Universiteit Utrecht

Educating for Scientific Citizenship

Scientific and Mathematical Literacy for Life

Research program Freudenthal Institute 2015-2020[1]

[1] This research program is in accordance with the Strategic Plan of the Faculty of Science [Strategisch Plan 2013-2017] and with the mission and core values of the University of Utrecht.

Management Summary

The mission of the Freudenthal Institute is to promote scientific and mathematical literacy for all. Such literacy involves both the practical skills and knowledge students need in their professional and personal lives, and the critical understanding they need as citizens. The research program of the Freudenthal Institute aims to advance the development of effective teaching approaches for scientific and mathematical literacy that are grounded in educational science and insights from the history and philosophy of science. The research will lead to frameworks for the design of innovative learning environments for mathematics and science, in both formal (classroom) and informal (such as media and museums) education and learning environments. The overarching theme of the institute's research is expressed in four guiding questions:

1. *What do people with different roles in society need in terms of mathematical and scientific literacy in order to function as citizens?* This question provides a strong theoretical and philosophical grounding for the study of mathematical and scientific literacy, and will focus on these key areas: historical developments in science and its relation to society; methodologies and responsible research and innovation; and the development of scientific attitudes and positive attitudes toward science in teachers and students.

2. *How should formal and informal teaching and learning situations that can foster mathematical and scientific literacy and citizenship be designed?* With this research question, the focus will be on modern approaches to science and mathematics education, such as inquiry-based learning environments, modeling as the heart of scientific reasoning, preparing citizens for personal and societal decision-making, arrangements for informal science and mathematics education and communication and modern developments in science as a vehicle for citizenship education.

3. *How can innovative ICT tools be designed and used to support teachers and learners in building scientific and mathematical literacy?* Research will focus on two main categories of ICT tools to support education for mathematical and scientific literacy: innovative tools for creating and/or exploring computational models and educational games.

4. *What should be in the mathematics and science teacher's toolbox and how are these tools best employed?* The professional behavior and repertoire of teachers play a pivotal role in supporting students in acquiring knowledge, skills and interest in mathematics and science. Research related to this question will focus on the understanding and support of teacher roles in open ICT-rich learning environments, differentiation and personalized learning, and will include teachers in the work of development and implementation of educational tools, through such approaches as teacher design teams and lesson study teams.

Implementation of the research program

The research program of the Freudenthal Institute combines research from various traditions, ranging from experimental evaluation of teaching methods to historical studies. The use of traditional design-based research will be continued and extended. This will be boosted by setting up a Teaching and Learning Lab, a physical and virtual organization involving school networks where teachers, educational designers and researchers can experiment with new forms of teaching, such as blended learning. New opportunities present in the use of big data analytics and gaming will be pursued. Moreover, the introduction of ICT tools makes it possible to monitor learning processes closely by registering students' interactions with the ICT environments; analysis of these interactions will inform the research.

Collaboration and Funding

The Freudenthal Institute collaborates with several partners, both internally within Utrecht University and its faculty of Science and externally with both national and international collaborators. Research partners include: Education for Learning Societies (University research focus area), Game Research (University research focus area), Dynamics of Youth (University research strategic theme), the Descartes Institute, CITO, SLO, Platform Bètatechniek and bèta-steunpunten.
The Freudenthal Institute collaborates closely with other science and mathematics education institutes in the Netherlands. Together these institutes work on securing continued support for research on science and mathematics education, for example through national expertise networks such as Elwier and ECENT. Collaboration with societal partners such as RIVM and KNMI is sought to establish a firm empirical base for public understanding of science and mathematics studies and educational programs.

Schools are an important target group for collaboration. In the U-Talent network, the Freudenthal Institute collaborates with schools on talent development, teacher training and research.
Funding opportunities within the Netherlands are provided by NWO (personal grants, Top Sectors) and by the "Nationaal Regieorgaan Onderwijsonderzoek" (NRO), in particular. The Freudenthal Institute will actively pursue the securing of these types of grants. Internationally, the Freudenthal Institute collaborates with institutes in Europe, which has already led to FP7 projects and which will ideally continue in Horizon 2020 collaborations. Moreover, current collaborations with institutes in the USA, Surinam, Indonesia, Singapore, Australia, Israel and China will be extended.

Educating for Scientific Citizenship

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Research program Freudenthal Institute 2015-2020

In its strategic plan for the years 2015-2020, the Freudenthal Institute for Science and Mathematics Education has defined five focal points for its activities: (a) training and developing professional mathematics and science teachers, (b) promoting academic skills and normative professional behavior in educational programs for mathematics and science, (c) developing curricula and content for teaching mathematics and science, (d) developing technology enhanced learning environments for science and mathematics and (e) strengthening partnerships for talent development in mathematics and science. This research plan elaborates the way the Freudenthal Institute conceives the scientific foundation of the activities in the light of pursuing these focal points. The research themes defined in this plan align with the general goals the Freudenthal Institute has set for itself in the strategic plan.

Introduction

Science and mathematics play an important role in many of today's social issues, from sustainability and regenerative medicine to the future of our food supply. However, the general public finds it difficult to assess these scientific developments and the solutions they provide for social issues. This may result in valid scientific solutions not being readily accepted or not enough awareness of possible dilemmas arising from promising scientific breakthroughs. Therefore, it is important that citizens receive help in becoming better able to assess scientific developments, through science education and communication both in the classroom (formal education) and through science media, museums, and the like (informal education).
The Freudenthal Institute wants its research on education to contribute to promoting scientific and mathematical literacy that is useful in daily and professional life. In line with this mission, the institute investigates the full spectrum of the what, how and why of learning mathematics and science.
This research leads to frameworks for the design of innovative learning environments that include effective methods for the teaching of and communication about mathematics and science. The development of such frameworks includes teachers and other educators as central agents in the teaching and learning process. Furthermore, by investigating science and mathematics as practice and culture from both an historical and a philosophical perspective, the Freudenthal Institute intends to contribute to high levels of scientific and mathematical literacy for the members of our knowledge society, from youth through adulthood.

Scientific and Mathematical Literacy as a basis for citizenship

Research on science and mathematics education calls for an approach that looks more broadly than just the teaching and learning of scientific and mathematical concepts. We cannot merely investigate questions such as `what should we know?' to fully understand the impact that science can have on society. In order to accomplish this, we also need to consider the questions 'how do we know?´ and `why is it important to know?´ .
The Freudenthal Institute integrates expertise from the fields of mathematics and science education and the fields of history and philosophy of science. This combined expertise engenders the new capability to bring together insights about science in its social context with insights from studies of how students learn science and mathematics. In this way it becomes possible to design and evaluate programs of study that aim to enhance Scientific and Mathematical Literacy (DeBoer, 2000; Steen, 2001) as a basis for Scientific Citizenship.

Mathematical literacy is defined by the OECD (2010) as an individual's capacity to:

- identify and understand the role that mathematics plays in the world;
- make well-founded judgments;
- use and engage with mathematics in ways that

meet the needs of that individual as a constructive, concerned and reflective citizen.

This definition can be broadened to include science, leading to a joint definition by Boerwinkel, Veugelers, and Waarlo (2009) of scientific and mathematical literacy that requires:

- knowledge and skills regarding concepts in science and mathematics;
- knowledge about the nature of science and mathematics, including their methodology and foundations;
- insight into norms and values, both personal and societal.

Together these concepts constitute a basis for empowering citizens in a knowledge society (Hodson, 2010). For instance, to be able to decide whether or not to vaccinate their children, people need to know what vaccination is (conceptual knowledge), to be aware of the strength of the claims in favor of and against vaccination (nature of science), and have insight into the consequences for themselves and others and into current societal norms and values with respect to vaccination (insight into norms and values).

Scientific citizenship relates such knowledge and insights to a perspective on how to act as a citizen, in this case with respect to vaccination. We can therefore define scientific citizenship as the set of knowledge, skills, attitudes and values related to mathematics and science that contribute to a person's actions as a citizen.

The Freudenthal Institute addresses two target groups:

1 the general citizen, who needs knowledge of and about science and mathematics to function as a citizen
2 (potential) students intending to pursue further education and a career in mathematics or science, who obviously need greater proficiency in science and mathematics.

Research Questions

The overarching research theme is the study of formal and informal education and learning environments, with the aim of building and fostering mathematical and scientific literacy and citizenship from youth through adulthood.

This theme encompasses the study of the history and philosophy of science and its relation to society to provide a firm base for the understanding of science and scientific literacy. It also includes research into the design and evaluation of learning situations for science and mathematics, using innovative means and with a focus on the teacher as a central agent in the teaching and learning process.

All research projects within the Freudenthal Institute will contribute in some way to addressing this theme

Attitudes among the general public

Digital methods are used to investigate ideas and attitudes among the general public with respect to questions concerning science, health, drug abuse, cultural issues and general worldview. In the NWO-sponsored Translantis project, FI researchers are investigating the growing influence of the USA since WW II on Dutch attitudes concerning such issues, in order to better understand the role that international models and development play in changing these attitudes. See Van Eijnatten, Pieters and Verheul (2013) and Huijnen et al. (2014).

at multiple levels, with both theoretical and practice-oriented results. The overarching theme is elaborated below in four main research questions.

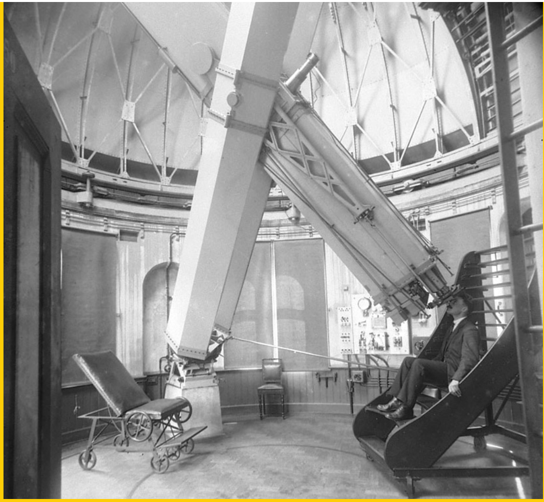
1 What do people with different roles in society need in terms of mathematical and scientific literacy in order to function as citizens?

The pursuit of this question includes conceptual analyses of scientific concepts from an educational perspective, definitions of the key concepts in understanding socio-scientific issues, philosophical studies into the nature of science and its processes, and studies into the history of science in order to provide a historical perspective on the development of scientific knowledge and its relation to society (e.g., Meijer, Bulte, & Pilot, 2009).

Empirical research into people's views on science and their interest – or lack thereof – in mathematics and science also contributes to addressing this question (e.g. van Aalderen-Smeets & Walma van der Molen, 2013). Within the scope of this research question, the focus will be on:

Historical developments in science and its relation to society.

The study of the history of science teaches us how science has developed over the centuries and how views of the relation between science and society have



How Science works

The Freudenthal Institute research on History and Philosophy of Science has as its joint fundamental aim to elucidate how science does its work: how have attitudes concerning what constitutes proper scientific method changed over time, how have the major concepts in the sciences been developed, interpreted and reinterpreted, what constitutes scientific authority and expertise, and how are developments in science and society related. This research also include the study of views and attitudes with respect to scientific integrity, both conceptually and in historical perspective.
See, for instance, Theunissen and Hakvoort (1997), Van Dongen (2010) and Van Lunteren, Theunissen and Vermij (2002)

Inquiry-based Learning

Inquiry-based Learning (IBL) does not necessarily imply that students follow complete cycles of inquiry. Activities that are inspired by a single phase can also foster students' inquiry skills and conceptual learning. For example, an activity of sorting cards with definitions that are never, sometimes or always true appeared successful for implementing IBL in everyday practice. A characteristic of IBL activities is that they do not structure the students' solution strategies (Swan, Pead, Doorman, & Mooldijk, 2013). Instead, such activities need structured lesson plans to scaffold the whole class learning process.

changed. Using historical sources, including digital archives of historical data, the way the relation between science and society has developed over time will be studied. This leads to further investigation of scientific methodology, the next research focus.

Investigations into methodology and responsible research and innovation.

By studying scientific methodology, along with the nature of scientific concepts that are fundamental for the sciences, we can develop insight into the nature of science. Such insight is necessary for understanding how scientific knowledge can be interpreted and understood, particularly in educational contexts. This strongly relates to the issues of responsible research and innovation and scientific integrity. What methods are considered to be ethically valid and what is considered to be responsible behavior for scientists?

The development of scientific attitudes and positive attitudes toward science in students and teachers.

In addition to mathematical and scientific skills, it is important that attitudes such as interest in science, a view to a possible career in science and knowledge about the processes of science are developed. Such attitudes are important predictors of choices students make for their further education and careers. This line of research will study what determines students' and teachers' attitudes and how these attitudes can be measured and improved.

2 How should formal and informal teaching and learning situations that can foster mathematical and scientific literacy and citizenship be designed?

Learning for scientific and mathematical literacy and citizenship takes place in formal environments such as schools and universities, semi-formal environments such as science museums or other more informal ones. Learning environments need to contribute to all aspects of scientific literacy. Therefore, research should focus on the characteristics of learning situations in which students engage in authentic practices (Bulte, Westbroek, de Jong, & Pilot, 2007; Dierdorp, Bakker, Eijkelhof, & van Maanen, 2011; Entwistle, 2000; Prins, Bulte, van Driel, & Pilot, 2008). In such environments students acquire knowledge and skills in the context of solving real-life problems. It is important in such environments to strengthen the connections between basic scientific knowledge, its nature and related norms and values. In particular, research in this area will focus on the characteristics of environments for formal education, with a special focus on:

Inquiry-based learning and problem solving related to socio-scientific issues and the professional world.

In educating for scientific citizenship, it is clear that education must bring the outside world into the school (Bakker & Akkerman, 2014). Learning situations involving realistic tasks and providing effective sup-

Effect of interventions on attitudes and achievements
Many types of interventions to improve students' attitudes and achievement in science and mathematics have been implemented and studied, including inquiry-based learning, context-based learning, learning with ICT, collaborative learning and field trips. What are the effects of these types of interventions on attitudes and achievement in science and mathematics? A systematic review of experimental studies on this question shows that such interventions on average have a positive effect on attitudes and achievement (Prins et al., in prep.).

Drawing-based modeling
Drawing-based modeling has as its goal to make modeling accessible to young students (age 10-15). With the program SimSketch, students create models of systems such as the solar system, traffic or evolutionary processes. The main goal of these studies is to investigate students' reasoning processes with the models and to support building insight into the roles of models in science, as part of students' growing scientific literacy (Bollen & van Joolingen, 2013; van Joolingen, Aukes, Gijlers, & Bollen, 2015).

port for the learning processes can yield learners with higher order, 21st century skills such as collaboration, creativity and critical thinking.
The great need for such tasks is firmly based in a body of research (Doorman et al., 2007). They will often be interdisciplinary and rely on basic mathematical and scientific knowledge as well as on cross-cutting concepts and characteristic ways of working and thinking across the sciences (SLO, 2013). Views of concepts such as, for instance, energy may change when considered in different contexts.
Such ways of working include inquiry and problem solving; one of the main potential outcomes of the research in this area is to provide models for these environments, justified by empirical evidence from school practices.

Modeling as the heart of scientific reasoning.
One shared way of working in both mathematics and science is the construction and use of models. Creating models of scientific phenomena to understand, explain and predict is the core activity of almost any science (Giere, 2004; Nersessian, 1999; Windschitl, Thompson, & Braaten, 2008).
Modeling is an activity that is strongly supported by mathematical reasoning. In mathematics, models also play the role of representing mathematical concepts, such as linear functions (Drijvers, 2012; Gravemeijer, 2009).

Modeling in education has a dual goal. The first is providing students with the skills for creating models: abstracting from information, reasoning about what should and should not be included in the model and putting the ideas into a mathematical or other formal representation. The second is to provide insight into the role of models in mathematical and scientific practice and to appreciate both the strengths and limitations of scientific models. The focus in this line of research is the design of learning situations in which modeling is made accessible and usable by students of all ages. Such situations will include modeling tools and activities, as well as specific attention to the role of models in science (Sins, Savelsbergh, & van Joolingen, 2005; Sins, Savelsbergh, van Joolingen, & van Hout-Wolters, 2009). As such, this line of research will combine expertise from mathematics, the sciences and philosophy of science.

Preparing citizens for personal and societal decision making.
Scientific and mathematical literacy includes more than understanding of the relevant concepts in order to prepare citizens for decision making in socio-scientific issues. New technological possibilities such as nano- and biotechnology generate new kinds of decisions for which citizens should be empowered. The discourse on these issues, both in personal and societal decision making, is more about values and interests

than about risk (Boerwinkel, Swierstra & Waarlo, 2014). In order to prepare students for informed decision making on socio-scientific issues, teaching strategies have to be developed which stimulate to reflect on both the technology and the possible consequences, now and in the future. This should be done together with curricular reform and specific teacher professional development (van der Zande, 2011).
Arranging informal science education and communication.
Mathematics and science are often brought to the public through news items, websites, television programs and in science museums, and not in formal contexts. It is part of the core of scientific citizenship to learn to interpret, understand and value messages about science in the various media.
Freudenthal Institute research can contribute to increased understanding of how to foster scientific citizenship by studying the public understanding of science and the way this is influenced by science communication in the general sense. A specific context in which this will be studied is the science museum. One goal of science museums (e.g., the University Museum, Naturalis and NEMO) is to increase the understanding of science among the general public. In collaboration with these museums, the design of educational activities in and around the museum as well as their relation with formal education at schools will be studied; for example, how lessons at school combined with museum visits can strengthen the development of scientific literacy and citizenship.

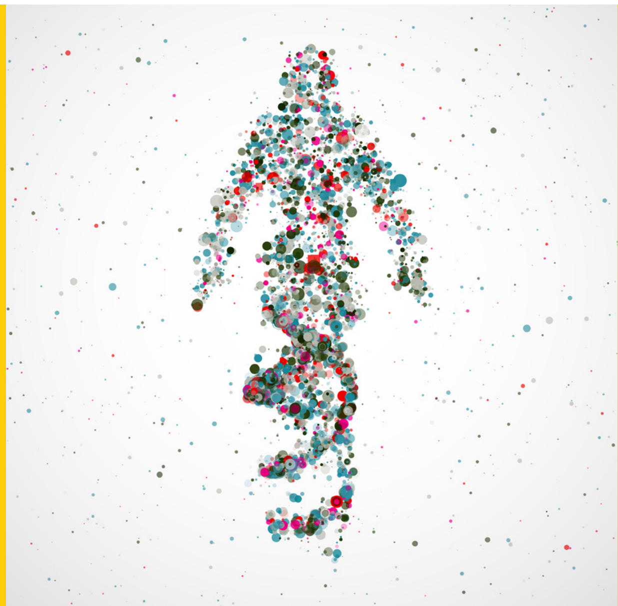
Modern developments in science as a vehicle for citizenship education.

By definition, school curricula and assessments lag behind current developments in the sciences. The time gap between course exams and science can be up to a century (e.g., in physics). The design of learning situations needs to address this problem in order to build scientific citizenship and to provide realistic views of the current state of science. The best approach to these questions will lie in a combination of design-based research (e.g., Barab, 2006) and evaluative studies in which designed learning set-ups are tested for effective learning outcomes.

3 How can innovative ICT tools be designed and used to support teachers and learners in building scientific and mathematical literacy?

Modern applications of information and communication technology have permeated our lives and offer great possibilities for education.
It is a task of the Freudenthal Institute to investigate how these technologies can be used in an effective and responsible way in mathematics and science

Structuring the teaching-learning process
In an authentic modeling practice professionals share purposes, create common modeling procedures and apply relevant knowledge. The educational challenge is to adapt such practices to suit students' abilities and lead to desired learning outcomes.
A design framework for the application of modeling practice in chemistry education entails a synthesis of learning phases, instructional functions and design principles. This design framework provided effective heuristic guidelines for structuring the teaching-learning process using authentic practices as contexts for learning about models and modeling. (Prins et al., 2008)



Genetic Literacy
On the curriculum level a genetics literacy project, organized together with the Weizmann Institute defines several types of knowledge needed for citizenship. On the level of designing strategies, the use of fiction has proved to be effective in stimulating opinion forming (Knippels, Severiens & Klop, 2009). FI spearheads the EU PARRISE project in which teacher professional development programs on SSI are developed. Strategies that discuss developments in Synthetic Biology are developed in cooperation with the Rathenau Institute and within the EU Synenergene project. Both the PARRISE and the Synenergene projects address also informal science education.

education, in both formal and informal contexts. The use of ICT tools will be studied in all relevant learning contexts, formal and informal, from whole class teaching to individual interaction between student and computer.
In the context of educating for scientific citizenship, research will focus on two main categories of ICT tools to support education:

Innovative tools for creating and/or exploring computational models.
Modeling tools allow students to create and simulate models of phenomena they investigate (Bollen & van Joolingen, 2013; Louca & Zacharia, 2015; Ogborn, 1999). Such tools support the development of scientific reasoning and understanding in which models play a central role, as was indicated in the previous research question. Many scientific domains can be investigated with such tools by using a variety of model representations and simulation mechanisms. Simulations allow students to explore given models, and in this way support learning by inquiry (de Jong & van Joolingen, 1998; Rutten, van Joolingen, & van der Veen, 2012).

Educational games.
Educational games provide a context for learning about science and mathematics in formal and informal contexts:

- Games offer a great opportunity for engaging users in a playful environment, but need to be carefully designed to align the gameplay with the learning goals (e.g. Moreno-Ger, Burgos, Martínez-Ortiz, Sierra, & Fernández-Manjón, 2008).
- Games offer a challenging means that can take target users into historical contexts or allow them to experience scientific concepts from unexpected angles. An example of an historical game-project is the collaborative Dutch/Iranian historical numerical systems competition game that uses a 12th century Isfahan trade context to engage 11-14 year olds in mathematical thinking activities.

Studies in this area will include design-based research. Collaboration will be sought with partners which are strong in ICT development. ICT tools provide a unique opportunity for collecting data on learning processes. Rich data on the progress, detours and successes of students can be collected by tracing their interactions with ICT tools. With its Digital Mathematics Environment, the Freudenthal Institute possesses a platform for developing and delivering ICT tools and for collecting data produced by these tools. Using technologies such as educational data mining, these data collection facilities will be used to provide answers to research questions that involve the interactions of students with ICT tools for learning mathematics and science.

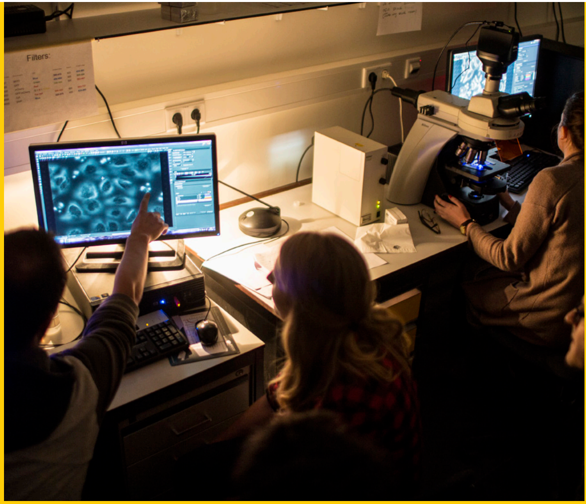
4 What should be in the mathematics and science teacher's toolbox and how are these tools best employed?

ICT tools for conceptual mathematical development
A versatile view of a mathematical function includes the function as dependency relationship, as a model for co-variation, and as a mathematical object with different representations. These views of function are embodied in applets which grade 8 students use in a technology-intensive learning situation. The results suggest that the use of the ICT tools fosters conceptual development by offering representations that allow for progressively more advanced levels of reasoning, and from blending with paper-and-pencil work. (Doorman, Drijvers, Gravemeijer, Boon, & Reed, 2012)

Teachers play a pivotal role in formal learning contexts, and to a lesser extent also in informal contexts, for instance in the context of school visits to museums. Their professional behavior in the classroom and their repertoire of actions may or may not support students in acquiring knowledge, skills and interest in mathematics and science. Their role in society is of crucial importance in the development of students' proficiency and attitude towards mathematics and science. Within the realm of this research question, the Freudenthal Institute will study both the contents of the teacher's toolkit and the way teachers can acquire them, for instance, in teams for professional development. The focus will be on:

Teacher roles in open ICT-rich learning environments.
Approaches to science education such as inquiry learning and modeling require specific roles for the teacher, in terms of stimulating inquiry behavior and motivating students. Studying these roles as well as ways that teachers can be involved in the design and implementation of innovative learning environments in order to shape these roles will contribute to the professional development of teachers in mathematics and science.

Differentiation and personalized learning.
In order to stimulate the development of talent in mathematics and science, it is important that teachers have tools to recognize students' individual differences in science aptitude and attitude and to act upon



Integration of digital tools in teaching
Studies into the development of an appropriate repertoire of teaching techniques with regard to the integration of digital tools in teaching show that mathematics teachers both extend their repertoire through their engagement in projects and in collaboration with their colleagues, and develop this repertoire in line with their views on education and the role of digital tools therein (Drijvers, Doorman, Boon, Reed, & Gravemeijer, 2010; Drijvers, Tacoma, Besamusca, Doorman, & Boon, 2013).

these differences in order to stimulate the development of mathematics and science talent at a level that is suitable for each individual student (van der Valk, 2014).
Studies related to this research question will focus on means for working with teachers on developing and implementing differentiated and personalized education, for instance in teacher design teams (Binkhorst, Poortman, van Joolingen, & Handelzalts, 2015; Mooney Simmie, 2007) and lesson study teams (Fernandez & Yoshida, 2004). In such teams, teacher professional development, development of innovative teaching and research on learning go together. Additionally, studies related to this research question will include research on the transfer from innovative educational approaches developed in differentiated talent programs to the regular science and mathematics curricula, and the role science teachers play in this transfer as developers and teachers.

Implementation of the research program

Methodology
This research program combines research from various traditions, ranging from historical studies to experimental evaluation of teaching methods. Methods will be chosen on a study-by-study basis. In this section some directions in the development of methodology will be sketched.

The availability of large databases of historical data, such as digital newspaper archives, can be a rich addition to the traditional sources for historical research. Within the Freudenthal Institute's research program, the exploitation of these new sources will be pursued, as well as means to make them accessible to the public. In this way the Freudenthal Institute has the ambition to contribute to digital history (Huijnen et al., 2014; van Eijnatten et al., 2013).

Traditionally, the Freudenthal Institute has been strong in design-based research (Bakker & van Eerde, 2015; McKenney & Reeves, 2013). By developing and evaluating subsequent versions of educational design, the development of practical application and theoretical insights go hand in hand. This tradition will be continued and extended, especially by emphasizing the involvement of teachers in the design and implementation cycle and in devising methods for strong validation of the designed learning situations. Collaboration with schools will take shape in a Science Teaching and Learning Lab, in which the Freudenthal Institute will collaborate with schools as well as the programs for bachelor education within Utrecht University to design, develop, implement and evaluate innovative means for science teaching. The Science Teaching and Learning Lab is described in more detail in a separate document.

Finally, the introduction of ICT tools makes it possible to monitor learning processes closely by registering students' interactions with the ICT environments. This makes it possible to study the effects of teaching interventions on student behavior and of student behavior on learning outcomes. In order to accomplish this, the Freudenthal Institute will start collecting data in a data shop connected to the Digital Mathematics environment. Tools and applets within the environments will store their data securely in this repository, thus making it available for analysis. This data shop will be designed so that it ensures data integrity and privacy.

Collaboration and Funding
Funding and collaboration with partners are essential for implementing a research program. The Freudenthal Institute collaborates with several partners within Utrecht University and its Science Faculty in particular, within the Netherlands and internationally. In this section the principal partners are discussed.
Within Utrecht University, the Freudenthal Institute is a partner in the focus area Education for Learning Societies. Moreover, the Freudenthal Institute collaborates with the Game Research focus area and plays a role within the strategic theme, Dynamics of Youth. Funding for these collaborations consists mainly of seed money aimed at initiating collaboration and research grant acquisition.

The Descartes Institute for the History and Philosophy of the Sciences and the Humanities unites Utrecht researchers from all seven faculties. Its mission is to stimulate teaching and research in the history and philosophy of science and scholarship. The Descartes Institute embodies the Utrecht focus area of History and Philosophy of Science. One of its research themes is 'Science in Transition', which aims to develop an historically and philosophically informed perspective on the future role of science and science education in society. The investigation of scientific integrity is a pivotal aspect of the research effort of the Freudenthal Institute.

Within the Netherlands, natural collaborations exist with CITO and SLO and other partners in the educational infrastructure (Platform Bètatechniek, bèta-steunpunten). Together with sister institutes, related to other science teacher education groups, the Freudenthal Institute takes the lead in the common endeavor to secure continuous continued support for research on science and mathematics education, for example, through national expertise networks such as Elwier and ECENT. Collaboration with public partners such as RIVM and KNMI, especially as related to science communication studies, will be sought.

Schools are an important target of the work of the Freudenthal Institute. Therefore, strong collaboration with schools has been set up in the form of the U-Talent network. A structural dialogue will be established between the FI researchers and the schools in the U-Talent network, to create a strong community of researchers and practitioners. The purpose of this community is to make sure that questions and problems from teaching practice inform the formulation of FI research questions and – vice versa – that teaching practice is informed by the results from FI research. The community also supports the creation of consortia for specific research FI projects. Increasingly, EU and national research funding depends on the quality of such consortia.

Funding opportunities within the Netherlands are provided by NWO (personal grants, Top Sectors) and by the "Nationaal Regieorgaan Onderwijsonderzoek" (NRO) in particular. The NRO issues specific calls for practice-based and other research in areas in which the Freudenthal Institute is strong. A positive development is that policy-making bodies are increasing the emphasis on science and mathematics education. For instance this is expressed in the expected continuation of DUDOC-funds, allowing science and mathematics teachers to pursue PhDs or postdoc projects. Also other funds, specifically targeting science education are now being considered, for instance by the Ministry of Education. In the coming years, these developments provide important funding opportunities for the Freudenthal Institute on a national level.

Internationally, the Freudenthal Institute collaborates with institutes in Europe, which has already led to FP7 projects and will be continued in Horizon 2020 collaborations. Moreover, current collaborations with institutes in the USA, Surinam, Indonesia, Singapore, Australia, Israel and China will be extended.

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