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Editorial

From Early Interest to Career Persistence: Understanding and Supporting STEM Pathways

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Knowledge, competencies, and reflective attitudes regarding STEM (science, technology, engineering, and mathematics) are essential for navigating global and societal changes in the economy and workforce [1]. As we advance further into the 21st century, knowledge and skills in STEM become increasingly important. New professional fields are emerging that require a blend of mathematics, computer science, natural sciences, engineering, and technology. The value of STEM knowledge and skills goes beyond academic settings and personal needs, significantly impacting society overall [1].

Despite this importance, a long line of research highlights numerous obstacles hindering the development of students' STEM competencies [2,3]. From elementary through high school, STEM subjects often rank low in popularity and are not commonly favored for academic pursuits or career paths, especially for girls in the Global North [4]. A deficit in STEM proficiency undermines innovation, economic growth, and competitiveness, hampering the development of critical thinking, problem-solving abilities, and digital literacy, which are essential for addressing complex global challenges and driving progress in a rapidly evolving world. However, it is not only knowledge and skills that contribute to learning and applying STEM. Personal attitudes like interest, values, and positive self-assessments are also crucial for engagement with STEM.

Against this background, the overarching question of this Special Issue emerged: "Sticking with STEM: Who Comes, Who Stays, Who Goes, and Why?" Answering this question should help to better understand the "leaky pipeline" in STEM [5], which involves the loss of interested and skilled students from STEM starting from early childhood and continuing through adolescence and into adulthood. This leaky pipeline manifests in academic choices against STEM in school, career choices outside of STEM in adolescence and adulthood, or a lack of persistence in staying on a STEM career path. The nine articles in this Special Issue address this question, aiming to provide solutions to attract young people to STEM and ensure they stay on the STEM pathway.

When young people choose a STEM subject at school or embark on an education and/or career pathway in STEM, they have already encountered various experiences, support, challenges, and barriers, as illustrated in Figure 1.

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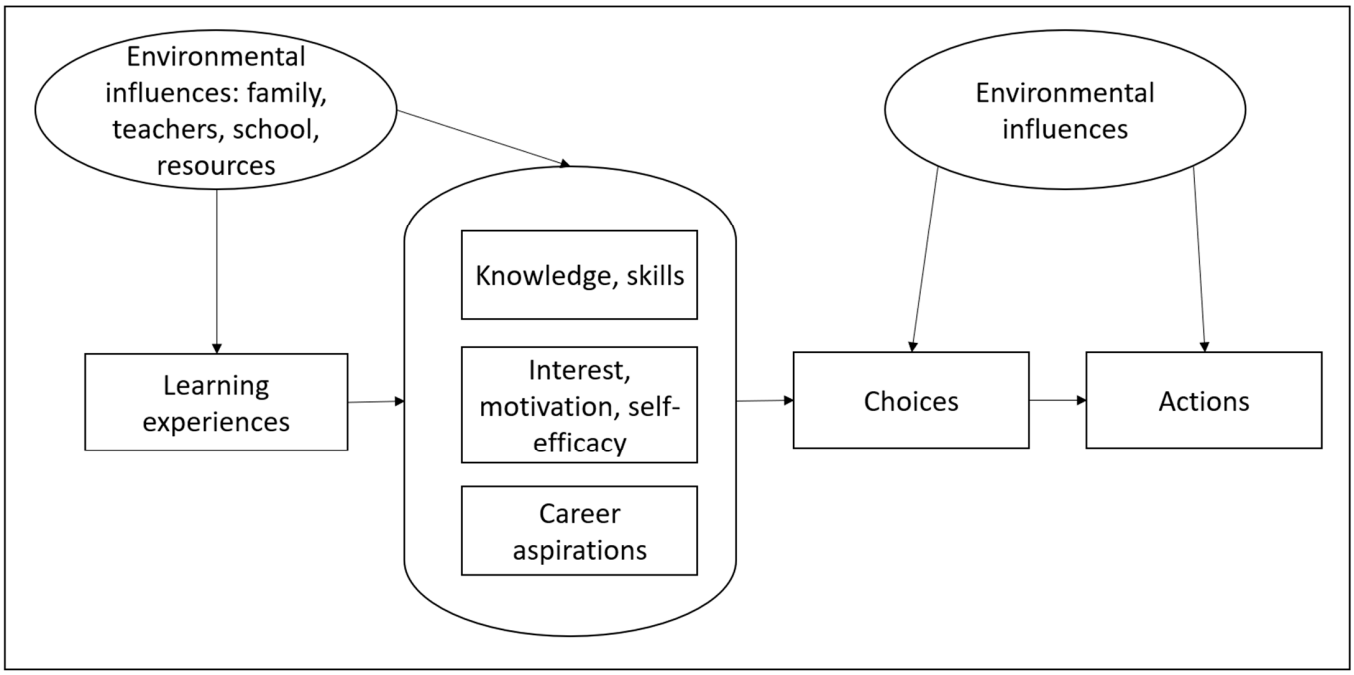

Figure 1. Experiences and influences on the path to STEM.

Positive learning experiences are key to developing favorable attitudes and good skills in STEM. Children and young people engage with STEM learning experiences in different contexts, including school and family. Supporting positive learning experiences in school and other educational settings is one way of making STEM attractive. It is well documented that girls in particular face obstacles in STEM due to external attributions, stereotypes, and lesson designs that appeal more to boys [6–8]. One way of appealing to the target group of girls and motivating them to take up STEM is to make STEM lessons more interdisciplinary, combining popular subjects such, as biology, with more challenging ones, such as physics (see contribution by Bahr and Zinn).

Learning experiences accumulate over time and ideally form positive STEM capital, associated with positive mindsets and STEM identities (see contribution by Davis and Wilson-Kennedy). Such capital significantly impacts student retention and persistence in STEM disciplines [9]. However, not all students have the same chance to develop STEM capital. There are specific at-risk groups, such as low-income students, who struggle to build positive STEM capital due to various obstacles and face particular challenges in their STEM studies due to external barriers (see contributions by Davis and Wilson-Kennedy, Endendijk, and Preuß et al.).

Educators play a crucial role in the STEM development of children and young people. However, they often harbor critical attitudes towards STEM, negative self-assessments, and gender stereotypes. This issue is particularly pronounced among educators of younger children (e.g., pre-school or elementary education), who are predominantly female [10,11]. This raises the need for professional training for all educators focused on gender-sensitive STEM didactics, aiming to improve not only educators' skills but also attitudes and/or self-concepts in STEM (see contribution by Feierabend and colleagues).

The nine articles of the Special Issue concur that developing a positive mindset, self-concept, and self-efficacy expectations are essential for a long-term engagement with STEM. It is not just knowledge and skills in STEM that make these fields attractive for school or career choices. Personal attitudes and attributes, such as interest, aspiration, self-concept of ability, and a sense of belonging to the STEM community, play significant roles in STEM decisions and persistence (see contributions by Reichardt et al. and Hofer et al.).

Another set of variables concerns gender and science cognitions, including implicit gender stereotypes, explicit gender identity, and explicit occupational self-concept. These

attitudes towards STEM affect different age groups, from school students (see contributions by Hofer et al. and Reichardt et al.) to university students (see contributions by Endendijk and Mouton et al.), as well as professionals such as educators (see contribution by Feierabend et al.).

Not all children, young people, or adults have equal access to STEM. Several articles in this Special Issue examine at-risk groups. Drawing on numerous studies and a long tradition of research, this naturally includes girls and women, who face gender stereotypes [2,5,7]. Other affected groups include individuals from lower socio-economic backgrounds with less access to STEM experiences or university students who face difficult external barriers in their studies [12]. Educators and teachers in different educational institutions can benefit from diagnostic tools that identify individual risks, such as profiles of at-risk students (see contribution by Mouton et al.). Furthermore, educators and students can benefit from support measures tailored to at-risk individuals (see contributions by Reichardt et al. and Endendijk).

Finally, the pathway to STEM and the decision to remain on or leave this path should be considered within a temporal framework [7,12]. Interest in or rejection of STEM begins in early childhood, with gender stereotypes taking effect at a young age. Critical phases require understanding and support to foster sustained engagement and success in STEM fields. For example, early adolescents tend to be more gender egalitarian or favor their own gender, but by late adolescence, stereotypes typically shift towards the traditional view that boys are better at STEM (see contribution by Starr et al.).

Ultimately, it is essential to provide students with favorable conditions on the pathway to STEM to ensure individuals embark on and remain on this path. This involves creating an environment rich in supportive resources, both social and material, that nurture interests, motivation, and positive self-assessments in STEM from an early age. By addressing and mitigating the effects of stereotypes and anxiety, particularly for at-risk groups, and supporting STEM educators, we can foster more inclusive and sustained engagement in STEM fields.

Current research has thoroughly examined the reasons and profiles of students staying in or leaving STEM. Coming back to Blickenstaff's leaky pipeline [5], future research may examine the pipeline aspect longitudinally and aim to reveal specific critical events or triggers that lead to decisions for or against STEM.

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