussion about the unconscious bias that they have.
- **Encouraging critical-thinking and creativity** as an approach to **problem-solving**. Interdisciplinary STEAM curriculum can improve learning outcomes for both boys and girls. Have pupils work on STEAM projects that align with their personal interests or culture.
- **Encourage collaboration** with peers of varied backgrounds and experiences. Research shows that girls prefer active and equal participation by all team members, whereas boys tend to prefer competition, which can be detrimental to the girls' learning experience).
- **Introducing role models** to inspire pupils with concrete examples of people who succeeded before them. Invite STEAM professionals in the classroom to connect learning and real-life examples. You can also create a mentoring system with older pupils to support the younger ones.

If you are in need of inspiration on how to advocate for more gender equality in STEAM, you can have a look at these **initiatives promoting women in STEAM**:

- **Soapbox Science** (International)
- **Girls in STEAM** (International)
- **Girls Who Code** (International)
- **The European Platform of Women** (Europe)
- **FeSTEM** (Europe)
- **Frauen in MINT Berufen** (DE)
- **Komm, mach MINT** (DE)
- **Female Engineer of the Year Izbor Inženirka leta** (Slovenia)
- **We are HERe** (Italy)
- **Associazione Donne e Scienza** (Italy)
- **Donne nella scienza** (Italy)
- **WomInTech** (Belgium)
- **Mulheres na Ciência** (Portugal)
- **STEM for Her** (USA)
- **Stemettes** (UK)

Inspiring girls and women in STEAM

Always remember that representation matters! We have already documented the importance of introducing girls to female role models from a very young age. However, such as in actual STEAM fields, there is a lack of representation of girls and women in STEM in pedagogical material as well as pop culture where high-quality portrayals of female scientists, mathematicians or engineers are also absent. Research conducted by the Geena Davis Institute in 2012 found that **for every 15 male characters working in a STEAM field, there was only 1 female character in a STEM career** (Portray her, 2023). However, the impact of being introduced to inspiring female role models in media (literature, cinema, television, etc.) has been demonstrated on many occasions. For example, "The Scully Effect " refers to the positive influence that the character Dana Scully from the TV series "The X Files" - portraying an ambitious medical doctor and FBI agent – had on women. Nearly two-thirds of women currently working in STEAM cite the character as a role model and part of the reason they chose a STEM career (The Scully effect, 2023).

Research has also demonstrated that children's interest in STEAM increases if they are exposed to **stories** before and engaged in **hands-on activities** (Morais, 2021).

Teachers and educators are therefore encouraged to actively search for good media representation and share good role models with their pupils. By exposing children to media content that reflects a variety of perspectives and experiences in a positive and accurate manner, they will become more aware of the existing possibilities offered to them. Showcasing the many jobs and careers that exist within the STEAM fields also allow pupils to see beyond STEM as theoretical subjects but rather provide inspirational examples to which they can relate.

Given the comprehensive evidence at hand, the **STEAM Tales** project endeavours to foster the inclination

of female youths towards Science, Technology, Engineering, Arts, and Mathematics (STEAM) disciplines through the dissemination of **narratives featuring 12 exemplary women in STEAM**, complemented by **hands-on experiments**. Employing **storytelling** as a pedagogical approach, the project seeks to elucidate STEAM concepts in a manner conducive to the cognitive grasp of young learners, thereby stimulating their engagement and interest.

Our selection of **female role models** spans **diverse cultural, ethnic, and religious backgrounds**, echoing our commitment to inclusivity. We aim to empower girls by showcasing that birthplace, skin colour, or beliefs pose no barriers to success in STEAM. Rather than focusing on the already renowned figures like Marie Curie or Rosalind Franklin, we intended to put in the spotlight the fascinating stories of sometimes **overlooked women** as well as **contemporary women** currently shaping the STEAM landscape. Following an adapted **storytelling methodology** (Campbell's model revised by Universidade do Porto), each story begins with relatable childhood anecdotes, offering a familiar starting point for young minds. As the narratives unfold, we unveil the remarkable achievements and the hurdles these women conquered to earn their esteemed positions. These tales are more than just accounts of success; they're testaments to resilience, inspiring every girl to reach for the stars and rewrite history on her own terms.

The STEAM Tales will tell the story of **these exceptional women**: Ana Mayer-Kansky, Andreja Gomboc, Ángela Piskernik, Asta Hampe, Domitila de Carvalho, Elvira Fortunato, Emmy Noether, Maryam Mirzakhani, Rita Levi Montalcini, Rose Dieng-Kuntz, Samantha Cristoforetti, Zita Martins.

Conclusion

The significance of **STEM disciplines**—Science, Technology, Engineering, and Mathematics—extends far beyond mere academic domains, encompassing not only the conventional categories of mathematics, natural sciences, engineering, computer, and information sciences, but also social sciences such as psychology, economics, sociology, and political sciences. **STEM education** is a multifaceted approach focused on the resolution of **real-world problems** by drawing on concepts and procedures from science and mathematics. This approach integrates various STEM areas along with other curricular subjects, framed within real-life contexts to connect with students' daily experiences. STEM education employs an integrated teaching approach where specific content is not siloed but **interconnected**, utilizing dynamic and fluid instructional methods to foster comprehensive understanding and application.

STEAM approach then integrates subjects such as **arts**, language, history and humanities in the educational model, progressing from **interdisciplinary** to **transdisciplinary** integration, and aiming to enhance learning through fostering **21st century skills** such as problem solving, metacognition, creative and critical thinking as well as developing interpersonal communication and collaboration skills, and cultivating curiosity and openness to new ideas.

Storytelling plays a crucial role in STEAM education by engaging students both cognitively and emotionally, thus enhancing their understanding and interest in STEM subjects. It serves as a strategy to **entertain** and **teach** children while linking **theoretical concepts** to **practical applications**. By presenting scientific information through narratives, storytelling aligns with the natural mode of human thought and aids in **memory retention**. It not only facilitates the acquisition of knowledge but also inspires curiosity and positive attitudes towards science. This concept is especially useful for promoting the successes of female role models and inspiring more girls to take interest in STEM and tackle the persisting gender gap in STEM fields.

Hands-on (or kinesthetic or experimental) **learning** is another approach highly valid for STEAM education and fostering the participation of all pupils. It´s based on their direct engagement in the learning process through active participation, manipulation of materials, and real-world application of knowledge and skills. In fact, active pedagogical methods help develop a deeper understanding of the subject matter as well as strengthen the **4 C's skills**: creativity, communication, collaboration, and critical thinking. Hands-on activities are particularly useful when introducing STEAM concepts to younger children and help spark an interest in STEM subjects to improve the participation of underrepresented groups. **Project-based** and **inquiry-based learning** have also strongly beneficial impact on STEAM education and girls´ empowerment as they are student-oriented, process-driven, and rooted in the real world.

Underrepresentation of women in STEM education and profession is evident in all partner countries as well as across the EU and OECD countries. The root causes of **female underrepresentation in STEM fields** are multifaceted and interconnected, stemming from various societal, cultural, institutional, and individual factors. **Societal expectations and gender roles** often dictate that women are primarily responsible for caregiving and domestic duties, while men are expected to pursue careers as primary providers. These societal norms can influence educational and career choices from an early age, leading to the underrepresentation of women in STEM fields. **Gender stereotypes and biases** perpetuate the belief that STEM field is more suited to men than women. These stereotypes can manifest in subtle ways, such as biased language, cultural representations, and societal attitudes, which can discourage girls and women from pursuing STEM education and careers. **The scarcity of visible female role models** and mentors in STEM fields can make it difficult for girls and women to envision themselves succeeding in these domains. Without positive role models to look up to, girls may feel discouraged or isolated in pursuing STEM-related interests and careers. Finally, **structural barriers** within educational systems and institutions, such as biased teaching methods, curriculum design, and institutional policies, can perpetuate gender disparities in STEM education and careers. Additionally, the lack of support and resources for women in STEM programs and workplaces can further hinder their advancement and retention.

Existing stereotypes and societal beliefs regarding gender roles in STEM fields translate into **internal barriers** for girls and women, including **negative self-perception** and **stereotype threat**.

These internal barriers can lead to reduced confidence, impaired performance, decreased motivation, and limited career aspirations, hindering girls' and women's participation and success in STEM.

Acknowledging and addressing both internal and external barriers is crucial for promoting gender equity and diversity in STEM fields and empowering girls and women to pursue their interests and aspirations in these domains.

Fortunately, there are multiple ways how girls´ participation in STEM can be encouraged. A pivotal role is played by **teachers** and **educators** together with **parents and family members**. Teachers and educators in STEAM education go beyond traditional teaching, they empower their students with subject-specific knowledge and essential skills for success in an evolving world including the 21st century skills, thereby making a meaningful impact on their community and beyond. **Empowering educators** is therefore essential for the success of STEAM education and for pupils' overall development, their progress as well as motivation and future aspiration. Competent STEAM educators recognize the importance of interdisciplinary approaches in addressing real-world challenges. They possess key competencies including interdisciplinary knowledge, pedagogical expertise, assessment literacy, and inclusive practices. These educators create engaging learning environments that stimulate students' curiosity and encourage experimentation with technology. However, schools play a crucial role in supporting educators too by offering necessary training and opportunities for teachers´ professional development, resources, and a conducive culture for STEAM education. Overall, empowering teachers ensures students are prepared to thrive in the dynamic world of STEAM.

However, teachers integrating STEAM education in primary schools face various challenges that hinder its effective implementation. These challenges include limited **resources** and **infrastructures**, such as technological tools, due to budget constraints. Additionally, traditional curricular frameworks often fail to prepare educators for delivering STEAM education, lacking interdisciplinary and project-based approaches. School textbooks may reinforce gender stereotypes, discouraging girls from pursuing STEM careers. Moreover, there are limited professional development opportunities for teachers to gain confidence and knowledge in integrating the STEAM approach.

Inclusive curricula are essential components of promoting STEAM education and ensuring girls' active engagement. By incorporating diverse perspectives, approaches, and activities into the curriculum, educators can create a learning environment that resonates with all students, regardless of their backgrounds or identities. Inclusive curricula not only challenge gender stereotypes but also provide opportunities for girls to see themselves represented in STEAM fields, fostering a sense of belonging and confidence in their abilities. By embracing inclusivity in their curricular design, educators can cultivate a supportive and empowering educational experience that inspires all students to pursue their interests and excel in STEAM disciplines.

Participation in **extracurricular STEAM activities** can also significantly impact girls' interest in STEM careers, with studies showing clearer career understanding and more positive attitudes toward science among participants. Teachers play a vital role in promoting these activities, acting as agents of change in education. All-girl clubs in STEAM provide safe spaces for girls to explore STEM interests and connect with peers and female role models, despite some criticisms. Encouraging participation in such activities can help bridge the gender gap in STEM education and empower girls to pursue STEM careers.

Moreover, **parents** play a crucial role in shaping their daughters' interest and participation in STEM subjects, as their beliefs, attitudes, and support greatly influence children's engagement in these fields. Known as "scientific capital," parents' knowledge and perceptions of STEM subjects significantly impact their children's involvement in STEAM studies. While having a family member working in a STEM field can increase motivation, many parents still hold gender stereotypes about girls' abilities in STEM, affecting the support and encouragement they provide.

Ultimately, achieving **gender equality and diversity in STEM** requires concerted efforts from teachers, educators, parents but also policymakers, and society as a whole. By challenging stereotypes, expanding access to educational opportunities, and nurturing an inclusive culture, we can unlock the full potential of all individuals and harness the power of diverse perspectives to drive innovation and progress in STEM fields. As we strive towards a more equitable future, initiatives like STEAM Tales serve as catalysts for change, empowering the next generation to realize their potential and contribute meaningfully to the advancement of science and technology.

In conclusion, the **STEAM Tales project** is dedicated to nurturing girls' interest in STEM disciplines by sharing captivating stories of 12 inspiring women in STEM fields, coupled with engaging hands-on experiments. Through the power of **storytelling**, this initiative aims to make STEAM topics accessible and captivating for young learners, igniting their curiosity and potentially shaping their future careers. By promoting STEAM education through storytelling and providing practical resources, including lesson plans and experiments, the project not only empowers teachers to enhance their STEM knowledge but also fosters an inclusive learning environment where all children, regardless of background, can thrive. Through research, development, and piloting activities, STEAM Tales seeks to make a lasting impact on STEAM education, enriching the quality of resources available and inspiring a new generation of STEM enthusiasts.

Further reading

Chapter 1: Understanding the STEAM and Storytelling Approach

- ☐ **Article (DE)** about the importance of STEAM education in primary schools, highlighting its significance for children's development: https://www.robowunderkind.com/blog/mint-bildung-grundschule
- ☐ **Article (DE)** about the importance of creating a gender-sensitive environment in early childhood education: https://blog.stiftung-kinder-forschen.de/kleine-forscherinnen-geschlechterunterschiede-im-kita-alltag
- ☐ **Website (DE)** "MINT-freundliche Schule" - Schools that are constantly working to improve the quality of their STEM profile in Germany can apply for a "STEM-friendly School" certificate, under a nationwide initiative: https://mintzukunftschaffen.de/mint-freundliche-schule-2/
- ☐ **Article (SI)** titled Teaching science content by telling an interactive fictional story (Poučevanje naravoslovnih učnih vsebin s pripovedovanjem interaktivne domišljijske zgodbe). In this article, you can read about a case study in a primary school in Slovenia during science days (in two 5th grades) that involved storytelling and experiments: https://www.zrss.si/wp-content/uploads/2023/09/12_AnaLaraSchwarzbartl-RominaPlesecGasparic.pdf
- ☐ **Ministerial Guidelines for teaching STEM (IT):** https://www.miur.gov.it/documents/20182/0/Linee+guida+STEM.pdf/2aa0b11f-7609-66ac-3fd8-2c6a03c80f77?version=1.0&t=1698173043586
- ☐ **Web article (IT)** "Storytelling – an essetial tool for teaching": https://direzionedidatticabastia.edu.it/storytelling-uno-strumento-essenziale-per-linsegnamento-2/
- ☐ **Policy Brief about STEM in Portugal (PT)** by Baptista, M. (2023). Educação STEM em Portugal: iniciativas e desafios para o futuro. IE-Ulisboa: http://www.ie.ulisboa.pt/publicacoes/policy-brief/educacao-stem-em-portugal-iniciativas-e-desafios-para-o-futuro
- ☐ **Article (B/FR)** "What do kids learn in each cycle?": https://www.jereussis.be/guide-de-l-ecole-primaire-et-maternelle/le-guide-de-lenseignement-11-que-doivent-ils-apprendre-a-chaque-cycle/
- ☐ **Article (B/FR)** "The subjects that your kids will learn in kindergarten": https://www.rtbf.be/article/maternelles-voici-ce-que-vont-apprendre-vos-enfants-des-la-rentree-2020-10303065

- ☐ **Article (EN)** about Stereotype threat and its effect on performance and well-being of stereotyped groups by Spencer, S. J. et al. (2016). Stereotype threat. *Annual Review of Psychology*, 67(1), 415–437. https://doi.org/10.1146/annurev-psych-073115-103235
- ☐ **Article (EN)** Examining the effect of early STEM experiences as a form of STEM capital and identity capital on STEM identity by Cohen, S. M., Hazari, Z., Mahadeo, J., Sonnert, G., & Sadler, P. M. (2021). *Science Education*, 105(6), 1126-1150. https://doi.org/https://doi.org/10.1002/sce.21670
- ☐ **PISA 2022 Results: The State of Learning and Equity in Education (EN)** https://www.oecd-ilibrary.org/education/pisa-2022-results-volume-i_53f23881-en
- ☐ **Article (EN)** by Deutsche Akademie der Naturforscher Leopoldina e. V. – the German National Academy of Sciences – that delves into recommendations for achieving gender equality in the field of science: https://www.leopoldina.org/en/press-1/news/leopoldina-presents-recommendations-for-gender-equality-in-science/
- ☐ **Report (DE)** STEM Young Talent Barometer is a nationwide trend report: https://www.acatech.de/publikation/mint-nachwuchsbarometer-2023/
- ☐ **Interview (DE)** about gender-neutral approaches to STEM education in early childhood and how to address gender disparities in STEM: https://blog.stiftung-kinder-forschen.de/kleine-forscherinnen-geschlechterunterschiede-im-kita-alltag
- ☐ **Podcast (SI)** titled »What are some of the biggest obstacles for women in science«. A debate between three well established Slovenian women scientists and researchers, all three coming from STEM field: https://www.rtvslo.si/radio/podkasti/intelekta/49/175043697
- ☐ **Article (IT)** about gender gap in the Italian university system by Cagno, M. (2021): https://traileoni.it/2021/10/gender-gap-in-the-italian-university-system-a-reversed-leaky-pipeline/
- ☐ **Article (IT)** about the roots of gender gap in Italian education by Cimpanelli, G. (2023): https://www.repubblica.it/dossier/economia/valore-italia/2023/06/15/news/gender_gap_la_voragine_femminile_nelle_discipline_stem_nasce_a_scuola-404552109/
- ☐ **Article (B/FR)** "The representation of women in sciences is not enough": https://www.rtbf.be/article/dans-les-sciences-les-femmes-toujours-sous-representees-10695036
- ☐ **Article (B/FR)** "The need of reducing the gender bias in sciences": https://www.rtbf.be/article/sarah-baatout-cest-important-de-reduire-les-biais-de-genre-dans-les-sciences-et-les-technologies-11147407
- ☐ **Article (B/FR)** "The need of including women in technological sectors": https://www.lesoir.be/427507/article/2022-03-14/labsolue-necessite-dinclure-les-femmes-dans-les-secteurs-technologiques-de
- ☐ **Article (B/FR)** "In science, there aren't enough women in managing positions": https://www.lalibre.be/debats/opinions/2023/02/07/dans-le-domaine-des-sciences-les-femmes-ne-sont-pas-suffisamment-nombreuses-aux-postes-de-direction-XZKSUAWE5ZG67P4KIL4GJFD3IY/

- ☐ **Document (EN)** - Tasiopoulou, E., Grand-Meyer, E., & Gras-Velazquez, A. (2022). Getting to know the STE(A)M IT learning Scenarios. http://files.eun.org/STEAMIT/STE(A)M-IT-GettingtoknowtheSTE(A)MITlearningScenariosin_v01.pdf
- ☐ **Web page (EN)** "STEAM IT: Learning Scenarios for Primary Education": https://steamit.eun.org/category/primary-education/
- ☐ **Article (EN)** - World Economic Forum article highlighting the influence of gender bias on perceptions of STEM fields, particularly in relation to categorising them as 'soft' or 'hard' sciences by Light, A. (2022, January 28). *How are gender stereotypes affecting perceptions of STEM careers?* World Economic Forum: https://www.weforum.org/agenda/2022/01/stem-science-women-gender-stereotypes-bias-equality
- ☐ **Project** (in 6 languages, including **EN** and **SI**) STEMbot. One can find 20 science experiments video tutorials and a pedagogical guide on how to use and create chatbot for STEM teaching: https://www.stembot.eu/
- ☐ **Initiative (DE)** "Frauen in MINT Berufen" (Women in STEM professions): The aim of the initiative is to specifically encourage girls and women in their decision for STEM professions and to accompany them on their way into the STEM working world: https://mint-frauen-bw.de/
- ☐ **iMINT Academy (DE)** supports teachers in Berlin and Brandenburg with special learning opportunities for pupils (the "i" stands for "inclusive"): *https://bildungsserver.berlin-brandenburg.de/i-mint-akademie/*
- ☐ **Initiative (DE)** "Komm, mach MINT" (Come, do STEM): The aim of the initiative is to use the potential of women for scientific and technical professions in view of the emerging shortage of skilled workers: https://www.komm-mach-mint.de/
- ☐ **Scientists Foundation (DE)** "Stiftung Kleine Forscher (Little)": A nationwide educational initiative in which all daycare centers, after-school care centers and primary schools can participate: https://www.stiftung-kinder-forschen.de/
- ☐ **Article (IT)** "The teaching of STEM disciplines in Italy" by Scippo, S., Montebello, M., & Cesareni, D. (2020). *ITALIAN JOURNAL OF EDUCATIONAL RESEARCH*, (25), 35–48: https://ojs.pensamultimedia.it/index.php/sird/article/view/4362
- ☐ **Educational resources (EN, IT)** "Inspiring Next Generation of Girls through Inclusive STE(A)M Learning in Primary Education – IN2STE(A)M": https://in2steam.eu/outputs/?lang=it
- ☐ **Article (PT)** - presenting findings on the impact of an integrated STEM approach on the development of didactic knowledge among prospective teachers in a higher education institution in Portugal by Correia, M., & Martins, M. (2021). Abordagem Integradora das STEM: Uma Experiência na Formação Inicial de Professores. In P. Membiela, M. I. Cebreiros y M. Vidal (eds). Perspectivas y prácticas docentes en la enseñanza de las ciencias (pp. 443-448).

- ☐ **Conference Paper (PT)** - Correia, M., Martins, M., & Camacho, G. (2021). *As potencialidades da Educação STEM no 1.º Ciclo. Uma experiência na formação de professores*: https://www.researchgate.net/publication/357468808_Abordagem_Integradora_das_STEM_Uma_Experiencia_na_Formacao_Inicial_de_Professores
- ☐ **Web page (PT)** "GoSTEM: Eventos": http://gostem.ie.ulisboa.pt/participantes/
- ☐ **Paper (PT)** *Cenários integrados de aprendizagem – trabalho interdisciplinar de Ciências, Tecnologia, Engenharia, Artes e Matemática* by Cerqueira, S., Oliveira, I., & Fernandes, A.: https://escolamais.dge.mec.pt/sites/default/files/2021-07/1.3.5.-roteiro_recuperar-experimentando.pdf
- ☐ **Article (B/FR)** "The Educational Foundation wants to attract young people to Stem jobs": https://www.lecho.be/economie-politique/belgique/wallonie/la-fondation-pour-l-enseignement-veut-attirer-les-jeunes-vers-les-stem/10458395.html
- ☐ **Article (B/FR)** "NO STEM, no future": https://www.digitalwallonia.be/fr/publications/no-stem-no-future/
- ☐ **Publication by UNESCO (EN + multiple languages)** "Cracking the code: girls' education in science, technology, engineering and mathematics (STEM)" a report of the UNESCO International Symposium and Policy Forum: https://unesdoc.unesco.org/ark:/48223/pf0000260079

- ☐ **Article (EN)** - A review of existing STEAM initiatives worldwide, but specifically in Europe, as well as the most popular activities provided by these initiatives: Hasti, H.; Amo-Filva, D.; Fonseca, D.; Verdugo-Castro, S.; García-Holgado, A.; García-Peñalvo, F.J. *Towards Closing STEAM Diversity Gaps: A Grey Review of Existing Initiatives*. Appl. Sci. 2022, 12, 12666. https://doi.org/10.3390/app122412666
- ☐ **Article (EN)** developed by Vernier Science Education, a science education company dedicated to providing high-quality solutions for today's STEM classrooms, that highlights five research-based Best Practices for STEM Education: https://www.vernier.com/blog/five-research-based-best-practices-for-stem-education/
- ☐ **Video testimonies (EN)** *STEMFAIRNET project*: https://stemfairnet.home.blog/video-testimonies/
- ☐ **Article (DE)** about the significance of hands-on, extracurricular STEM activities to encourage students' active engagement in STEM subjects: https://www.studienkreis.de/infothek/journal/ausserschulische-mint-angebote/
- ☐ **Museum Exhibition (DE)** "ExperiMINTa Science Center" is an interactive museum opened in Frankfurt in March 2011 where STEM comes to life through hands-on exploration: https://www.experiminta.de/
- ☐ **Audiovisual (PT)** *Educação STEAM | Atividades Escolas 1º, 2º e 3º CEB*: https://www.youtube.com/watch?v=MZyXL5NFnEU
- ☐ **Article (B/FR)** "The Higher Education Institutes of the Wallonia-Brussels Federation (FWB): practical and professional education.": https://www.rtbf.be/article/les-hautes-ecoles-de-la-fwb-un-enseignement-pratique-et-professionnalisant-11030722
- ☐ **Website (B/FR)** – a database of scientific experiments, exercises, videos and other materials for teaching and learning about science: eSCIENCES - Les sciences à la maison

- ☐ **White Paper (EN)** - A study by Microsoft titled "Why aren't European girls in STEM?" which examines the underrepresentation of women in STEM fields in Europe: https://news.microsoft.com/wp-content/uploads/2017/02/Microsoft_girls_in_STEM_final-Whitepaper.pdf
- ☐ **Interview (EN)** - A written interview with Stefanie Dimmeler, a distinguished German biologist renowned for her expertise in the pathophysiological mechanisms underlying cardiovascular diseases, where talks about her pioneering research on the treatment of cardiovascular diseases and the hope of being a role for younger female scientists to pursue their career and follow their visions: https://www.elsevier.com/connect/meet-prof-stefanie-dimmeler-winner-of-the-2022-otto-warburg-medal
- ☐ **Video (EN)** that highlights some of the greatest inventions made my female scientists from Germany: https://www.youtube.com/watch?v=O6qN0VMHYk4
- ☐ **Web article (DE)** "The German MINT Action Plan" is a comprehensive plan to promote STEM education for children and young people at all levels of education. The plan focuses on strengthening early STEM education: https://www.bmbf.de/bmbf/de/bildung/digitalisierung-und-mint-bildung/mint-bildung/mint-aktionsplan.html
- ☐ **Web article (IT)** Didattica: 5 Tips to Encourage Girls to Pursue STEM: https://blog.matematica.deascuola.it/articoli/didattica-stem-ragazze
- ☐ **Video (IT)** about women in science in past, present and future by SMA - Sistema Museale d'Ateneo Università di Pavia: https://www.youtube.com/watch?v=8CafA0WSzIo&list=PLlgIfikBMHGkAcdepiu1iX8zizYkjh7U-
- ☐ **Audiovisual materials (PT)** "Soapbox Science: Mostrar a ciência no feminino." https://youtu.be/ExzQENvVtPw
- ☐ **Web page (PT)** "Medalhas de Honra L'Oréal Portugal para as Mulheres na Ciência.": https://www.fct.pt/financiamento/premios/medalhas-de-honra-loreal-portugal-para-as-mulheres-na-ciencia/
- ☐ **Exhibition (PT)** "Exposição "Ciência no Feminino 2.0" para ver no Departamento de Física da Universidade de Coimbra." https://noticias.uc.pt/artigos/exposicao-ciencia-no-feminino-2.0-para-ver-no-departamento-de-fisica-da-universidade-de-coimbra/
- ☐ **Web article (B/FR)** "Podcasts about women in science": https://www.rtbf.be/article/sciences-et-tech-elles-prennent-leur-place-une-serie-de-podcasts-creee-par-les-grenades-11162263

Bibliography

Acatech / IPN / Joachim Herz Stiftung (2023). *MINT Nachwuchsbarometer 2023 [STEM Young Talent Barometer 2023].* Cooperation publication between Acatech – National Academy of Science and Engineering & Joachim Herz Stiftung. IPN – Leibniz-Institut für die Pädagogik der Naturwissenschaften und Mathematik. Kiel, Germany.

Aguilera, D., & Ortiz-Revilla, J. (2021). STEM vs. STEAM Education and Student Creativity: A Systematic Literature Review. *Education Sciences*, *11*(7).

Alam, S. et al. (2021). STEM Education in Europe: Inclusively inspiring and enabling more young people to pursue aerospace and STEM. In *Women in Aerospace Europe*. WIA - Europe. https://www.wia-europe.org/wpcontent/uploads/2022/03/STEM_EDUCATION_WIA_EUROPE_WHITE_PAPER.pdf

Anger, C., Betz, J., & Plünnecke, A. (2023). *MINT-Frühjahrsreport 2023: MINT-Bildung stärken, Potenziale von Frauen,* Älteren *und Zuwandernden heben [STEM Spring Report 2023: Strengthening STEM education, raising the potential of women, older people and immigrants].* Institut der deutschen Wirtschaft Köln e. V. Cologne, Germany.

Archer et al. (2010). L. Archer, J. DeWitt, J. Osborne, J. Dillon, B. Willis, B. Wong. "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, 94 (2010), pp. 617-639

Baillie, C., & Levine, M. (2013). Engineering ethics from a justice perspective: A critical repositioning of what it means to be an engineer. *International Journal of Engineering, Social Justice, and Peace*, *2*(1), 10-20.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American psychologist*, *37*(2), 122.

Baptista, M. (2023). *Educação STEM em Portugal: iniciativas e desafios para o futuro*. IE-ULisboa.

Barchas-Lichtenstein, J., Sherman, M., Voiklis, J., & Clapman, L. (2023). Science through storytelling or storytelling about science? Identifying cognitive task demands and expert strategies in cross-curricular STEM education [Original Research]. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1279861

Becker, J. 1995 'Women's Ways of Knowing in Mathematics'. In Rogers, P and Kaiser, G. (Eds) Equity in Mathematics Education: Influences of Feminism and Culture, Falmer Press, London.

Beegle, K., Hammond, A., Kumaraswamy, S & Matulevich, E. (2020). *THE EQUALITY EQUATION. Advancing the Participation of Women and Girls in STEM*. The World Bank Group. Available at: https://openknowledge.worldbank.org/server/api/core/bitstreams/d85229dc-c43c-527e-b014-bd6a37d666a8/content

Bergamante, F. & Mandrone, E. (2022). *RAPPORTO PLUS 2022: Comprendere la complessità del lavoro*. Istituto Nazionale per l'analisi delle politiche pubbliche.

Bertrand, M. G. & Namukasa, I. K. (2020). STEAM education: student learning and transferable skills. *Journal of Research in Innovative Teaching & Learning, 13*(1), 43-56. https://doi.org/10.1108/JRIT-01-2020-0003

Bevan, B., Peppler, K., Rosin, M., Scarff, L., Soep, E., & Wong, J. (2019). Purposeful Pursuits: Leveraging the Epistemic Practices of the Arts and Sciences. In A. J. Stewart, M. P. Mueller, & D. J. Tippins (Eds.), *Converting STEM into STEAM*

Programs: Methods and Examples from and for Education (pp. 21-38). Springer International Publishing. https://doi.org/10.1007/978-3-030-25101-7_3

Bevan, R. (2001). Boys, Girls and Mathematics: Beginning to Learn from the Gender Debate. *Mathematics in School, 30*(4), 2-6. https://doi.org/10.2307/30215463

Bonito, J., & Oliveira, H. (2022). A abordagem STEAM no currículo português: distanciamentos e aproximações. In A. S. Neto, A. C. Silva, & I. Fortunato (Orgs.), Coletânea do Congresso Paulista de Ensino de Ciências: discutindo o ensino de ciências nos países ibero-americanos (pp. 19-48). Edições Hipótese.

Borsotti, V. (2018). Barriers to gender diversity in software development education: actionable insights from a danish case study. In *Proceedings of the 40th International Conference on Software Engineering: Software Engineering Education and Training* (pp. 146-152).

Boström, A. (2006). Sharing lived experience: How upper secondary school chemistry teachers and students use narratives to make chemistry more meaningful.

Botella, C., Rueda, S., López-Iñesta, E., & Marzal, P. (2019). Gender diversity in STEM disciplines: A multiple factor problem. *Entropy*, *21*(1), 30.

Braund, M., & Reiss, M. (2019). The 'Great Divide': How the Arts Contribute to Science and Science Education. *Canadian Journal of Science, Mathematics and Technology Education*, *19*. https://doi.org/10.1007/s42330-019-00057-7

Breiner, J. M., Johnson, C. C., Harkness, S. S., & Koehler, C. M. (2012). What Is STEM? A Discussion About Conceptions of STEM in Education and Partnerships [Article]. *School Science & Mathematics*, *112*(1), 3-11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

Bridging the STEM Gap: 5 Things Parents Can Do – Built by Me ® – STEM learning. (06/03/2019). Built by Me ® – STEM Learning - Built by Me STEM Learning – the Learning Center for the 21st Century®. https://www.builtbyme.com/bridging-the-stem-gap-things-parents-can-do/

Brugeilles, C., & Cromer, S. (2009). *Promoting gender equality through textbooks: a methodological guide*. UNESCO.

Cech, E. A. (2014). Culture of disengagement in engineering education?. *Science, Technology, & Human Values*, *39*(1), 42-72.

Ceci, S. J., Ginther, D. K., Kahn, S., & Williams, W. M. (2014). Women in academic science: A changing landscape. *Psychological science in the public interest*, *15*(3), 75-141.

Cheryan, S., Drury, B. J., & Vichayapai, M. (2013). Enduring influence of stereotypical computer science role models on women's academic aspirations. *Psychology of women quarterly*, *37*(1), 72-79.

Cheryan, S., & Plaut, V. C. (2010). Explaining underrepresentation: A theory of precluded interest. *Sex roles*, *63*, 475-488.

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others?. *Psychological bulletin*, *143*(1), 1.

Chiangpradit, L. (2023). Alternatives to Standardized STEM testing. STEM Sports. Accessed 11/12/2023. Available at: https://stemsports.com/alternatives-to-standardized-stem-testing/

Choi, B. C. K., & Pak, A. W. P. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. *Clinical and Investigative Medicine 29*(6), 351-364. http://europepmc.org/abstract/MED/17330451

Cimpanelli, G. (2023, June 15). Gender Gap, *la voragine femminile nelle discipline stem nasce a scuola.* la Repubblica. https://www.repubblica.it/dossier/economia/valore-italia/2023/06/15/news/gender_gap_la_voragine_femminile_nelle_discipline_stem_nasce_a_scuola-404552109/

Claris, L., & Riley, D. (2012). Situation critical: critical theory and critical thinking in engineering education. *Engineering Studies*, *4*(2), 101-120.

Closing the STEM Gap: Why STEM classes and careers still lack girls and what we can do about it. (2018). Microsoft. https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE1UMWz

Cohen, S. M., Hazari, Z., Mahadeo, J., Sonnert, G., & Sadler, P. M. (2021). Examining the effect of early STEM experiences as a form of STEM capital and identity capital on STEM identity: A gender study. *Science Education*, *105*(6). https://doi.org/10.1002/sce.21670

Consulio, Smart Venice, VHTO, Wide, LIST, & PRoF. (2020). *GENDER AWARE EDUCATION AND TEACHING IN STEM Collection of resources and best practices*. Gender4STEM. https://wide.lu/wp-content/uploads/2020/05/Gender4STEM-best-practices.pdf

Corbett, C., & Hill, C. (2015). *Solving the Equation: The Variables for Women's Success in Engineering and Computing*. American Association of University Women. 1111 Sixteenth Street NW, Washington, DC 20036.

Dasgupta, N. (2011). Ingroup experts and peers as social vaccines who inoculate the self-concept: The stereotype inoculation model. *Psychological Inquiry*, *22*(4), 231-246.

DBS (n.d.). *Lehrpläne* für die *Grundschule. [Primary school curricula].* Deutschen Bildungsserver - German Education Server. Retrieved 23/10/2023: https://www.bildungsserver.de/lehrplaene-fuer-die-grundschule-1660-de.html.

Dernières ressources Mises en Ligne. (n.d.), https://www.pass-education.be/.

Destatis - Federal Statistical Office of Germany (2023, August 8). *Studierende in Mathematik, Informatik, Naturwissenschaft (MINT) und Technik-Fächern* [Dataset]. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bildung-Forschung-Kultur/Hochschulen/Tabellen/studierende-mint-faechern.html

DGE. (2018). *Aprendizagens Essenciais*. http://dge.mec.pt/aprendizagens-essenciais-ensino-basico.

Di Cagno, M. (2021). Gender gap in the Italian university system: a "reversed" leaky pipeline? *Tra I Leoni.* https://traileoni.it/2021/10/gender-gap-in-the-italian-university-system-a-reversed-leaky-pipeline/

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological science*, *21*(8), 1051-1057.

Diemer, M. A., & Rapa, L. J. (2016). Unraveling the complexity of critical consciousness, political efficacy, and political action among marginalized adolescents. *Child development, 87*(1), 221-238.

Digital Skills and Jobs Platform of the European Union. (2022). Female Engineer of the Year - Slovenia. Retrieved on 20th December 2023 from https://digital-skills-jobs.europa.eu/en/inspiration/good-practices/female-engineer-year-slovenia

Dyer, E. B. (2017). *Teachers Often Lack of Access to Quality STEM Professional Development*. American Institute for Research. New York, NY: 100kin10. Available at: https://grandchallenges.100kin10.org/assets/downloads/teachers-often-lack-access-to-quality-stem-professional-development-1/GrandChallengesWhitePapers_Dyer.pdf

Education and Training Monitor 2022. (2022). https://op.europa.eu/webpub/eac/education-and-training-monitor-2022/en/country-reports/italy.html#4-school-education.

El-Hout, M., Garr-Schultz, A., & Cheryan, S. (2021). Beyond biology: The importance of cultural factors in explaining gender disparities in STEM preferences. *European Journal of Personality*, *35*(1), 45-50.

Encinas-Martin, M., & Cherian, M. (2023). Gender, Education and Skills: The Persistenceof Gender Gaps in Education and Skills. *OECD Skills Studies*, 1-54.

Engel, A., Lucido, K., & Cook, K. (2018). Rethinking Narrative: Leveraging storytelling for science learning. *Childhood Education*, *94*(6), 4-12. https://doi.org/10.1080/00094056.2018.1540189

Ertl, B., Luttenberger, S., & Paechter, M. (2017). The impact of gender stereotypes on the self-concept of female students in STEM subjects with an under-representation of females. *Frontiers in psychology*, *8*, 703.

European Institute of Gender Equality, 2018. Overview | Gender Statistics Database. EIGE.

Eurostat. (2024, February 12). 41% of people employed as scientists and engineers are women. https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20240212-1

Farias, S. S. (2021). O PISA 2018 e a educação STEM das raparigas. *Instituto de Sociologia da Universidade do Porto*. http://www.barometro.com.pt/2021/08/02/o-pisa-2018-e-a-educacao-stem-das-raparigas/

Fernandes, D., Neves, C., Tinoca, L., Viseu, S., & Henriques, S. (2019). Políticas educativas e desempenho de Portugal no PISA (2000-2015). Lisboa: Instituto de Educação.

Gilligan, C. 1982 In a Different Voice: Psychology Theory and Women's Development, Harvard University Press, Cambridge, Ma.

Gottfredson, L. S. (1981). Circumscription and Compromise: A Developmental Theory of Occupational Aspirations. *Journal of Counseling Psychology Monograph*, *28*(6). https://doi.org/0022-0167/81/2806-0645$00.75

Gottfried, M., Owens, A., Williams, D., Kim, H. Y., & Musto, M. (2017). Friends and family: A literature review on how high school social groups influence advanced math and science coursetaking. *Education Policy Analysis Archives*, *25*, 62-62, https://epaa.asu.edu/index.php/epaa/article/view/2857/1923.

Gouvêa, M., Santoro, F., Cappelli, C., Motta, C., & Borges, M. (2019). *Epos: The Hero's Journey in organizations through Group Storytelling*. https://doi.org/10.1109/CSCWD.2019.8791860

Hanekamp, G. & MINT Forum (2021). MINT-Personal An Schulen [STEM staff in schools]. Nationales MINT Forum (Hrsg.). Dortmund, Germany.

Hands On Learning – Definition & Meaning. ProctorEdu.com. https://proctoredu.com/glossary/hands-on-learning

Heybach, J., & Pickup, A. (2017). Whose STEM? Disrupting the gender crisis within STEM. *Educational Studies*, *53*(6), 614-627.

Herrington J., Oliver R., Reeves T., (2002). Authentic activities and online learning. 25th HERDSA Annual Conference, Australia. (pp. 562 – 567). https://ro.ecu.edu.au/cgi/viewcontent.cgi?article=4899&context=ecuworks

Herrmann, S. D., Adelman, R. M., Bodford, J. E., Graudejus, O., Okun, M. A., & Kwan, V. S. (2016). The effects of a female role model on academic performance and persistence of women in STEM courses. *Basic and Applied Social Psychology*, *38*(5), 258-268.

Hessisches Kultusministerium (n.d.). Hessische Kerncurricula - Primarstufe [Hessian Core Curricula - Primary level]. Ministry of Education and Cultural Affairs of Hessen. Retrieved 24/10/2023: https://kultusministerium.hessen.de/Unterricht/Kerncurricula-Primarstufe.

Hill, C., Corbett, C., & St Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. American Association of University Women. 1111 Sixteenth Street NW, Washington, DC 20036.

Hu, J., Gordon, C., Yang, N., & Ren, Y. (2021). "Once Upon A Star": A Science Education Program Based on Personification Storytelling in Promoting Preschool Children's Understanding of Astronomy Concepts. *Early Education and Development*, *32*(1), 7-25. https://doi.org/10.1080/10409289.2020.1759011

Huser, J. (2020). *STEAM and the Role of the Arts in STEM*. New York: State Education Agency Directors of Arts Education. Available at: https://www.nationalartsstandards.org/sites/default/files/SEADAE-STEAM-WHITEPAPER-2020.pdf

ILOSTAT. (2020). How many women work in STEM? Retrieved 13th October 2023 from https://ilostat.ilo.org/how-many-women-work-in-stem/

Indicazioni nazionali per il curricolo della scuola dell'infanzia e del primo ciclo di istruzione. (2012). In *MIUR*. Ministero dell'istruzione dell'Università e della Ricerca, https://www.miur.gov.it/documents/20182/51310/DM+254_2012.pdf.

Jacques, C. (2017). *Teachers lack funding to provide quality STEM instructional experiences.* American Institute for Research. New York, NY: 100kin10. Accessed 10/12/2023. Available at: https://grandchallenges.100kin10.org/assets/downloads/teachers-lack-funding-to-provide-quality-stem-instructional-experiences/GrandChallengesWhitePapers_Jacques.pdf

Jirout J. J., Vitiello E., Zumbrunn S. K. (2018). Curiosity in Schools. Gordon G. (ed.) *The New Science of Curiosity*. (Chapter 10). Nova Science Publisher, Inc. https://www.researchgate.net/profile/Jamie-Jirout/publication/329569586_CURIOSITY_IN_SCHOOLS/links/5ef39deb4585153fb1b3858f/CURIOSITY-IN-SCHOOLS.pdf

Johnson, O. (2019). *The Impact of Parent Involvement on High-Achieving Females' Mathematics Performance and Decision to Major in Science, Technology, Engineering, and Mathematics* [PhD Dissertation]. Columbia University. https://academiccommons.columbia.edu/doi/10.7916/d8-bqqp-yg29

Journée de lutte pour les droits des femmes - Trop peu de femmes dans les métiers STEM, pourtant en pénurie, pointe le Forem. (n.d.). [web log]. Retrieved from https://www.lesoir.be/427901/article/2022-03-03/trop-peu-de-femmes-dans-les-metiers-stem-pourtant-en-penurie-pointe-le-forem

Kang, J., Hense, J., Scheersoi, A., & Keinonen, T. (2019). Gender study on the relationships between science interest and future career perspectives. *International Journal of Science Education*, *41*(1), 80-101

Kekelis, L. (2017, October 26). *Parent engagement: Key for girls in Stem*. ETR Blog. https://www.etr.org/blog/parent-engagement-key-for-girls-in-stem/

Kerkhoven, A. H., Russo, P., Land-Zandstra, A. M., Saxena, A., & Rodenburg, F. J. (2016). Gender stereotypes in science education resources: A visual content analysis. *PloS one*, *11*(11), e0165037.

Klemm, K. (2022). *Entwicklung von Lehrkräftebedarf und -angebot in Deutschland bis 2030* [Development of teacher demand and supply in Germany until 2030]. Verband Bildung und Erziehung (VBE). Berlin, Germany.

Konrad, A. M., Ritchie Jr, J. E., Lieb, P., & Corrigall, E. (2000). Sex differences and similarities in job attribute preferences: a meta-analysis. *Psychological bulletin*, *126*(4), 593.

Krajewski Lockwood, D. (2020). *The Future is Female: STEAM Education Analysis* [Doctoral Dissertation]. University of South Carolina. https://scholarcommons.sc.edu/etd/6097

Lin-Siegler, X., Ahn, J. N., Chen, J., Fang, F. F. A., & Luna-Lucero, M. (2016). Even Einstein struggled: Effects of learning about great scientists' struggles on high school students' motivation to learn science. *Journal of Educational Psychology*, *108*(3), 314.

Lloyd, A., Gore, J., Holmes, K., Smith, M., & Fray, L. (2018). Parental influences on those seeking a career in STEM: The primacy of gender. *International Journal of Gender, Science, and Technology*, *10*(2), 308–328. http://genderandset.open.ac.uk/index.php/genderandset/article/download/510/959

Lockwood, P., & Kunda, Z. (1997). Superstars and me: Predicting the impact of role models on the self. *Journal of personality and social psychology*, *73*(1), 91. https://doi.org/10.1037/0022-3514.73.1.91

Lourenço, V., Duarte, A., Nunes, A., Amaral, A., Gonçalves, C., Mota, M., & Mendes, R. (2019). PISA 2018 – Portugal. Relatório Nacional. Lisboa: IAVE.

Main P., (2023). *Hands-on Learning*. Structural-learninig.com. https://www.structural-learning.com/post/hands-on-learning

Makarova, E., Aeschlimann, B., & Herzog, W. (2019). The Gender Gap in STEM Fields: The Impact of the Gender Stereotype of Math and Science on Secondary Students' Career Aspirations. *Frontiers in Education*, *4*. https://doi.org/10.3389/feduc.2019.00060

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, *6*(1), 2. https://doi.org/10.1186/s40594-018-0151-2

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education*, *103*(4), 799-822. https://doi.org/https://doi.org/10.1002/sce.21522

Master, A., Cheryan, S., & Meltzoff, A. N. (2014). Reducing adolescent girls' concerns about STEM stereotypes: When do female teachers matter?. *Revue internationale de psychologie sociale*, *27*(3), 79-102.

McNally, S., Gillic, C., O'Reilly, N., & Dobrus, H. (2022). Parents as facilitators of STEAM learning in early childhood: A literature review. *The Childhood Development Initiative*.

Milanovic, I., et al. (2023). INCLUSIVE STEM LEARNING ENVIRONMENTS: CHALLENGES AND SOLUTIONS. *Scientix*. https://www.scientix.eu/documents/10137/121801/Scientix-STNS_Inclusive-STEM-Learning-Enviroments-Ready-for-publication.pdf/9f8ebd46-a84f-feac-8bb3-748e3a7f582f?t=1676035712496

Milgram, D. (2011). How to recruit women and girls to the science, technology, engineering, and math (STEM) classroom. *Technology and engineering teacher*, *71*(3).

Moore, J., (2022). *Benefits of a Hands on Learning*. Sec.act.edu.au. https://sec.act.edu.au/benefits-of-a-hands-on-learning/

Moore, L. (2022). *How too much parental pressure can affect kids' mental health.* Psych Central. https://psychcentral.com/lib/parental-pressure-and-kids-mental-health

Morais, C., Moreira, L., Baptista, M., & Martins, I. (2021). Digital tools entering the scene in STEM activities for Physics teaching. In A. Reis, *Technology and Innovation in Learning, Teaching and Education* TECH-EDU 2020. Communications in Computer and Information Science, Cham.

Murphy, M. C., Steele, C. M., & Gross, J. J. (2007). Signaling threat: How situational cues affect women in math, science, and engineering settings. *Psychological science*, *18*(10), 879-885.

N.S.T. Association, *et al.* Nsta position statement: Elementary science education (2018) in Norismiza Ismail, Umi Kalsom Yusof (2023). A systematic literature review: Recent techniques of predicting STEM stream students, Computers and Education: Artificial Intelligence, Volume 5, 2023, 100141, ISSN 2666-920X, https://doi.org/10.1016/j.caeai.2023.100141.

OECD. (2021). Education at a Glance 2021: OECD Indicators. Retrieved on 20th December 2023 from https://www.oecd-ilibrary.org/sites/e7ee86cb-en/index.html?itemId=%2Fcontent%2Fcomponent%2Fe7ee86cb-en

OECD (2023). OECD Education GPS (Version 2023) [Dataset]. https://gpseducation.oecd.org/CountryProfile?primaryCountry=ITA&treshold=10&topic=EO

OECD (2023), PISA 2022 Result (Volume I): The State of Learning and Equity in Education, PISA, OECD Publishing, Paris, https://www.oecd-ilibrary.org/education/pisa-2022-results-volume-i_53f23881-en.

Olmedo-Torre, N., Carracedo, F. S., Ballesteros, M. N. S., López, D., Perez-Poch, A., & López-Beltrán, M. (2018). Do female motives for enrolling vary according to STEM profile?. *IEEE Transactions on Education*, *61*(4), 289-297.

Paiva, A., Gomes, A., Silva, V., Machado, I., & Dias, R. (2019). O storytelling e a literacia científica. *Rev. Ciência Elem.*, *7*(03:051). https://doi.org/10.24927/rce2019.051

Parent engagement: key for girls in STEM. (10/26/2017). ETR Blog. https://www.etr.org/blog/parent-engagement-key-for-girls-in-stem/

Peixoto, A., González, C. S. G., Strachan, R., Plaza, P., de los Angeles Martinez, M., Blazquez, M., & Castro, M. (2018, April). Diversity and inclusion in engineering education: Looking through the gender question. In *2018 IEEE Global Engineering Education Conference (EDUCON)* (pp. 2071-2075). IEEE.

Perales, F. J., & Aróstegui, J. L. (2021). The STEAM approach: Implementation and educational, social and economic consequences. *Arts Education Policy Review*, 1-9. https://doi.org/10.1080/10632913.2021.1974997

Piloto, C. (2023). *The gender gap in Stem*. MIT Professional Education. https://professionalprograms.mit.edu/blog/leadership/the-gender-gap-in-stem/#:~:text=The%20gender%20gap%20in%20STEM%20has%20been%20attributed%20to%20several,pursuing%20STEM%20education%20and%20careers.

Portray her: Geena Davis Institute. (2023, September 29). https://seejane.org/research-informs-empowers/portray-her/

Publications Office of the European Union. (2020). Education and Training Monitor 2020 - Slovenia. Retrieved on 20th December 2023 from https://op.europa.eu/webpub/eac/education-and-training-monitor-2020/countries/slovenia.html

Project Based Learning in STEAM. Pi-top.com https://www.pi-top.com/pbl/for-steam/resources#anchor-form

Ramsey, L. R., Betz, D. E., & Sekaquaptewa, D. (2013). The effects of an academic *Psychology of Education*, *16*, 377-397. https://doi.org/10.1007/s11218-013-9218-6

Roberts T. &Schnepp J. (2020). Building problem-solving skills through STEAM. *Technology and Engeneering Teacher*, *(79)* 8, 8-13. https://www.researchgate.net/publication/340598164_Building_problem-solving_through_STEAM

Robinson, R. (2021). *Girls' Experiences with Gender-Inclusive Curriculum: Effects on Perception, Confidence, and Belief in Ability to do Science* [PhD Dissertation]. Columbia University. https://academiccommons.columbia.edu/doi/10.7916/d8-tfvv-4m19

Roehrig, G., Dare, E., Ring-Whalen, E. & Wieselmann, W. (2021). *Understanding coherence and integration in integrated STEM curriculum*. International Journal of STEM Education, Ed. 8, 2. https://doi.org/10.1186/s40594-020-00259-8

Rosin, M., Wong, J., O'Connell, K., Storksdieck, M., & Keys, B. (2021). Guerilla Science: Mixing Science with Art, Music and Play in Unusual Settings [Article]. *Leonardo*, *54*(2), 191-195. https://doi.org/10.1162/leon_a_01793

Rowcliffe, S. (2004). Storytelling in science. *The School science review*, *86*, 121-125.

Salvatierra L & Cabello VM. (2022) Starting at Home: What Does the Literature Indicate about Parental Involvement in Early Childhood STEM Education? Education Sciences. 12(3):218. https://www.mdpi.com/2227-7102/12/3/218

Scott-Barrett, J., Johnston, S.K., Denton-Calabrese, T., McGrane, J., Hopfenbeck, T. (2023). *Nurturing curiosity and creativity in primary school classrooms*. Teaching and Teacher Education. Vol. 135. 104356. https://doi.org/10.1016/j.tate.2023.104356

Singh, M. (2021). Acquisition of 21st Century Skills Through STEAM Education. *Academia Letters*, Article 712. https://doi.org/10.20935/AL712

Simard, C., Henderson, A. D., Gilmartin, S. K., Schiebinger, L., & Whitney, T. (2008). *Climbing the technical ladder: Obstacles and solutions for mid-level women in technology.* Anita Borg Institute for Women and Technology and the Clayman Institute for Gender Research, Stanford University.

The Scully effect: I want to believe in Stem. Geena Davis Institute. (2023, September 29). https://seejane.org/research-informs-empowers/the-scully-effect-i-want-to-believe-in-stem/

Singh, M. (2021). Acquisition of 21st Century Skills Through STEAM Education. https://doi.org/10.20935/AL712

Sullivan, A. (2019a). *Breaking the STEM Stereotype: Reaching Girls in Early Childhood*. Rowman & Littlefield

Sullivan, A. (2019b). *Supporting Girls' STEM Confidence & Competence: 7 Tips for Early Childhood Educators*. EdTech Review. Accessed 12/12/2023. Available at: https://www.edtechreview.in/trends-insights/insights/supporting-girls-stem-confidence-competence-tips-for-early-childhood-educators/

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of personality and social psychology*, *69*(5), 797.

Stewart, A., Mueller, M., & Tippins, D. (2019). *Converting STEM into STEAM Programs: Methods and Examples from and for Education*. https://doi.org/10.1007/978-3-030-25101-7

Stoeger, H., Hopp, M., & Ziegler, A. (2017). Online mentoring as an extracurricular measure to encourage talented girls in STEM (science, technology, engineering, and mathematics): An empirical study of one-on-one versus group mentoring. *Gifted Child Quarterly*, *61*(3), 239-249.

STA. (2020). Gender stereotypes, discrimination still holding women back in Slovenian STEM careers. Retrieved on 20th December 2023 from https://www.total-slovenia-news.com/lifestyle/5602-gender-stereotypes-discrimination-still-holding-women-back-in-slovenian-stem-careers?utm_content=cmp-true

Sullivan, K., Byrne, J. R., Bresnihan, N., O'Sullivan, K., & Tangney, B. (2015, October). CodePlus—Designing an after school computing programme for girls. In *2015 IEEE Frontiers in Education Conference (FIE)* (pp. 1-5). IEEE.

Taylor, P. (2016). *Why is a STEAM Curriculum Perspective Crucial to the 21st Century?*

Taylor, P.C. (2016). *Session N: why is a STEAM curriculum perspective crucial to the 21st century?,* 2009-2016 ACER Research Conferences. Paper 6, Australian Council for Educational Research (ACER), Melbourne. Available at: https://research.acer.edu.au/cgi/viewcontent.cgi?article=1299&context=research_conference

The Importance of Hands-On Learning. (2021). Thethinkingkid.org. https://www.thethinkingkid.org/post/the-importance-of-hands-on-learning#:~:text=What%20is%20Hands%2DOn%20Learning,a%20problem%20or%20create%20something.

UnderstandingScience.org (2022). The scientific community: Diversity makes the difference - understanding science. *The social side of science: A human and community endeavour.* (2022, September 13). Barkeley Univerisity of California. Available at: https://undsci.berkeley.edu/understanding-science-101/the-social-side-of-science-a-human-and-community-endeavor/the-scientific-community-diversity-makes-the-difference/#:~:text=Diversity%20invigorates%20problem%20solving,shed%20new%20light%20on%20problems.

Tytler, R. & Self, J. (2020). *Designing a contemporary STEM curriculum*. UNESCO. IBE/2020/WP/CD/39. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000374146

UNESCO. (2017). *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM)*. ISBN: 978-92-3-100233-5. (CC BY-SA 3.0 IGO) [12461]. 85 p., illus. English ed. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000253479

UNESCO. (2017). *UNESCO moving forward the 2030 Agenda for Sustainable Development*. https://unesdoc.unesco.org/ark:/48223/pf0000247785

UNICEF (2020). *Towards an equal future: Reimagining girls' education through STEM*. ISBN: 978-92-806-5178-2. New York, 2020. Available at: https://www.unicef.org/media/84046/file/Reimagining-girls-education-through-stem-2020.pdf

United Nations. (1948). Universal Declaration of Human Rights, https://www.ohchr.org/sites/default/files/UDHR/Documents/UDHR_Translations/eng.pdf.

Van Laetehm, M., & Verstraete, C. (2018, June). Étudier les sciences et techniques, une affaire d'hommes ? *Focus N°26*.

Verdugo-Castro, S., García-Holgado, A., & Sánchez-Gómez, M. C. (2022). The gender gap in higher STEM studies: a systematic literature review. *Heliyon*.

Vivian, R., Robertson, L., & Richards, M. (2020). *The GIST: Classroom strategies for inclusive STEM learning environments*. Education Services Australia. https://www.thegist.edu.au/media/a21ldion/gist_classroom_strategies_booklet_web.pdf

Wannapiroon, N., & Petsangsri, S. (2020). Effects of STEAMification Model in Flipped Classroom Learning Environment on Creative Thinking and Creative Innovation. *TEM Journal*, *9*, 1647-1655. https://doi.org/10.18421/TEM94-42

Weng, X. & Jong, M. & Chiu, Thomas K.F. (2020). *Implementation Challenges of STEM Education: from Teachers' Perspective.*

Why Europe's girls aren't studying STEM. (2017). Microsoft. https://news.microsoft.com/uploads/2017/03/ms_stem_whitepaper.pdf

Yoder, B. L. (2013, November). Women in engineering. ASEE Prism, 17.

Zachmann, K. (2018). Women in STEM: Female role models and gender equitable teaching strategies.

Zollman, A. (2012). Learning for STEM Literacy: STEM Literacy for Learning. *School Science and Mathematics*, *112*(1), 12-19. https://doi.org/10.1111/j.1949-8594.2012.00101.x

STEAM Tales

Co-funded by the European Union

STEAM Tales (KA220-HE-23-24-161399).
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Nationalen Agentur im Pädagogischen Austauschdienst. Neither the European Union nor the granting authority can be held responsible for this.