From Cosmos to Classroom:

The Einstein Telescope as booster for STEM fascination[1]

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The promotion of STEM subjects by the Einstein Telescope fulfills a cross-cutting social task:

- **Educational access and diversity**: Extracurricular learning opportunities enhance social participation and enable pupils from different backgrounds to actively experience science and technology.
- **Gender diversity**: Programs specifically designed for young women and girls can increase the proportion of female students in STEM subjects and break down prejudices.
  Linking science and society: The importance of technical innovation and social responsibility in the context of research can be conveyed at the Einstein Telescope.

In 2024, Germany is expected to have a shortfall of over 250,000 skilled workers in STEM[1], crucial for developing innovative solutions to global challenges (Anger et al. 2024). Nearly half of this shortage pertains to academic STEM professions, particularly in information technology, electrical engineering, and mechanical engineering. At the same time, fewer and fewer first-year students are opting for a STEM subject. In 2021, 38 percent of first-year students chose a STEM subject (Destatis 2023). Women are underrepresented in all STEM professions (Drescher et al., 2020) and only a third of first-year STEM students are female, compared to the significantly higher proportion among all first-semester students at around 50 percent (Destatis 2023). At a European level, women constituted 32.8% of STEM graduates in 2021 (European Commission n.d.).

To counteract the shortage of skilled workers, it is important to encourage children, teenagers and young adults to take an interest in STEM subjects and get them excited about them. Motivation and interest are fundamental for professional development and further training. Students interested in physics or other natural sciences are more likely to choose a degree program and a career in the STEM subjects (Malespina et al. 2022). Additionally, fostering self-confidence at an early age can combat pervasive self-doubt, especially among young women, and inspire engagement in STEM disciplines (Ketenci et al. 2020).

1. Motivation and interest in STEM subjects

It's crucial to integrate STEM subjects into daily school activities from an early age to foster interest and motivation among students. If children of primary school age are introduced to scientific content, physics and chemistry, for example, become a natural area of knowledge for the children. These subjects are often not introduced until middle school, although it is precisely then that it is difficult for students to engage with new subjects (Dehnen 2024). The German

Stifterverband demands that recognizing the connections between STEM subjects should be part of general education (Stifterverband, n.d.).

If students identify with natural sciences (especially physics) at an early age, a ‘physical identity’ develops earlier, which can influence children's career expectations. Physical identity is influenced by conceptual understanding and context-based connection, i.e. the application of learned content to larger contexts. The concept of physical identity, which also includes career aspirations, interest, motivation and self-confidence, also impacts the number of bachelor's degrees in STEM subjects (Hazari et al. 2010). Physical identity is also linked to self-efficacy and motivation.

Women in particular, often underestimate their own abilities in the STEM subjects (‘intelligence mindset’), which is often influenced by the working environment (Malespina et al. 2022). Self-efficacy should already be promoted at school through exploratory and innovative learning, curiosity-awakening content, experimental elements and fascination, including, for example, astronomy content or extracurricular learning locations (Musilek und Lengauer 2023). In particular, active and exploratory learning that does not take place formally in the classroom has a positive influence on the motivation and interest of students (Habig und Gupta 2021), i.e. extracurricular learning locations or teaching concepts such as project-based learning (PBL). A study from Finland shows that PBL in physics lessons significantly increases pupils' interest and motivation to learn (Makkonen et al. 2021).

The social significance and responsibility of technical innovation and research processes plays a decisive role for female pupils, students and scientists (Bertsch und Arztmann 2021). Demonstrating the relevance of social responsibility at school can have a positive influence on the proportion of female students and employees in the STEM sector. According to the Standing Conference of the Ministers of Education and Cultural Affairs - KMK (2024), active participation in social communication and barrier-free STEM education are also among the goals and competencies of STEM subjects in order to promote social diversity. Encouraging an interest in STEM subjects at an early age can help to prevent this.
The motivation, interest and self-efficacy of children and young people in STEM subjects is important so that more pupils decide to study or train in these subjects (KMK 2024). In addition to learning at extracurricular learning centers, research-based and active learning, motivated teachers are needed to encourage and support their students in developing their interests, motivation and self-efficacy (Musilek und Lengauer 2023).

2. Einstein- Telescope

2.1 Einstein Telescope as an extracurricular learning center

The underground Einstein Telescope is an observatory for gravitational waves. Researchers can listen to black hole collisions and gain insights into the origins of the universe. The Einstein Telescope and the scientific and technical research and science facilities of the Euregio Meuse-Rhine can serve as an extracurricular learning center to promote the motivation and interest of children and young people in STEM subjects. Extracurricular learning centers can supplement school education and present a possible range of professions, which has a positive effect on career guidance. Extracurricular learning centers also promote inclusion, as students can experience authentic science there. The Standing Conference of the Ministers of Education and Cultural Affairs (Schwermer 2024) recommends better networking and

expanding extracurricular learning centers. Extracurricular places of learning must, therefore, be well-networked regionally and professionally organized in order to provide attractive offers (Stifterverband).

Extracurricular places of learning and an attractive choice of topics make STEM subjects more accessible and appealing to students (Stiftung Haus der kleinen Forscher 2023) and contribute to future-oriented and interest-led STEM skills (Schwermer 2024). This access to research-based projects promotes interest and self-confidence in a science-related context (Habig 2021). Extracurricular learning centers and workshops play an important role in challenging stereotypical role models (Drescher et al. 2020). Drescher et al. (2020) show that this is particularly relevant for female students, as they are particularly impressionable at the age of 10-15 with regard to their career choice and STEM professions. Through career orientation workshops featuring female role models, participants learn to move beyond gender stereotypes in the STEM subject, which are known to impact their interest in STEM subjects and careers. Breaking down stereotypical ways of thinking increases interest in physics, technology, and STEM careers. For instance, at authentic scientific sites like the Einstein Telescope, schoolchildren can explore fascinating topics such as observing the sky. Topics from the field of astronomy often arouse great interest among students (Habig und Gupta 2021).

In the Euregio Meuse-Rhine, the Einstein Telescope can become a well-networked extracurricular learning center, as it is integrated into an existing research landscape. With RWTH Aachen University, one of the leading European and German technical universities, and Forschungszentrum Jülich, there already is a broad-based infrastructure for research in the natural sciences and technology, as well as many students in STEM degree programs who will benefit from the Einstein Telescope as a place of learning. RWTH Aachen University sees the assumption of social responsibility in research and innovation processes as the basis and objective of an excellent university. As a University of Excellence, RWTH sees Responsible Research and Innovation (RRI) as a ‘guiding principle’. As part of the Excellence Initiative, the RRI Hub was established in 2019 (Berg-Postweiler, Decker, Leicht-Scholten 2024). The RRI Hub operates across the university and promotes the implementation of RRI in research, teaching and transfer, including the promotion of cooperation between scientists and researchers.

The RRI Hub can draw on a network of stakeholders from society, the academic sector and stakeholders from politics and administration in the Euregio and support the development of a regionally networked extracurricular learning center around the Einstein Telescope in the Euregio Meuse-Rhine (teaching and transfer). The Hub can quantitatively and qualitatively investigate the impact of extracurricular learning centers on motivation and interest in STEM subjects and the choice of studies (research) and provide a platform for exchange and participation of civil society as a whole (transfer). The Einstein Academy, a partnership of three educational institutions from Limburg, is already committed to implementing the human capital agenda of the Einstein Telescope (de Vries 2024). In Kerkrade (Netherlands), the Einstein Telescope Education Centre (ETEC) has been opened, which will offer all-day lessons for high school students from the 2024/25 school year, coordinated with physics lessons at school, to develop the scientific background of the Einstein Telescope and motivate more students to study science (Einstein Telescope 2024). Based on the existing professorship with a gender denomination at RWTH Aachen University - Gender and Diversity in Engineering - the activities surrounding the Einstein Telescope can be used to further investigate how women can be inspired to study STEM subjects and what challenges and barriers women experience in

STEM. Among other things, projects and publications already realized by this research group on the integration of gender in STEM can be used as a basis (see: https://www.gdi.rwth-aachen.de/cms/GDI/Forschung/~jmnx/Publikationen/).

2.2 Physics and Astronomy

The Einstein telescope, which is used to detect gravitational waves, can be used as an extracurricular learning center to promote students' interest in physics and astronomy. Findings about black holes, the theory of relativity and the beginning of the universe, which can be achieved with the Einstein telescope, are topics that arouse interest among students (Schwarz und Lotze 2024). The interdisciplinary teaching of astronomy and other STEM subjects at extracurricular learning centers arouses pupils' interest, lays the foundation for their choice of studies and creates new potential for skilled workers. Astronomy topics can increase motivation to study other STEM subjects, as children and young people's interest can be aroused quickly and the interdisciplinary nature of the subject means that various STEM subjects are included (Schwermer 2024). An interest in astronomy can develop into an interest in physics by working out the underlying physical background. Fritz (2010) uses a specific example of a schoolgirl to show that enthusiasm for astronomical content can develop into an interest in physics (Fritz 2010).

In the former DDR (German Democratic Republic), astronomy was introduced as an independent school subject from the tenth grade, while in the Federal Republic of Germany, astronomy was taught as part of the subject physics. Today, astronomy continues to be a separate school subject in Saxony-Anhalt, Thuringia and Mecklenburg-Western Pomerania as an extension of science lessons (Lassak 2019). The reasons in favor of a focus on astronomy are clear: its great value for general education, the integration of content into larger contexts, a strong interdisciplinary character and the recognition of natural and social science principles. These arguments were formulated in an open letter from scientists in favor of (re)introducing astronomy as a school subject. However, due to a lack of staff and an exhausted quota of lessons, the counter-arguments prevailed in NRW (Fritz 2010). In NRW, astronomical observations are only included in the core curriculum as a possible context for learning about oscillations and waves, and not as a compulsory content area (QUA-LiS NRW 2024). Due to these challenges and the lack of contact points with astronomy in NRW, the Einstein Telescope as an extracurricular learning center offers the opportunity for students to come into contact with astronomy and benefit from the advantages of this science.

3. Outlook and conclusion

Extracurricular learning centers, such as the Einstein Telescope, combine practical experience and professional orientation with interesting astronomy and physics content and can increase the motivation of pupils to consider a STEM profession. The Euregio Rhine-Meuse offers an attractive location for the Einstein Telescope and the establishment of an extracurricular place of learning, as the region can be linked to a wide range of scientific and technical research and education and new partnerships and educational programs can be created. This can increase the attractiveness of STEM subjects for pupils and counteract the shortage of skilled workers.

[1] STEM is an umbrella term for teaching and study subjects or professions in the fields of mathematics, computer science, natural sciences and technology.

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