

Study programme

The SEC programme (120 EC) is built of the following components:

- [Core Courses](#)
- Specialisation Track:
 - [Teacher Degree](#)
 - [Research and Development](#)
- [Electives](#)
- [Research Project](#)

Core Courses

Did you start before September 2016 with SEC? You can find your study programme and final graduation date in the [EER](#) of your starting year.

The core courses provide the foundation for all further SEC courses and specialisations.

- FI-MSECINT - [Introduction to Science Education and Communication Theories](#) (3.75 EC)
- FI-MSECPSC - [Public Science Communication with Multi Media](#) (3.75 EC)
- FI-MSECDES - [Designing Science Education and Communication](#) (3.75 EC)
- FI-MSECRM1 - [Research Methods Science Education and Communication](#) (3.75 EC)
- FI-MSECRM2 - [Research Methods 2](#) (3.75 EC)

Please note: course codes are different from previous years. Course title and content did not change. You can find the transition table in the EER.

Track: Teacher Degree

Did you start before September 2016 with SEC? You can find your study programme and final graduation date in the [EER](#) of your starting year.

After completion of the teaching degree track, you are qualified to start as a teacher in your school subject.

- GSTMS1 - [Teaching practice 1](#) (15 EC)
- GSTDID1 - [Methodology 1](#) (7.5 EC)
- GSTMS2 - [Teaching practice 2](#) (15 EC)
- GSTDID2 - [Methodology 2](#) (7.5 EC)

[Primary Electives](#) (11.25 EC)

[Secondary Electives](#) (15 EC)

- FI-MSECR30 - [Research Project](#) (30 EC)

The regular version of the teacher education components is in Dutch. You may apply for the English language honours track [U-TEAch](#) instead, but U-TEAch will have its own, competitive, application procedure.

Please note: course codes are different from previous years. Course title and content did not change. You can find the transition table in the EER.

Track: Research and Development

Did you start before September 2016 with SEC? You can find your study programme and final graduation date in the [EER](#) of your starting year.

After completion of this track you are prepared for a career as a science education researcher or designer.

FI-MSECISE - [Internship Secondary Education](#) (11.25 EC)

FI-MSECIIE - [Internship Informal Education](#) (15 EC)

FI-MHPSPSI - [Professional Skills and Identity](#) (3.75 EC)

[Primary Electives](#) (11.25 EC)

[Secondary Electives](#) (15 EC)

FI-MSECR45 [Research Project](#) (45 EC)

Please note: course codes are different from previous years. Course title and content did not change. You can find the transition table in the EER.

Electives

Did you start before September 2016 with SEC? You can find your study programme and final graduation date in the [EER](#) of your starting year.

Primary Electives

Choose three out of the following courses:

- FI-MSECHPS– [History and Philosophy of Science for Education](#) (3.75 EC)
- GSTKO07 – [Sustainability Education](#) (3.75 EC)
- GSTKO20 – [Erfgoededucatie](#) (3.75 EC)
- GSTKO09 – [Cross-Disciplinary Science and Mathematics Education](#) (3.75 EC)
- GSTKO11 – [Talent-ontwikkeling in het VO](#) (3.75 EC)
- FI-MSECID – [Innovation and Dissemination in SEC](#) (3.75 EC)
- FI-MSECADS – [Advanced Design in SEC](#) (3.75 EC)
- FI-MSECSS – [Science meets Society](#) (3.75 EC)

- FI-MHPSPSI – [Professional Skills and Identity](#) (3.75 EC)

See the overview of all [electives of the Graduate School of Teaching](#).

For planning purposes you can use the [Bètaplanner](#)

Secondary Electives

You may select electives from a wide range of master's courses, as long as you take into account the following conditions:

- the courses are relevant to the learning aims of the SEC-programme;
- the total package of courses has sufficient depth and coherence (see EER, appendix)

The total package of electives is subject to prior approval by the programme coordinator. You will apply for approval by handing in your proposed study programme.

You will find a selection of suitable courses in the [Courseplanner](#).

Please note that registration periods can be many months in advance of the course, especially in the Faculties of Humanities and Social Sciences!

Research Project

In the research project, you will use the knowledge you acquired in the programme to investigate new issues.

The project must satisfy the following criteria:

- The research addresses a problem in Science Education or Communication;
- Expertise in science, mathematics or computer science plays a necessary role in doing the project;
- The project aims to answer a question by means of empirical educational research; a project mainly aiming at developing educational material or a literature review is not acceptable.

Most projects will be conducted within the context of ongoing research at the Freudenthal Institute, or in collaboration with partner. Each student who will start on a project from the list will be assigned to a research staff member (PhD) who will act as supervisor.

A required part of the Research Project are the accompanying student seminars, which will be held biweekly on Fridays 15:15 – 17:00.

- FI-MSECR30 [Teacher Degree track](#) (30 EC)
- FI-MSECR45 [Research and Development track](#) (45 EC)

Please find available projects [here](#).

[Several forms](#) have to be filled in regarding the Research Project, such as application forms and assessment forms.

Available Research Projects

Here you can find proposals for future research projects within the Master SEC programme. They are linked to ongoing research projects in the Freudenthal Institute or are conducted in cooperation with external partners. In this case, you will need an internal person to supervise in addition to the external supervisor.

If you are interested in a certain project, please contact the person mentioned in the respective proposal.

Under certain circumstances you might be eligible to propose your own research project. The proposed research has to be clearly connected to the domain of science and mathematics education and it has to be clear who will be supervising. The coordinators will decide on the feasibility of the proposal together.

Multidisciplinary projects

Intuitive interaction with simulations based on motion sensing and augmented reality

Contact: [Nico Rutten](#) and [Wouter van Joolingen](#)

Augmented reality can be used to support new ways of learning. Often, AR is implemented as follows: when looking at your mobile/tablet, you see how location-based information is added to what the camera registers. The present research project focuses on a different kind of AR-implementation: the augmented-reality layer is projected directly onto the material that the students can interact with to influence a simulation that creates the AR-layer.

In the Teaching and Learning Lab, the Freudenthal institute wants to create two possibilities to interact with simulations according to this AR-based approach:

- *Augmented reality sandbox.* The students can move physical sand in a box. The augmented reality layer that is projected on this sand, transforms it into a landscape with rivers. Kinect-technology registers every change in the sand configuration, which – based on an underlying simulation – results in changes in the river landscape. A possible learning objective is to configure the landscape in such a way to prevent floods from occurring.
- *Warehouse optimization.* The students can move blocks on a surface. These blocks are recognized by the system as units of a storage facility. The objective for the students is to optimize the layout of the warehouse.

Possible research questions are:

- How does learning with simulations based on using these tangible interfaces for interaction differ from interacting with a mouse?
- No more mouse means no longer is only one person in control. In other words, there is no more limit on the amount of students that can interact with the simulation simultaneously. How does this possibility to work together work out in practice?
- To what extent do the discussions between the students and their teacher reflect that they're engaged in an approach to learning that is embodied to a higher degree?

Implementing 'socio-scientific inquiry-based learning' (SSIBL) into science education

Contact: [Christine Knippels](#)

Education through an inquiry approach in science and technology prepares young citizens to participate in socio-scientific debate. For this purpose, students need to have an understanding of the process and products of science and technology and to appreciate them as human endeavour. In addition, students need to exercise informed decision-making, i.e. considering and balancing relevant facts, interests, values, costs and benefits.

The [PARRISE](#) project, which involves 18 European partners, aims at introducing the concept of Responsible Research and Innovation in science and mathematics education to contribute to a scientifically literate society (21st century skills). It does so by combining socio-scientific issues (SSI) and inquiry-based learning (IBL) to foster citizenship (CE) in science education; The SSIBL-approach.

Implementing the SSIBL-approach in science classrooms and teacher training programs is challenging. Many aspects still have to be investigated and analysed in order to make proper education trajectories and materials. Last year our teacher educators implemented activities in their teacher training programme and we have data available that can be used to evaluate these sessions. Moreover, based on the experiences of the first round of try-outs new learning and teaching activities can be developed and tested.

Implementing inquiry-based learning into the science and mathematics classroom

Contact: [Michiel Doorman](#) (mathematics)

Inquiry-based learning (IBL) has been advocated by science and mathematics educators as a means to make students be actively engaged in content-related problem-solving processes. Recent curricula across Europe underline the need to implement IBL into the science and mathematics classroom (see 21st century skills for NL). However, a discrepancy can be found between the need to make IBL accessible to students and teachers' current classroom practice. Therefore, large scale implementation projects like mascil provide tools and aids

for teachers to foster the innovation process and make it more visible and sustainable in actual classroom practice. The EU project mascil lays an additional emphasis on tasks related to contexts from the world of work that may be relevant for the students' future careers within the subjects.

Two research projects are proposed in close cooperation with the EU project mascil:

The first research project accompanies the implementation process of mascil tasks by selected teachers within a case study design. The teachers will be guided in this process and data is retrieved on their beliefs and implementation strategies (e.g., necessary aids and evaluation tools), classroom implementation is observed and students' responses during and after the implemented unit are considered (e.g., creativity and levels of inquiry). A sample collection of students' responses on a mascil (mathematics) task is available for an initial explorative study.

In the second project, the redesign of traditional tasks within teacher professional development units will be focused on. Teachers will be observed during the process of redesigning a closed textbook task into an IBL-oriented task within the world of work and interviewed afterwards. The aim is to extract the determinants for successful redesigning processes to be able to enhance a research-based tool kit containing redesigning aids to guarantee successful implementation of tasks. The tasks can be selected from subjects within the science or mathematics domain.

Examples and further literature can be found at the mascil website.

Playful drag-and drop programming, an effective primer for 'real' programming?

Contact: [Elwin Savelsbergh](#)

Building on a tradition that began with the LOGO programming environment, nowadays there is a wealth of playful drag and drop programming environments, such as Scratch, Lego Mindstorms NXT. Some of these implement rather advanced programming concepts, such as control loops or recursion. Even young children can learn programming with such tools, and it has been claimed that this would provide an effective preparation for programming with 'adult' programming languages, such as Java, C, or Python. However, there is little systematic research to support this claim.

This project in the early grades of secondary education will investigate the effects of prior experience with a drag-and-drop programming language on the subsequent learning of a text based programming language, both in terms of motivation/confidence, and in terms of conceptual transfer. Most likely, the research will be carried out in the context of an [after school computer club](#).

Franklin, D., Conrad, P., Boe, B., Nilsen, K., Hill, C., Len, M. & Waite, R. (2013, March). Assessment of computer science learning in a scratch-based outreach program. In

Proceeding of the 44th ACM technical symposium on Computer science education (pp. 371-376). ACM.

Meerbaum-Salant, O., Armoni, M., & Ben-Ari, M. (2013). Learning computer science concepts with Scratch. *Computer Science Education*, 23, 239-264.

Drawing-based modelling in lower grade science education

Contact: [Wouter van Joolingen](#)

In the new knowledge base for grade 7-8 science education the concepts of models and modelling are central. Models play a crucial role in scientific reasoning. Often they are seen as simplifications of reality, but more importantly they play a role as reasoning tool for understanding reality. Therefore constructing models is an important part of science education. For the lower grades (grade 7-9, 12-15 yr old) constructing models cannot involve extensive mathematics and hinges on the use of visual representation. For this reason modelling tools such as SimSketch (see modeldrawing.eu) allow young students to create scientific models based on drawings. In their drawings, students indicate the behaviour of the elements of the drawing. The tool can then simulate this behaviour, turning the drawing into an animation.

In this research project you will design a modelling task related to your school subject, observe students carrying out this task and analyse the interaction, using the framework of “Epistemic Games” (Tuminaro & Redish, 2007). In this way you will trace the developments in scientific reasoning in the interaction with the modelling task.

Tuminaro, J., & Redish, E. (2007). Elements of a cognitive model of physics problem solving: Epistemic games. *Physical Review Special Topics-Physics Education Research*, 3(2), 020101. doi:10.1103/PhysRevSTPER.3.020101

Bollen, L. & van Joolingen, W. (2013). SimSketch: Multi-Agent Simulations Based on Learner-Created Sketches for Early Science Education. *IEEE Transaction on Learning Technologies*, 6(3), 208–216. doi:10.1109/TLT.2013.9

Learning from unreal worlds

Contact: [Wouter van Joolingen](#)

Back in 1987, a famous educational computer system was the Alternate Reality Kit. The basic idea behind this system was that students could construct and explore alternative worlds to learn about the concept of physical laws and how they predicted behavior. Unfortunately, ARK never left the computer lab as the computing resources needed to run it were way beyond what schools could afford in these times.

Nowadays, the computing technology needed to run ARK and similar systems fits in anyone’s pocket. This justifies a new attempt to create and evaluate simulations of alternate worlds where students can play with the governing laws. For instance, one could create

worlds where the speed of light is within reach of normal cars, environments where conservation laws are not valid or where electrical forces between charged bodies are increasing with distance instead of decreasing, to name a few examples.

From a theoretical perspective such worlds are interesting for two reasons. By exploring these worlds students can experience the consequences of laws in extreme situations and in this way develop deeper understanding of the meaning of the laws. And by constructing alternate realities, students get acquainted to the idea of model construction and ideas of parsimony in scientific theories.

Your task is to design tasks for learning with alternate realities in the design process of an alternate reality game. You will collaborate with a game designer (a student in game design) who will co-design and implement the game. The game will be pilot tested and observations of students playing the game will feed the development of new versions. After a few iterations, the game will be delivered and tested using a study using pre-test and post-test to assess student learning with the game.

Smith, R. B. (1987). Experiences with the alternate reality kit: an example of the tension between literalism and magic. *ACM SIGCHI Bulletin*, 18(4), 61–67. doi:10.1145/29933.30861

Informal Education

Creating scientific practices with science museums

Contact: [Wouter van Joolingen](#) (first supervisor), and Yuri Matteman (Naturalis)

In science education, focus is on the construction of scientific practices. The idea of this is that students get in touch with real science, and engage in authentic scientific work. In such a way, students get engaged in the scientific reasoning encounter the creative and constructive aspects of science.

In this project you will design a scientific practice around a topic of study that is found in Naturalis, the centre for biodiversity in Leiden. In collaboration with a researcher you will set up teaching material and use proper ICT tools, such as modeling tools to create tasks that constitute a scientific practice. Topic will be chosen in collaboration with Naturalis and can be the evolution of snails, the spreading of diseases through parasites, or the dynamics of populations.

The scientific practice will involve preparatory work at school as well as a visit by the school to Naturalis, in which the students will collect data. For the students the practice should result in a scientific product, such as a model or a research report. Apart from the design, you will study the learning processes of the students by recording and observing their actions and assessing their final products.

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*, 25(2), 177–196. doi:10.1007/s10972-014-9384-1

Dillon, J. (2011). Teaching Science Outside the Classroom. In R. Toplis, How Science Works (pp. 134–147). Abingdon: Routledge.

Opbrengsten van de Summerschool Junior

Wie geïnteresseerd is in dit onderwerp kan het beste direct contact opnemen met externe begeleider: [Maarten Reichwein](#).

Alleen 45 ECTS (Summer school loopt januari-juli).

Biology education

The use of models in biology education

Contact: [Susanne Jansen](#) and [Christine Knippels](#)

Models are used in science both to explain certain phenomena and to test hypotheses about these phenomena. In biology education, models are of great importance. Every textbook is filled with different kinds of models to help students understand and work with the information that has been given. A drawing of a cell and its components, an ecological pyramid, or the process of photosynthesis are just a few of the many examples present in textbooks. The models used in science education are often based on two types of analogies. The first is in surface similarity, showing what the model is about. The second is in deep systematic process similarity that can develop conceptual understanding in students and has a higher educational value. Most teachers and other educators assume that students can work with the models that are present in textbooks and understand why these types of models are being used. In reality, most students do see the surface similarity and are thus able to explain what the model is about or where a certain process takes place, but are unable to map the deep systemic process similarity on their own.

The proposed project aims to unravel how this gap in understanding models in biology education can be closed. For this you will analyze what the SLO indicates as trivial knowledge about models and modeling in biology education, view what is taught in textbooks and biology classes about understanding models, and make suggestions in how we can improve students' understanding of models and modeling in biology.

Molecular representations in chemistry and biology

Contact: [Paulien Postma](#) and [Christine Knippels](#)

On school level, molecular concepts such as molecules, proteins, genes and cells are (often) taught in separate subjects. Hardly ever are these concepts connected when for example explaining (sub)cellular processes such as fotosynthesis, dissimilation or biosynthesis. As a result, secondary science education students end up with a collection of isolated facts about molecules and cells but are left on their own filling in the 'black box': explaining how cellular activities are actually the result of the joint activity of various molecules in the cell.

This may in part be due to by the use of different kind of representations (pictures, models, graphs and animations) in biology and chemistry class. It is questionable if these representations stimulate conceptual interplay when reasoning about the role of molecules in cellular processes. For example, it is expected that students do not link the chemical properties of proteins (learned in chemistry class) to the binding and activation of enzyme-substrate complexes (learned in biology class).

In the proposed project you will research what type of representations are frequently used in biology and chemistry textbooks, what they try to explain and what kind of reasoning these representations evoke among students when asked to explain cellular processes from a molecular perspective. The results of this research could inform the design of a learning- and teaching process aimed to achieve conceptual interplay between chemistry and biology concepts in students' reasoning about molecular processes in the cell.

Analysing Dutch biology textbooks on the extent of implementation of the crosscutting concept 'systems thinking'

Contact: [Melde Gilissen](#) and [Roald Verhoeff](#)

According to the Dutch examination standards (CvE, 2016), systems thinking is a crosscutting concept (in Dutch: *denkwijze*), which Boersma, Waarlo and Klaassen (2011) describe as thinking backward and forward between concrete biological objects and processes, and systems models representing systems theoretical characteristics. This definition illustrates the pervasive nature of systems thinking and its relation with all other biology domains within the examination standards, i.e. self-regulation, self-organisation, interaction, reproduction and evolution.

Biologie Voor Jou (BVJ) and Nectar are the most used biology textbooks by Dutch biology teachers in secondary education. Both publishers have recently revised their textbooks. Malmberg came up with a revised edition of BVJ in 2013, where they implemented the concept-context approach. In 2017 the revised edition (the fifth edition) of Nectar will appear for the lower secondary education classes. Noordhoff Uitgevers claims that this revised edition brings more coherence between biological topics.

This research project investigates whether the adjustments of both textbooks support a more coherent insight in biology and addresses to what extent the crosscutting concept systems thinking has been implemented in biology textbooks.

Before the revisions there was some criticism on these textbooks. Knippels (2002) analysis on textbooks showed that no explicit attention was paid to levels of biological organisation in the chapters on meiosis and inheritance and the conceptual relationships between these chapters were not made explicit. Verhoeff et al. (2009) determined that an average Dutch textbook introduces 577 new concepts related to the chapter about cell biology. Around 64% of these concepts are not explained in terms of the students' prior knowledge. In addition, a lot of concepts are only mentioned in the chapter about cell biology and are not used in later topics such as genetics or metabolism. Not explicitly relating important concepts to their level of organisation and not linking concepts at different organisational

levels might hinder a coherent insight in biology. The analysis of both Knippels (2002) and Verhoeff (2009) suggest that textbooks can be an important obstacle in learning biology in secondary education. This project builds on these outdated analyses and offers an insight into the current state of the textbooks. With this analysis it is possible to determine the extent of support textbooks give to the development of students' systems thinking skills.

Boersma, K., Waarlo, A. J., & Klaassen, K. (2011). The feasibility of systems thinking in biology education. *Journal of Biological Education*, 45(4), 190-197. DOI: 10.1080/00219266.2011.627139

Socio-scientific issues in biology education

Contact: [Christine Knippels](#)

Rapid developments in biology and the life sciences, like genomics and synthetic biology offer a lot of promises and potential. For instance development of personalised medicines, vaccines and biofuels. However, it also raises questions about biosafety or the moral boundaries of modifying DNA and making life ourselves. These kind of questions or issues are so called socio-scientific issues (SSI).

SSIs are problems which often arise in our society and have a scientific and/or a technological component. There is no consensus on how such problems might best be solved for the well-being of individuals and society at large. The public in general, and students in particular, should be able to negotiate and make informed decisions about these kinds of SSIs. Fostering these aspects of citizenship is an important aim of biology education both on the national (Examenprogramma Biologie, 2016) and European level (European Commission, 2015).

In order to support students and teachers in this process, adequate learning and teaching activities are desirable. In the context of an European project called [PARRISE](#) we have developed an approach that combines SSIs with inquiry based learning (called: socio-scientific inquiry-based learning).

Implementing this approach in biology classrooms and teacher training programs is challenging. Many aspects still have to be investigated and analysed in order to make proper education trajectories and materials. Last year our teacher educators implemented activities in their teacher training programme and we have data available that can be used to evaluate these sessions. Moreover, based on the experiences of the first round of try-outs new learning and teaching activities can be developed and tested.

European Commission (2015). *Science Education for Responsible Citizenship*. Brussels, European Union. http://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf

Virtual Reality in Molecular Biology (Place for two students)

Contact: [Wouter van Joolingen](#)

Biology textbooks typically depict molecular and cellular processes such as enzyme operation and protein synthesis with iconic representations of macro-molecules. Whereas this representation is useful to obtain a global view of the processes there are aspects that are not covered but are important for understanding the essence of the processes involved. For example, apart from the 'lock and key' idea of enzyme that is involved in order for molecules to 'snap' into each other, the molecules themselves are dynamic structures and their movement within the cells adds to the dynamics. Whereas the textbook representation may give rise to the misconception that molecules display purposeful behavior, a representation that incorporates dynamics can give rise to a more accurate 'mechanistic way' of reasoning that is capable of explaining the effects of external factors such as temperature and pH value in the cell.

Virtual reality can provide such a dynamic representation. In an environment where students can play with 3D models of molecular processes and in which they can modify the model, students can experiment with the molecular processes and literally see how they come to life and operate together. In this project we will use SimSketch as a modeling tool with which students can modify the dynamic behavior of the molecules and VR software from the lab of Prof. CAI Yiyu at NTU to display the 3D behavior. The research question is how this combination of representations can be integrated in the biology class.

In a team in which you will work together with students from Windesheim University of Applied Sciences (Zwolle), supervised by Dr. Teresa Dias Pedro Gomes and students from Nanyang Technical University (Singapore), you will develop and evaluate lessons around this topic. The validation of the designed pedagogies and lesson plans will be done via the Lesson Study method as developed by Professor Sui Lin Goei (Windesheim) implementing this method widely in Dutch schools in the Netherlands. The student teams will meet using videoconferences and once a year face-to-face during conferences and workshops to discuss the design of the lessons. Both master theses will focus on subtopics of the study, one will be related to the way students use and appreciate the VR aspects in learning about the molecular processes; the second will focus more on the modeling aspect and the specification of the dynamic behavior of the processes.

Chemistry education

Molecular representations in chemistry and biology

Contact: [Paulien Postma](#) and [Gjalt Prins](#)

On school level, molecular concepts such as molecules, proteins, genes and cells are (often) taught in separate subjects. Hardly ever are these concepts connected when for example explaining (sub)cellular processes such as photosynthesis, dissimilation or biosynthesis. As a result, secondary science education students end up with a collection of isolated facts about molecules and cells but are left on their own filling in the 'black box': explaining how cellular activities are actually the result of the joint activity of various molecules in the cell.

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In the proposed project you will research what type of representations are frequently used in biology and chemistry textbooks, what they try to explain and what kind of reasoning these representations evoke among students when asked to explain cellular processes from a molecular perspective. The results of this research could inform the design of a learning- and teaching process aimed to achieve conceptual interplay between chemistry and biology concepts in students' reasoning about molecular processes in the cell.

Students' learning of molecular modelling in pre-academic chemistry education

Contact: [Gjalt Prins](#)

Molecular Modeling is one of the fastest growing fields in science. It may vary from building and visualizing simple molecules (in 3-Dimensions) to performing complex computer simulations on large protein molecules. Using various molecular modeling software, one can visualize, rotate, manipulate, and optimize models on a computer display. Molecular Modelling is used, for instance, for designing drugs and new materials. In secondary chemistry education students should become acquainted with and gain insights in the technique of Molecular Modelling. This urges for high quality teaching materials in which students are meaningfully engaged in molecular modelling. In our institute an innovative curriculum unit has been developed, in which students perform a lead optimisation for designing a new drug against the malaria disease. The authentic practice of drug design is used as a context for learning. The designed curriculum unit, however, is only tested once among students grade 11. The results were positive, although it became apparent that the unit needs a thorough revision and a second try-out using the method of educational design research.

Dori, Y. J., & Kaberman, Z. (2012). Assessing high school chemistry students' modeling sub-skills in a computerized molecular modeling learning environment. *Instructional Science*, 40(1), 69-91. doi: 10.1007/s11251-011-9172-7.

Prins, G. T., Bulte, A. M. W., Driel, van J. H., & Pilot, A. (2009). Students' involvement in authentic modelling practices as context in chemistry education. *Research in Science Education*, 39, 681-700. doi: 10.1007/s11165-008-9099-4.

Mathematics education

Embodied graphs

Contact: [Paul Drijvers](#)

In this research project, two recent developments will be integrated, one practical and one theoretical. From the practical perspective, digital tools for math and science education have become more sophisticated over the last decades and are getting widespread. The recent start of the Freudenthal Institute's Science Teaching and Learning Lab (STLL) witnesses the relevance of this development in our institute.

One particular case of digital tools that may be used in mathematics education are motion sensors, that can be connected to handheld devices and laptops, and that can be used to measure motion, distance and speed. Such sensors may play a central role in exciting student activities (e.g., see Arzarello & Robutti, 2001). The effect of such activities on learning, however, is still unclear.

A theoretical perspective that may help here is the notion of embodied cognition. Core in embodied cognition is the awareness that mind and body are not separated entities, but that cognition is grounded in bodily experience. Perception and movement may drive cognitive development, and sensori-motor schemes form the basis for cognitive schemes (Lakoff & Núñez, 2000). The question is whether this view on cognition may help to exploit and explain the opportunities offered by the use of motion sensors in teaching the topics of graphs and functions to lower secondary students.

To investigate this question, introductory tasks will be designed for the topic of graphs and functions. These tasks will be field tested, either in the STLL, in local schools, or in a science museum (cf. Nemirovski, Kelton, & Rhodehamel, 2013). Both the design and the data analysis will be guided by notions from embodied cognition. The results should inform teachers, designers and researchers on the use of such digital tools in mathematics education.

For further details, please contact [Paul Drijvers](#).

Arzarello, F. & Robutti, O. (2001). From Body Motion to Algebra through Graphing. In *Proceedings of the 12th ICMI Study Conference*, Vol. 1, 33-40.

Lakoff, G. & Núñez, R. (2000). *Where mathematics comes from: How the embodied mind brings mathematics into being*. New York: Basic Books.

Nemirovsky, R., Kelton, M.L., & Rhodehamel, B. (2013). Playing mathematical instruments: Emerging perceptuomotor integration with an interactive mathematics exhibit. *Journal for Research in Mathematics Education*, 44(2), 372-415.

Hints, heuristics and compression

Contact: [Rogier Bos](#)

In the new curricula for mathematics in HAVO-VWO in the Netherlands one finds a renewed attention for mathematical thinking (wiskundige denkactiviteiten). The curriculum designers want to move away from learning mathematics solely by memorizing sets of routines. Mathematical problem solving is a central constituent of [mathematical thinking](#). To solve a

problem, one needs to combine mathematical activities that one mastered before. So one needs to make strategic decisions, on a level that transcends the procedural.

A way to guide a student with these strategic decisions is by providing heuristics. A heuristic (Pólya, 1945) is a general strategy to attack a problem, e.g., investigate special cases. In this research we study how such hints and heuristics should be structured in a course. About heuristics Schoenfeld claims (1985, p. 73): “many heuristic labels subsume half a dozen strategies or more. Each of these more precisely defined strategies needs to be fully explicated before it can be used reliably by students”. So how should the use of these heuristics be built up? The idea under investigation is that hints in a course should be developed parallel to the way mathematical thought develops. Central in development of mathematical thought is a cognitive process called compression (Thurston, 1990, Barnhard & Tall, 2001). Compression is a transition in the mind from isolated procedural steps to more integrated processes, ending in cognitive units that Tall calls procepts. With a cognitive unit Tall means “a piece of cognitive structure that can be held in the focus of attention all at one time” (p.1). Hints and heuristics may represent such cognitive units, heuristics being the highly compressed ones.

The goal of this research project is to contribute to the teaching of mathematical thinking and in particular problem solving in HAVO-VWO. To this purpose, a course in the Digital Mathematics Environment (DME) of the Freudenthal Institute will be designed. The DME offers the possibility to build a structure of hints and heuristics and to monitor the students use of these.

The designed course will be field tested with secondary school students . The first result for these student should be that they develop compressed procepts in the domain of the course, and use these in their reasoning. A second result should be that students learn to ask for hints on the right level of their mathematical development, not continue to ask for low procedural hints, when they should be able to handle heuristics (cf. Roll et al., 2014).

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Revealing why histograms are so difficult to understand

Contact: [Lonneke Boels](#). Co-supervisors: Arthur Bakker and Paul Drijvers.

A new curriculum for statistics education is recently implemented for statistics education on havo and vwo starting from grade 10. Part of this curriculum is statistical literacy. This includes the ability to draw inferences from statistical data including data presented in graphs. Although histograms seem to be simple graphs of statistical data, students make several mistakes with reading, interpreting and drawing inferences from these graphs (Boels, Bakker, Drijvers & Van Dooren, 2016).

The central question in this research is: Which thought processes of students of vwo grade 10 and which properties of histograms explain the mistakes students make?

In an explorative case study some of the mistakes that students of vwo grade 10 (4 vwo) with mathematics A or C make will be investigated. The thought process will be made visible through an eye-tracking study in which students answer questions about histograms while thinking aloud.

The goal of the research of the master student will be to develop a set of items that can be used in the eye-tracking study. The question is if these items are suitable to assess or exclude certain explanations for making the mistakes.

For further details, please contact [Lonneke Boels](#).

Boels, L.B.M.M., Bakker, A., Drijvers, P.H.M., Van Dooren, W. (2016). *Students' interpretations of histograms: a review*. Posterpresentation ICME 13, Hamburg. DOI: 10.13140/RG.2.2.24011.59680

Automated feedback for geometry tasks

Contact: [Paul Drijvers](#). Co-supervisors Peter Boon and Sietske Tacoma.

Online resources for mathematics are widely available. The Freudenthal Institute's Digital Mathematics Environment ([DME](#)) provides a rich set of digital activities for students, including teaching materials for geometry through the use of the software [Geogebra](#), which is embedded in the DME.

Core issues in digital resources for mathematics education are automated scoring of student responses, adaptive feedback, and partial credit for relevant steps in the solution processes. To a limited extent, these facilities for geometry are available in the DME, but further refinement is needed. The aim of this research project, therefore, is to investigate how feedback and automatized scoring including partial credit can be further developed in the DME and how students benefit from these features.

To do so, a theoretically underpinned student model for geometry in grade 9 will be designed. Based on this model, the automated scoring and feedback features of an existing module will be extended. The viability of the extensions will be assessed through a teaching experiment.

Improving the mathematical abilities of braille-dependent students

Contact persons: [Annemiek van Leendert](#) and [Michiel Doorman](#).

In January 2015 the research project 'Improving the mathematical abilities of braille-dependent students' started. In the first part of this project we will investigate how we can support braille-dependent students with reading and processing mathematical expressions. Our hypothesis is that insight in how sighted students perceive these expressions can give clues for support to braille-dependent students.

Let's take, for example, the equation:

This equation has global characteristics, e.g. the '=' sign and the sqrt-sign, and the equation has local characteristics, e.g. the 2 of x^2 and the '+3' part. A sighted person sees immediately that this is an equation, and almost immediately that this is an equation of two square roots. These insights provide direction to cognitive strategies for solving the problem.

How does a braille-dependent student perceive this equation? He reads this expression, with a braille-display connected to the laptop, in a Word-document. This is only possible when the expression is displayed in a linear form: $\sqrt{x^2/2} = \sqrt{(x+3)/2}$.

He reads the expression on a braille-display from left to right which makes it difficult to make a distinction between local and global characteristics. Therefore it is very hard to get an overview of the expression.

Research questions

The aim of this study is to better understand how braille-dependent and sighted students read and make sense of algebraic expressions and equations. We will perform an eye tracking sub study for the sighted students and a finger tracking sub study for the braille-dependent students.

The main questions of the eye tracking sub study and the finger tracking sub study are:

- What are the similarities and differences between the cognitive strategies of braille-dependent and sighted students?
- How are these similarities and differences related to tactile respectively visual strategies and to task characteristics?

For each sub study the following two research questions is addressed.

Finger tracking sub study

F1: What is the relation between the tactile strategies, cognitive strategies and the complexity of the task (in structure and in use of operations and numbers)?

Eye tracking sub study

E1: What is the relation between the visual strategies, cognitive strategies and the complexity of the task (in structure and in use of operations and numbers)?

We are looking for a master students to either contribute to the eye tracking study or to the finger tracking study.

The instruments for the studies are under development. A first set of tasks is designed. Methods for analyzing the eye-tracking data are based upon differences between number of fixation, duration, and switches and dwelling. Methods for analyzing the tracking data are under construction. The student will have to contribute to the optimization of these instruments, the data collection and the analysis.

Mathematics for higher technical professional education (hbo techniek)

Contact persons: [Nathalie van der Wal](#) and [Arthur Bakker](#)

Over the past decades, the use of ICT, technology and computer-driven equipment in the workplace has changed the professional practices of engineers. Calculations are performed by computers and therefore mathematics is often hidden (Hoyles, Noss, Kent & Bakker, 2010).

Because of these changes, other skills are necessary. These new skills are named 21st-century skills. Part of these skills are Techno-mathematical Literacies (TmL). They are a combination of mathematical, workplace and ICT knowledge, communicative skills, the ability to interpret abstract data, having a number sense and a sense of error.

Within higher professional education, there is an ongoing discussion on the mathematics curricula, which are mainly theoretical with limited application to practice and use of software. Students have limited motivation for mathematics because of the lack of seeing its relevance. To prepare these future engineers for their workplace tasks, it is imperative that TmL are implemented as learning goals in the mathematics curricula.

This research comprises the design of an innovative applied mathematics course by the research strategy of Design-Based Research. We will hold a pilot study in Spring 2016 at Avans Hogeschool in 's-Hertogenbosch. We are looking for a master student to participate in the first full cycle of design research in Autumn 2016, for example by focusing on pre-posttests or comparing hypothetical learning trajectories with actual learning.

For further details, please contact [Nathalie van der Wal](#).

Hoyles, C., Noss, R., Kent, P., & Bakker, A. (2010). Improving Mathematics at Work: The Need for Techno-Mathematical Literacies. London: Routledge.

Geogebra replacing graphing calculators during national examinations in mathematics?

Contact: [Paul Drijvers](#)

Since 2000, students in havo and vwo can bring their graphing calculator (GC) to the national central examinations mathematics. During the examinations, the GC is mostly used to approximate extrema, intersection points, slopes, and zeros of functions and graphs, and to calculate probabilities for normal and binomial distributions. Even if there are different assessment strategies with respect to ICT in examinations (Drijvers, 2009), so far there seems to have been some satisfaction with this approach in the Netherlands.

For different reasons, however, the level of satisfaction is decreasing. First, the new curricula stress algebraic and analytical skills, and as such reduce the importance of numerical and graphical approximations. Second, graphing calculators are limited tools, compared to more advanced tools such as tablets, laptops and smart phones that run sophisticated software such as Geogebra (GGB). Third, graphing calculators come with extensions and apps, which makes it hard for assessment authorities to define regulations that are fair and provide all students with equal opportunities. The authorities feel the need for better means of control. Fourth, students in schools where laptops or tablets are the mean learning tool, rather than the textbook, feel uncomfortable with the need to purchase a GC only for the sake of the national examination.

To address these issues, the idea emerged of designing a specific build of the software Geogebra that offers similar features as the graphing calculator, and that can be embedded in CvTE's assessment player Facet. The question is, however, if this change of environment and of software tool affects the assignments, the difficulty of the tasks, and the techniques needed to solve them. This question is all the more important, as it is known from previous research that the relationship between using a tool for doing mathematics and the corresponding mathematical thinking is a subtle one (Drijvers et al., 2013).

To investigate the above question, the study concerns designing and carrying out small scale pilot studies on students using the specific build of Geogebra while working on examination assignments, both in one-to-one settings and in pilot class settings (for example, in the context of school examinations). The theoretical framework will be formed by the theory of instrumental genesis (Trouche & Drijvers, 2010). The instrumentation schemes that students develop while using Geogebra will be compared with the corresponding schemes while using the GC. The hypothesis is that, due to its user-friendly features and mathematical sophistication, the students will perceive the GGB schemes as more natural and more efficient. The results will inform future directions of using digital tools in national mathematics examinations.

The study can be carried out either in the frame of an internship at Cito, or as a study hosted by the Freudenthal Institute. For further details, please contact Paul Drijvers.

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Physics Education

Spontaneous reasoning with signal travel time

Contact: [Elwin Savelsbergh](#) en [Floor Kamphorst](#)

The aim of secondary physics education is that students will experience the power of the physics way of describing the world, besides content knowledge. That is, to infer far reaching consequences from simple premises, which turn out to hold in the real world. This aim has proven hard to attain in many areas, but the theory of special relativity, a new topic in the Dutch secondary physics curriculum, is a promising choice to reach these ambitions (Dimitriadi & Halkia, 2012). The theory is based on two assumptions (postulates), that can be regarded as rather straightforward (Einstein, 1905). However, the implications of these assumptions are not straightforward at all, but are very abstract and counterintuitive (Scherr, Shaffer, & Vokos, 2001).

For students to gain conceptual understanding, the learning process should place them in such a position that they experience the need to extend their conceptual knowledge in a certain (scientific) direction (Lijse, 2010). To be able to create such a need, the physics content must be reconstructed for this specific educational purpose (Kattmann, Duit, Gropengiesser, & Komorek, 1996).

For the first postulate of Special Relativity, the relativity postulate, it is important that students understand the notion of 'intelligent observers' (i.e. that observers can correct for signal travel time). Scherr et. al. (2001) showed that many students do not distinguish between signal travel time and time dilation.

Your project will focus on spontaneous reasoning of pre-university students (5 VWO) on signal travel time. You will conduct a qualitative analysis of clinical interviews with 14 students. You will be expected to come up with an analysis frame for these interviews, identify various patterns in student reasoning and give implications on your findings for the design of education on this topic. The project is part of the PHD research of Floor Kamphorst. You will work on already collected data and will assist with collecting new data.

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Monitoring effects of physics curriculum innovation projects in exam tasks

Contact: [Maarten Pieters](#) and [Wilmad Kuijper](#)

This research project contributes to an investigation of long term effects of curriculum reform projects on textbooks, exams and teacher practice. The result of the project will help to answer the overarching question which factors over a longer period stimulate or impede that curriculum innovation ideals are realized in teachers' practice.

The case of study is physics education in upper secondary education (havo/vwo) in The Netherlands, since 1970.

The focus of this research project is on the national exams. Questions are:

how do exam tasks over the years reflect changes in curriculum content and pedagogical approaches as intended by the major curriculum reform projects?
what information, prescriptions and beliefs have influenced designers of exam tasks and the Board of Examinations (College voor Toetsen en Examens and its predecessors) in their decisions on the design specifications of exam tasks?

For the first of these questions, a scheme of indicators will be developed to analyze exam tasks. For this scheme, an existing instrument can be adapted, which has been used to analyze textbooks and project and policy documents. For the second question, interviews will be held. The interview questions will be designed on the basis of literature and tried out in test interviews.

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Inquiry-based, technology supported whole-class teaching

Contact: [Nico Rutten](#) en [Wouter van Joolingen](#)

Nowadays, a lot of technology is available that can be used while teaching. However, application of technology doesn't result in better teaching and learning in itself. It's better to take pedagogy as the starting point: what's the learning goal of my lesson and how can the use of technology support achieving this goal? Examples of pedagogical approaches are inquiry-based learning and Peer Instruction; examples of technologies are PhET simulations and the DWO (Digitale Wiskunde Omgeving). It's quite a challenge to bring these approaches and technologies in line in order to optimally support learning. In this research project you'll perform a design run in which you combine such approaches and technologies. You'll report on what barriers you're confronted with, and what are conditions for success.

This project need not be about physics (speak to Nico Rutten if you prefer chemistry, for example).

Crouch, CH, Watkins, J, Fagen, AP & Mazur, E 2007, 'Peer Instruction: Engaging students one-on-one, all at once', *Reviews in Physics Education Research*, vol. 1, no. 1.

Rutten, N, van der Veen, JT & van Joolingen, WR 2015, 'Inquiry-based whole-class teaching with computer simulations in physics', *International Journal of Science Education*, pp. 1-21.

Embedding ISP experiments in inquiry-based, technology supported learning

Contact: [Nico Rutten](#) en [Wouter van Joolingen](#)

The Ionising Radiation Laboratory allows students to experiment with ionising radiation. These activities are organized at the university as well as at the premises of the schools. Even though these experiments are interesting in themselves, learning gains might be improved by embedding these experiments in a context of inquiry-based, technology supported learning. Ways to support this are by having the students orient, hypothesize, or design in advance, or by having them analyze, interpret, or conclude afterwards. Many technologies are available that could support these learning activities. In this research project you'll design a way of embedding an ISP experiment in an inquiry-based, technology supported context, and assess its effectiveness.

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