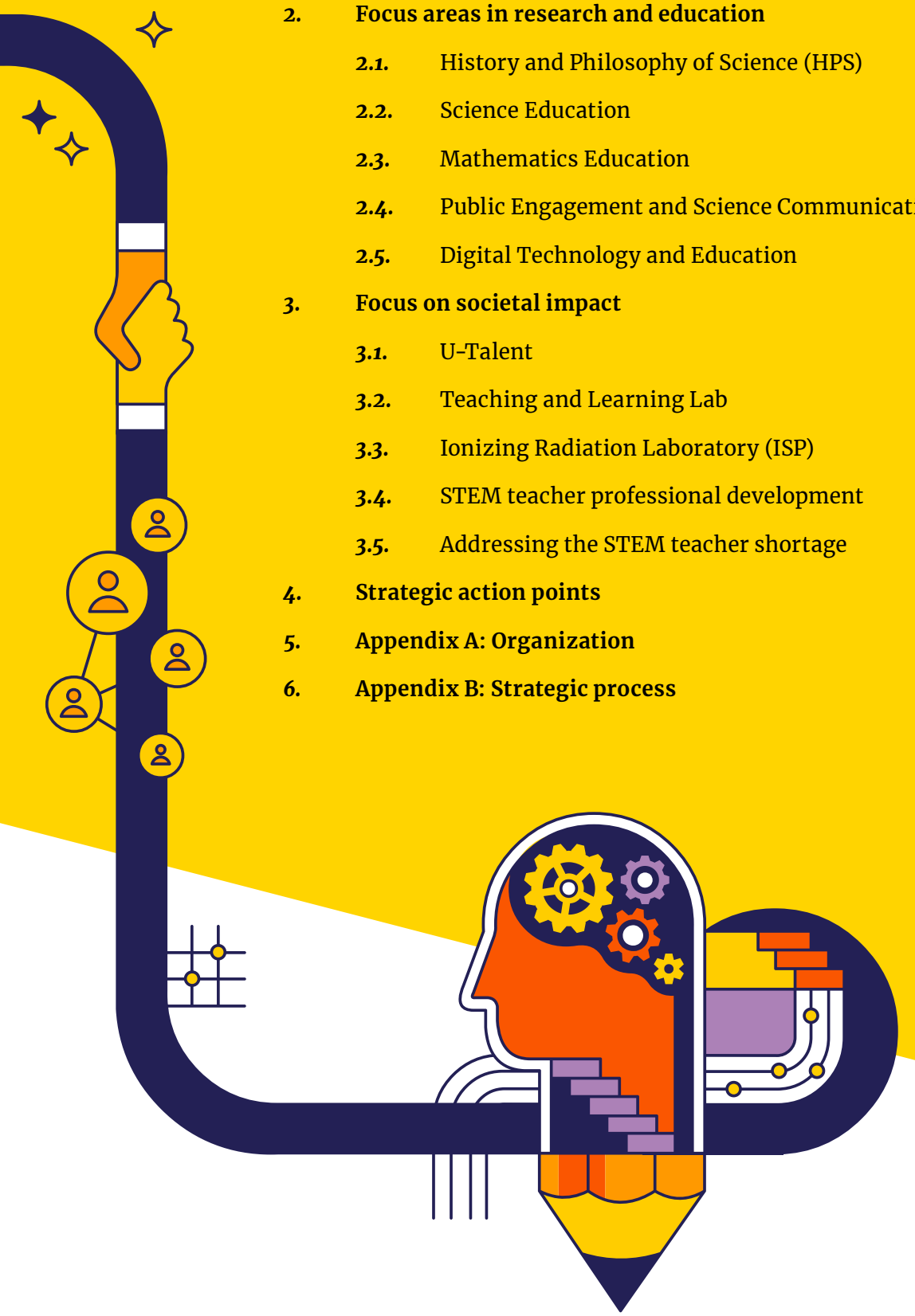
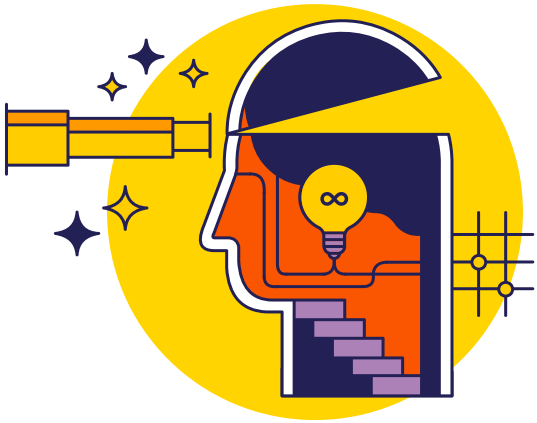
Strategic Plan
Freudenthal Institute
2022–2027

Utrecht University

Contents





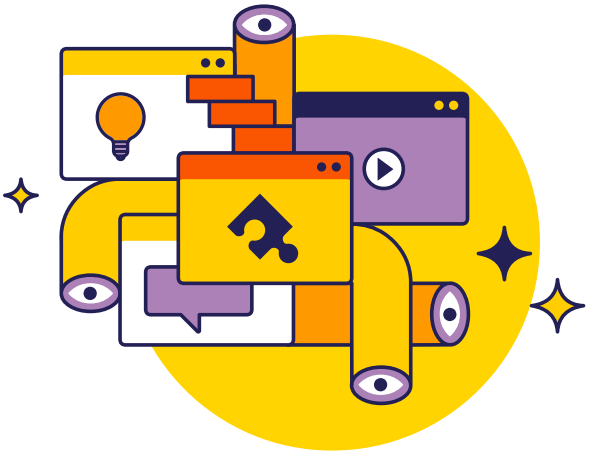
1. Mission

The Freudenthal Institute (FI) is dedicated to supporting scientific literacy for life. As such, it is a necessarily multidisciplinary institute concerned with science and mathematics education, science communication and public engagement, and the history and philosophy of science. It is home to researchers, teachers, and other experts working at the boundary between science and society. This versatility generates scientific and practical knowledge, rooted in the disciplines of the natural sciences—physics, chemistry, biology, computer science, pharmaceutical science, and mathematics—as well as in social sciences and humanities— educational science, communication science, history, and philosophy.

The institute's mission is to contribute to resolving societal issues through fostering the scientific literacy of students, professionals, and the general public. Scientific literacy is crucial for citizens to engage with scientific issues and to navigate today's highly scientific and technological world. Education is a natural place to propagate such literacy: the FI is uniquely positioned in that it performs research in science and mathematics education and incorporates this research into the education of secondary school teachers. Scientific literacy is also improved by familiarizing citizens with the roots and workings of science and scientific integrity. Finally, public engagement and science communication focuses on the "how" and "what" of public engagement with contemporary socio-scientific issues, such as climate change, sustainability, and equity and inclusion.

The FI is an academic research institute with a large project portfolio focused on impact. The FI is positioned within the Faculty of Science at Utrecht University, a fertile ground for developing sustainable forms of (inter)disciplinary education. For example, the FI's state-of-the-art Teaching and Learning Lab is an important vehicle for teaching innovations within the faculty and the university. A new group currently being established around digital technologies and education can increase the methodological repertoire used in the TLL and can support this with a solid scientific basis.

The FI makes essential contributions to the strategic plans of both the Faculty of Science and Utrecht University. It contributes to the strategic themes Dynamics of Youth, Pathways to Sustainability, and Institutions for Open Societies. It also connects local outreach programs to international impact: within the U-Talent program nearly all secondary schools in the Utrecht region are connected around science education, and new knowledge is exchanged internationally through the many different European research projects in which the institute participates. An example of this is that the FI hosts and organizes several of the big, nationwide conferences for secondary school science teachers. As a principal research group on scientific literacy for life, the FI is a natural reference for educators, scientists, policy makers, and the general public alike.



2. Focus areas in research and education

The FI houses five different research groups, which also provide education in bachelor's courses throughout the Faculty of Science and in the two FI master's programs Science Education and Communication and History and Philosophy of Science. The focus areas of these five groups are described below.

2.1. History and Philosophy of Science (HPS)

The HPS group investigates the origins and construction of knowledge, appreciating the differences between various kinds of academic and non-academic knowledge. Historical and philosophical methods offer a fruitful starting point for critical reflection, which is a crucial element of scientific literacy—especially in a time when knowledge is increasingly contested.

We believe that philosophical and historical perspectives can enrich any research program and that every student and researcher at Utrecht University (UU) should be challenged to reflect critically on their research field. To stimulate this, we offer bachelor's courses for students from the entire university, as well as a thriving HPS master's program that is one of the top programs in its field in Europe. Our academic integrity workshops are embedded in all parts of the Graduate School of Natural Sciences. The HPS group of the Freudenthal Institute is one of the main nodes of the UU-wide Descartes Centre for the History and Philosophy of the Sciences and the Humanities.

The HPS group includes researchers from many different disciplinary backgrounds. We use a growing range of philosophical and historical methods, including innovative digital humanities approaches, to explore the following four focus areas:

1. *The Nature of Knowledge*
2. *Knowledge and Values*
3. *Our Changing Relation to Nature*
4. *Community-Engaged Critical Reflection in Higher Education*

2.2. Science Education

Scientific literacy for life is the main focus of the Science Education (SciEd) group. This group adheres to the principle that an increasingly complex society cannot function without basic knowledge of and about science for all citizens and therefore strives to strengthen the quality of formal and informal science education. The group achieves this by focusing on:

1. Research into the components of scientific literacy: It is essential to know what citizens need to know of and about science in order to make informed decisions in their lives. Apart from basic scientific knowledge, this includes knowing how science works (nature of science) and how science impacts society (socio-scientific issues) as well as citizens' personal decisions (e.g., as witnessed during the COVID-19 pandemic).
2. Research into formal and informal science education: Processes of teaching and learning towards the development of scientific literacy, both in formal (e.g., schools and universities) and informal educational settings (e.g., museums), including designing and studying the effects of interventions to improve science teaching and learning (for instance based on the use of modern technology).
3. Educating teachers and other educational professionals: Broad scientific literacy can never be reached without great science teachers in secondary education. Therefore, the SciEd group contributes to educating and training science teachers through evidence-informed teacher training, both in initial education and for second-career teachers. Furthermore, in cooperation with the Public Engagement and Science Communication group (section 2.4), the SciEd group educates and trains excellent (informal) science communication professionals within the Master-SEC program.

In working towards these goals, the SciEd group connects to related research groups worldwide and, just as importantly, to educational practice (for instance by actively pursuing research projects together with schools and museums, such as PhD research grants for teachers).

2.3. Mathematics Education

The Mathematics Education (MathEd) group's mission is to foster mathematics education in the Netherlands and beyond through (1) the design of and didactic research on innovative mathematical activities, both in formal and informal education and (2) the education of mathematics teachers through research- and development-informed pre- and in-service teacher training. As such, the team contributes to the FI's overall mission to foster scientific and mathematical literacy in life and society and connects to the multidisciplinary overarching themes central in the institute's work. The MathEd group's focus lies in secondary education.

The MathEd group's main strategic aims include:

1. To provide excellent research-informed pre-service and in-service BSc- and MSc-level mathematics teacher education;
2. To be a leading research institute on the topic of digital technology in mathematics education and the higher-order learning trajectories and goals that emerge from digitization;
3. To be a leading institute, central in the educational network, in the field of secondary mathematics education, as well as primary and tertiary education, in relation to developments in subjects such as science and language.

The main overall strategic challenge for the MathEd group over the next five years will be to make choices in line with the above strategic aims and to hire new staff to support realizing these aims. To this end, a staffing plan for the coming five years will be established that includes both quantity and quality.

2.4. Public Engagement and Science Communication

The Public Engagement and Science Communication (PESciCom) group contributes to education and research for stimulating informal education and increasing scientific literacy for all in society. This group has a long history of providing up-to-date science communication education for a variety of student cohorts. It is leading in national and international networks of science communication teachers and active in the area of open science and communication skills in higher education.

The group combines face-to-face and online teaching with digital learning environments at Utrecht University. Following Open Science principles, the group investigates the effectiveness of the interactions between scientists and society related to the central question *"How can scientists effectively fulfil their communicative role in a post-truth world and combine reliable research with societal relevance?"* Its research focuses

around two main areas of application: 1) climate & sustainability literacy and 2) equity, diversity, and inclusion within natural and life science communication.

The PESciCom group's main strategic aims include:

1. To provide excellent teaching in science communication;
2. To increase the impact, visibility, and reach of our teaching and research within UU;
3. To increase the international recognition of FI research in Public Engagement and Science Communication.

2.5. Digital Technology and Education

There is an increasing need for research and expertise at the academic level on the role software technology and Artificial Intelligence (AI) play in learning and teaching. Serious games, intelligent tutoring systems, e-learning applications, collaboration environments, digital assessment tools, and many more software artefacts have been developed to support students and teachers. From the early computer years on, AI technology for learning and teaching has been considered promising for supporting teachers and for improving student learning. Until recently, AI technology has only partly delivered on this promise. Technology is used for supporting the teaching process by providing information, administering results, and to some extent facilitating the learning process via web lectures, clickers, supporting 'learning by doing', and various other means. More advanced technology however, such as serious games and intelligent tutoring systems, is not yet being used much.

AI technology for learning and teaching is used everywhere people learn—from primary schools, many of which use smart-boards and serious games, to learning in the workplace, where employees learn new procedures on the job using technology, and management is trained using serious games. Higher education uses a range of technologies for learning and teaching, from web lectures and digital assessment tools to intelligent tutoring systems and serious games. Developing technology for learning and teaching is challenging: the technology requires a high degree of interactivity, excellent feedback, and a strong connection between the subject domain and the user model. It should support collaboration and creativity, and it should be easily adaptable. Advanced systems are complex and require knowledge about human cognition, learning sciences, and several fields within computer science. For example, the development of a serious game for learning programming requires knowledge about how people learn programming; game design knowledge; translating user interactions to a user model; facilities for specifying and adapting tasks, solutions, and feedback; and software architecture and technology to describe, maintain, and adapt the relation between the various software components.

The Digital Technology and Education group designs, develops, and experiments with AI technologies for learning and teaching such as serious games, automatic feedback and hints, student modeling and task selection, learning analytics, automated assessment, and intelligent tutoring systems.

3. Focus on societal impact

The Freudenthal Institute is host to many activities which foster scientific literacy and educational innovation aimed at societal impact. All the activities mentioned in this section are an integral part of the institute and are in direct contact with the research groups. In this way, the FI aims to create mutual exchange of knowledge between academic work and practical experiences in society.

3.1. U-Talent

U-Talent is a partnership in which Utrecht University, HU University of Applied Sciences Utrecht, and more than 50 secondary schools in the region cooperate. We work together to strengthen and enrich education by engaging schools, students, and teachers with topical themes and practices in the university and research. At U-Talent, we organize (inter)disciplinary activities for secondary school students and their teachers, and we have a network function for our partner schools. The coordination and administrative elements of this partnership are handled by the Freudenthal Institute. Moreover, the U-Talent team at the Freudenthal Institute organizes a broad spectrum of activities for high school students and their teachers in the fields of natural science and mathematics.

As a program we aim to achieve:

1. A better transition from secondary education to higher education by better aligning the educational systems;
2. Strengthened education in local secondary schools and higher education institutions through activities for students and teachers;
3. Valorization of scientific knowledge by making crossovers between secondary schools and higher education institutions.

We organize activities for students of different ages and levels, through which students' talents are explored, fostered, and developed. The activities are interdisciplinary and challenging, supporting higher order thinking skills and with equity and inclusion as guiding principles.

For the younger students, we organize days at our university campus, which is for most students their first encounter with scientific research and education. We offer several interdisciplinary activities around topics such as plastic soup, saving the rainforest, and the science of music. For older students, we organize masterclasses, which are one- or two-day activities consisting of lectures, seminars, lab work, field work, and/or tours. There are various topics ranging from math to language and from culture to pharmacy. The more gifted students can apply for our campus program, the U-Talent Academy.

We strive to equip all these students with insight into how scientific research can contribute to a better society, to enrich their scientific literacy, and to support them in engaging with socio-scientific issues. All activities are connected to topical scientific research applying state of the art innovative learning environments (such as in our Teaching & Learning Lab).

Furthermore, we organize activities for (science) teachers, technical teaching assistants, and school leaders. These offer a wide range of tools and skills to design appealing and challenging (science) education. Our teacher program consists of teacher communities, didactical as well as (inter)disciplinary workshops, an annual conference, and a diverse offering of in-company training. In all of these, we put first the principles of co-creation and co-design.

3.2. Teaching and Learning Lab

Since its foundation in 2016, the Teaching & Learning Lab (TLL) has become a national hub for experiments in educational innovation, with an emphasis on digital, activating, and collaborative education. The physical component of the TLL comprises two learning spaces (for twenty and thirty-six students) and a recording studio.

The TLL's mission is to improve the integration of novel, technology-enhanced teaching concepts within secondary and tertiary education. To this end, the TLL facilitates:

1. Innovative and flexible learning spaces for UU and non-UU teachers to test novel ways of teaching;
2. The evaluation and improvement of educational practices;
3. Sharing and implementation of educational research and lessons learned, both on- and off-campus.

The TLL's principal learning spaces offer teachers in secondary and tertiary education the possibility to create, perform, and evaluate their active learning sessions. It is a testing ground for new educational technology, including interactive whiteboards,

enhanced hybrid education, and an interactive wall. Overhead cameras and portable microphones facilitate the recording and evaluation of lectures and workshops. The lab is also the primary location for U-Talent masterclasses.

TLL's state-of-the-art studio provides recording facilities, including transparent lightboard and greenscreen technology with dedicated technical support. Especially during the COVID-19 pandemic, use of the studio for recording educational videos and subsequent editing has soared. The TLL is firmly embedded within the Freudenthal Institute and as such offers its users direct access to the latest developments in educational research in technology-enhanced education. Many new insights, for example on hybrid education, have found their way to mainstream applications in university education.

Lessons learned during these activities are shared on the TLL website and through monthly inspiration sessions and a newsletter. Thus, TLL-based activities have been instrumental in creating a variety of active learning spaces across and beyond the UU campus.

3.3. Ionizing Radiation Laboratory (ISP)

The Ionizing Radiation Laboratory (in Dutch: Ioniserende Stralen Practicum) provides secondary- Schools, MBO and HBO schools in the Netherlands with the possibility of doing experiments with radioactive substances and X-ray sources related to topics in the examination programs. There is a wide variety of experiments, such as: the properties of ionizing radiation (ionizing and penetrating power), activity, half-life, absorption, half-value thickness, and range. The ISP also collaborates with the Dutch Society of Radiation Protection in a project to support school research projects on ionizing radiation.

The ISP owns three mobile laboratories which can be temporarily installed in a standard school laboratory. The ISP also owns a permanent laboratory serving the Utrecht regional schools.

The ISP currently has three fulltime staff members and two part-time student assistants, who combined support lab experiments in over 300 secondary schools each year. The staff members of the ISP are part of the Science Education group. In this capacity, they can provide the Science Education group with valuable insights about everyday practices of secondary education. Furthermore, they can apply new insights from the didactics research in the Science Education group in their lab experiments at schools.

3.4. STEM teacher professional development

The FI aims to help secondary STEM teachers with their professional development. This is done through, for example, organizing many national conferences for STEM secondary teachers, such as the Woudschouten Chemie Conferentie, WND Conferentie, Nationale Wiskunde Dagen, ECENT/ELWiER conferentie. These conferences provide

educators with new insights both from within their science disciplines and on didactics. U-Talent also provides teacher activities through, for example, hosting a teacher network, where teachers can meet and exchange ideas and best practices.

3.5. Addressing the STEM teacher shortage

The teacher shortage in STEM subjects at secondary schools is a pressing problem in the Netherlands. The FI initiates and organizes several national programs to address this shortage. One such program is the Beta4all program, where professionals with a STEM university education but without a teacher degree can more easily obtain such a degree and start working in secondary education. The Beta4all program provides courses for degrees in mathematics, physics, chemistry, and computer science. Because of the high demand for more computer science education, the FI has also initiated the Co-Teach Informatica program, which provides schools which cannot find computer science teachers with both an online education environment and IT professionals as guest teachers. The goal is to provide 3,000 extra students with computer science in 2023/2024.

The 'Student op School' program is another program to support secondary education. This program matches bachelor's or master's students from the UU with secondary schools. The university students can support teachers while gaining experience working in education.

4. Strategic action points

To guide the direction that FI will go in the next five years, we have formulated five concrete points of action.

Synergy within the institute

Within the FI, many crossovers between different groups are waiting to be explored. One example is how the Mathematics and Education groups could work more closely together with U-Talent to involve U-Talent schools in research. Another example is how the PESciComm and the HPS groups are working more closely together to both study the fundamentals of science in society and to determine how to engage a broader audience with science. Creating more links and collaborations between the groups within the institute will allow for mutual learning. Furthermore, since societal issues do not adhere to disciplinary boundaries, more collaboration between the groups will make the FI more capable of responding to relevant societal issues related to the core mission of scientific literacy.

Societal relevance

The FI staff aims to connect their research and education to relevant issues in society and to act progressively in line with future trends in education and public engagement. To be aware of these trends, it is important that members of our group participate and play a leading role in national and international consortia and projects (e.g., Horizon COSMOS consortium, Groeifonds AI Nationaal OnderwijsLab, Groeifonds Open Leermiddelen, Nationaal Centrum voor Wetenschapscommunicatie) committees and organizations (e.g., Vakvernieuwingscommissies, BETA4all, beta-lerarenkamer, StudentinzetopSchool, OCW, UNL, VO-raad) and science and mathematics conferences (Woudschoten Chemie en Natuurkunde, NWD, NIBI-conferentie). To further this involvement, it is important that we continue our efforts to be visible and 'findable,' both within the university and outside. The FI will continue to keep close connections with relevant governmental and national bodies regarding education policies. The FI will also play a leading role in large-scale national projects, such as the National Education AI lab.

Educational expertise

The FI wants to maintain and expand its educational expertise, not only in the field of science, mathematics, and informatics education, but also on topics such as research ethics and integrity, and equity, diversity and inclusion education. Expertise on new initiatives such as 10-14 middle schools, and integrated approaches to STEM in primary and secondary education will be further developed. Think, for example, of activities on open schooling, on interdisciplinary STE(A)M education, and on establishing tight collaboration with 2-3 schools in the Utrecht region, together with U-Talent. Moreover, the expertise on interdisciplinary topics such as the nature of science, uncertainty in science, and sustainability education will be elaborated, in line with the UU strategic theme of Pathways to Sustainability. This puts demand on the future recruitment of new staff.

(Inter)national network and recognition

The FI wants to be visible and recognizable both for its academic work and for its impact activities. Because a large part of FI activities are project-based, the FI staff need to remain relevant within their fields, build networks, and seize opportunities when they arise. FI's role in international networks, e.g., the STEM Teacher Academy and the ICSE network, will be expanded. International collaboration with partners such as IND in Copenhagen will be prioritized.

For the FI's academic work, it is important to be present at (inter)national conferences and symposia. We will strategically target internationally renowned conferences and symposia to showcase our work and seek opportunities to collaborate with international partners.

Increasing participation in university-wide initiatives on educational innovation

The U-Talent program will broaden its focus to include the talent development of all secondary education students (havo/vwo) in the fields of humanities, science, and social sciences. The FI also plays an important role in the UU ambitions for collaboration with other educational partners in the Utrecht region. The HPS group aims to strengthen our connections with other departments and programs at the UU, both within and outside the Science Faculty, since critical reflection is relevant for all researchers and students. Together with the university-wide Descartes Centre, we aim to engage the UU community in critical discussions about: i) academic culture and values (including academic integrity, recognition and rewards, and (in) equality, diversity, inclusion); ii) the nature and role of knowledge in connection to the Sustainable Development Goals; and iii) open science, public engagement, and public trust in science.

The PESciCom group will engage with (inter)faculty networks and develop 'teach-the-teacher' material. We will work with other experts across the university to develop teaching materials which will be useful for lecturers in GSNS, GSLS, and GSG who want to lecture on science communication and public engagement in their own courses or programmes.

5. Appendix A: Organization

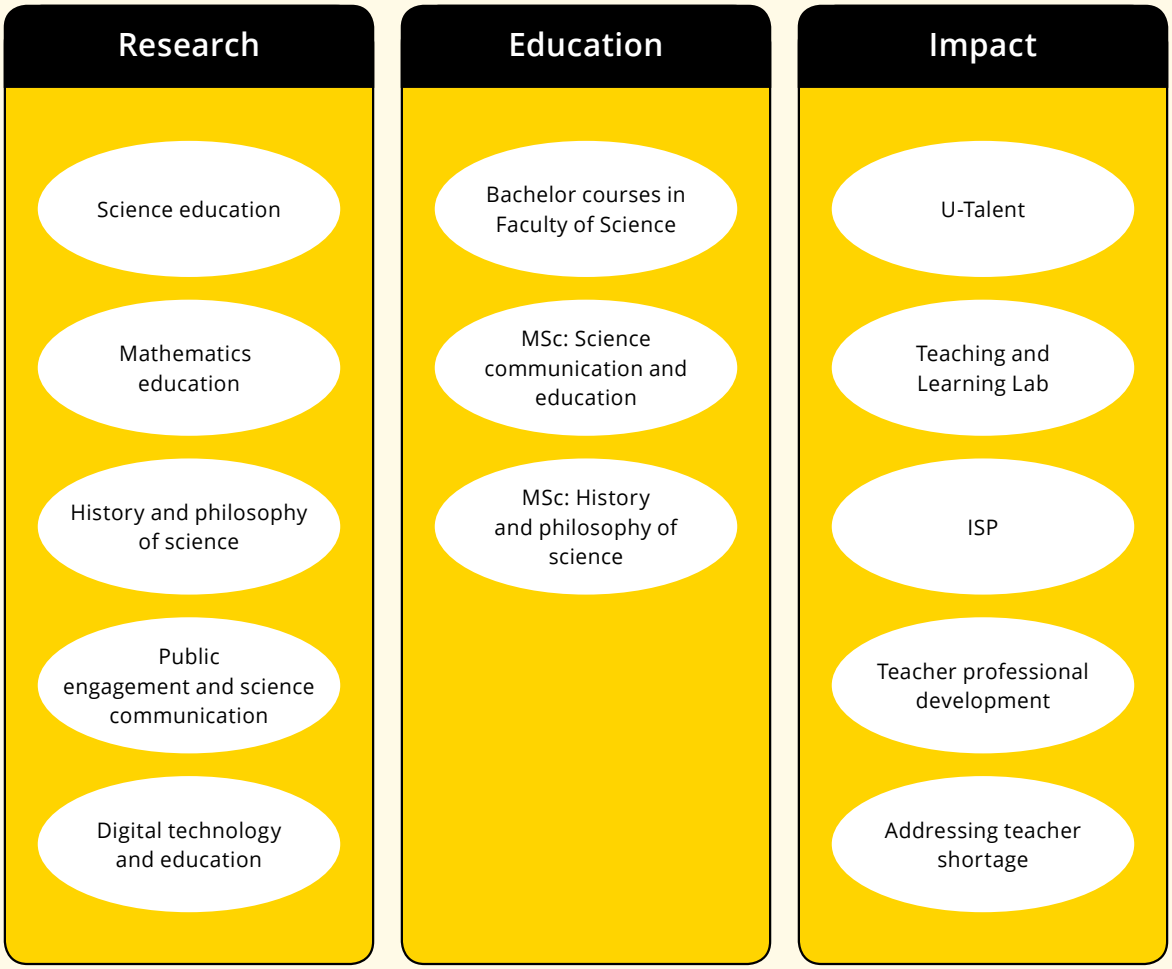


Figure 1 Organization of the Freudenthal Institute

6. Appendix B: Strategic process

This strategic plan has been made using a co-creative process with input from FI staff. The FI board started this process by looking at the old strategic plan and the changing environment (described above) in which the FI operates. After that, some FI staff members were assigned to a design team and designed a strategy day with the whole institute. Through this process, it became clear that the main focus of that day would be to get to know each other (again, after almost two years of COVID-19 lockdowns) and to look for crossovers between the different groups which would mutually benefit them.

The FI strategy day took place on the 28th of October 2021 and many people were present. The day showed that, on the one hand, a lot of common ground could be found and that a common mission (*Scientific literacy for all*) fit all activities well. On the other hand, it also demonstrated that most daily activities still happen within the different groups of the FI and that bringing together people in this way inspired new ideas and possible collaborations. It also became clear that creating societal impact, whether through training secondary school teachers, creating impact directly in the classroom, or performing public engagement activities, is very important for all staff at the FI, and creating synergy by collaborating across the different groups would actually help strengthen this impact. On the 16th of June 2022, the new strategy was officially kicked off during an afternoon with the whole institute.

Utrecht University

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shaping tomorrow