# INTERNATIONAL EXPERT SEMINAR:

# EVIDENCE OF THE IMPACT OF SCIENCE EDUCATION IN ATTRACTING YOUNG PEOPLE TOWARDS SCIENCE STUDIES AND SCIENCE-RELATED CAREERS

29 September 2022

Estonian Academy of Sciences

Tallinn, Estonia

ACADEMIA SCIENTIARUM ESTONIAE

TARTU ÜLIKOOL · UNIVERSITY OF TARTU · 1632

The seminar is supported by Horizon 2020
Twinning project “Addressing Attractiveness
of Science Career Awareness” (SciCar)

This project has received funding from the European
Union’s Horizon 2020 research and innovation
programme under grant agreement No 952470

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The seminar is part of the International Year of Basic Sciences
for Sustainable Development, (IYBSSD2022) events in
Estonian Academy of Sciences

Compiled by Miia Rannikmäe
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Background photos by Reti Kokk

# FOREWORD

Europe seeks to become a smart, sustainable and inclusive economy, good education and training especially on STEM fields are essential to achieve that. Although our world is increasingly science and technology based, the workforce in STEM in Europe is decreasing.

Europe needs a new generation of researchers and practitioners who can identify and solve major challenges such as energy, water, climate change, food, health and transport related issues. Educational sector, in particular science education, has a prominent role in supporting the ambitions of resolving these issues.

School STEM curricula are frequently not organised systematically across the years of schooling and emphasise discrete facts rather than providing students with engaging opportunities to experience how science is actually undertaken. On the other hand studies have shown that students do not see school science as useful for their lives and future career developments. The relevance of science during adolescence becomes essential to sustain students' interests and maintain a strong motivation to learn.

STEM jobs require several additional competences – 'tools for working' (information literacy), 'ways of working' (communication; collaboration and teamwork), 'ways of thinking' (creativity and innovation; critical thinking; problem solving; decision making; metacognition) and 'living in the world' (personal and social responsibility). These skills help prepare students for the transition to adulthood and adapt to the evolving nature of future challenges in STEM and the social impact. However, little research has been done on how students themselves evaluate and value those skills.

The intended actions assume that research excellence can only be achieved and maintained if research is closely integrated with education. By committing to research-based teaching in preparing/empowering new generations of capable, competent educators, the current expert seminar emphasises

- integration of research into science and teaching of research in science education,
- improving the quality of science education within international networks.

*Miia Rannikmäe*
*Professor of Tartu University*
*Coordinator of SciCar project*

PROGRAMME

# 29 SEPTEMBER 2021

Chair of the Seminar: Prof. Miia Rannikmäe, University of Tartu

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|---|---|
| 10:00–10:30 | Arrival. Welcome coffee |
| 10:30–11:10 | *Opening remarks. Setting the scene and introduction of the programme.*<br>Prof. Jaak Järv, Secretary General, Estonian Academy of Sciences<br>Prof. Jakob Kübarsepp, Head of the Committee of Education, Estonian Academy of Sciences<br>Prof. Miia Rannikmäe, University of Tartu, Coordinator of SciCar project |
| 11:10–11:45 | *Toward the Renewal of the "Teacher-Scientist Concept" Attributed to Roland Eötvös: Content Pedagogy Research Programme at the Hungarian Academy of Sciences*<br>Prof. András Patkós (prof. emeritus),<br>Eötvös Lorand University, Hungary<br>Session Chair: Prof. Miia Rannikmäe, University of Tartu |
| 12:00–12:30 | Discussion in groups<br>Session Chair: Ass. Prof. Regina Soobard, University of Tartu |
| 12:30–13:15 | Lunch |
| 13:15–13:45 | Feedback from group discussions |
| 13:45–14:30 | *What are Climate Change Competencies? Views from a climate expert.*<br>Marianne Santala, University of Helsinki, Finland<br>Session Chair: Prof. Priit Reiska, University of Tallinn |
| 14:30–15:15 | *Introducing Contemporary Research Topics into School Science Programmes: Impact on Students' Motivation to Become Scientists*<br>Prof. Ron Blonder, Weizmann Institute of Science, Israel<br>Session Chair: Dr. Rachel Mamlock-Naaman,<br>Weizmann Institute of Science, Israel |

PROGRAMME

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| 15:15–16:00 | Panel discussion: *Which competences are essential for a career in the private sector and in industry – expectation of the input from school science education*<br>Panelists: Prof. András Patkós, Prof. Ron Blonder, Dr. Katrin Vaino, Dr. Helin Semilarski<br>Chair: Prof. Jari Lavonen, University of Helsinki |
| 16:00–16:30 | *Concluding remarks. SciCar vision.*<br>Prof Miia Rannikmäe, Prof Jari Lavonen, Dr. Rachel Mamlock-Naamann |
| 16:30–17:00 | Reception |

A BRIEF BIOGRAPHY OF THE PRESENTERS AND ABSTRACTS

# PROF. MIIA RANNIKMÄE

**Tartu University**
**Head of the SciCar project**
**Chair of the seminar**

Miia Rannikmäe is professor in science education and the head of the centre for Science Education in the Institute of Earth and Life Sciences within the University of Tartu Science and Technology faculty. She has considerable experience in science education in Estonia, Europe and worldwide (Fulbright fellow – University of Iowa, USA). She has a strong background of teaching at school, extensive experience in pre- and in-service teacher training and has strong links with science teacher associations worldwide.

**Estonian Academy of Sciences**
**Tartu University**

# PROF. JAAK JÄRV

Professor Jaak Järv holds a PhD in organic chemistry and is Doctor of Chemical Sciences (DSc in physical biochemistry). He is Professor of Organic Chemistry at the University of Tartu; Doctor Honoris Causa, Kuopio University, Finland; Medical Doctor Honoris Causa, Uppsala University, Sweden. Prof. Järv's main research interests are focused on the design and synthesis of bioactive compounds and investigation into the molecular mechanism of their action. An accompanying interest is chemistry education, related to the development of the learning environment and teaching tools by using computers and information technology.

## Estonian Academy of Sciences and Science education

The Estonian Academy of Sciences is closely involved in the development of science and innovation in the country. Therefore, we also follow the problems related to science education, especially those that are the focus of this seminar. Not surprisingly, it can be concluded that the interest of students in understanding our world and studying science can grow but can also fade at school. The choice between these possible paths is probably determined by the learning environment, but also by the attitude that surrounds the student at school.

PROF. JAKOB KÜBARSEPP

**Estonian Academy of Sciences**
**Tallinn Technical University**

Professor Jakob Kübarsepp holds a PhD in materials engineering. He was Professor of Tallinn University of Technology in 1992–2021. Since 2021 he is Professor Emeritus and Senior Research Scientist. His main research interests are focused on powder metallurgy of wear resistant composite materials, in particular cermets, engineering ceramics, and tribology.
In administrative positions related to education, Jakob Kübarsepp served as Dean of the Faculty of Mechanical Engineering (1994–2000) and Vice Rector for Academic Affairs (2000–2011 and 2014–2017) at Tallinn University of Technology. Since 2022 he is Chairman of the Education Committee of the Estonian Academy of Sciences.

## The Education Committe of Estonian Academy of Sciences

The Estonian Academy of Sciences provides scientists and their partners with a cooperation platform, contributing to solving social and economic development issues facing the country. The Academy emphasises the necessity to be present at different levels of society, including providing scientific advice and science-based recommendations to the government on key issues of Estonian science, education, economy, and culture. Different committees coordinate the Academy's initiatives, for example in the fields of energy, marine sciences, cyber security, etc. The Education Committee was launched in 2022. The Committee deals with issues related to the shaping of national education policy, which includes responding to reports on education and schools, organising (in partnership with universities) relevant conferences and symposiums, etc. In the field of schools, the Committee promotes science-based education, with a primary focus on mathematics, natural sciences, and technology, as well as teacher training.

**Member of Hungarian Academy of Sciences**
**Eötvös Lorand University**

# PROF. ANDRÁS PATKÓS

*András Patkós* (pronounced Andrash Patkosh) is Professor Emeritus of Theoretical Particle Physics at Eötvös Loránd University in Budapest. His main research directions include the quark structure of nucleons, the origin of matter-antimatter asymmetry in our cosmic neighbourhood and the (meta) stability of the ground state of our universe. In addition to more than 100 original research papers and 4 textbooks, he has published about 80 science popularisation articles and a collection of essays. András Patkós was elected a member of the Hungarian Academy of Sciences in 2001. He has been Chairman of the Hungarian Society of Physics for two terms. For more than two decades, he has been involved in discussions on modernisation of high-school science curricula. To achieve progress in this field, he gives priority to collaborative projects between researchers and teachers. András Patkós has served as Director of the Bolyai College of Eötvös University, which is Hungary's best university-level talent-nurturing institution in natural sciences. His latest activity in the field of education was his contribution as Academic Coordinator of the Content Pedagogy Research Programme at the Hungarian Academy of Sciences in 2016–2020.

## Toward the Renewal of the "Teacher-Scientist Concept" Attributed to Roland Eötvös: Content Pedagogy Research Programme at the Hungarian Academy of Sciences

Roland Eötvös (1848–1919), indisputably Hungary's greatest experimental physicist, also played an important role in shaping the teacher training system of the country. He considered the "scientific preparedness" of teachers to be

the most important element in ensuring the quality of teaching. According to him, a teacher should be able to follow the latest results of world science and make use of them in teaching. Generations of science teachers educated in the training college founded by Eötvös followed this prescription until the 1970s. For the Hungarian public this is the accepted image of an ideal science teacher even today.

The impossibility of keeping pace with the increasing volume and complexity of scientific knowledge resulted in increased frustration among both students and teachers by the end of the last century. At the same time it became obvious that without scientific literacy no successful careers would be imaginable in the 21st century. The new model of teacher-scientist is an active teacher, involved in developing and implementing efficient methods that provide a solid foundation for lifelong scientific self-orientation for all students and guide those who are more interested towards science-intensive professions.

In this contribution I will introduce the Content Pedagogy Research Programme, run by the Hungarian Academy of Sciences in 2016–2021. The presentation starts with a historical flashback on the pedagogical views of Eötvös. Next, the first years of the Content Pedagogy Programme will be outlined. Finally, I will focus on the progress achieved by several research groups in renewing the traditional image of teacher-scientist.

## Tartu University

Regina Soobard is Associate Professor of Science Teaching at the Centre for Science Education, Institute of Ecology and Earth Sciences, Faculty of Science and Technology, University of Tartu. She completed her PhD in 2015, investigating the development of scientific literacy of 10th–12th grade students based on the determinants of cognitive learning outcomes and self-perception. Regina Soobard is known for her work in conceptualising scientific literacy, assessment in science education and investigating science-related career awareness (students' and teachers' perspective). She has experience in participating in national and international research and development projects. In 2014, she was appointed the OECD/PISA study science expert in Estonia. Since 2016, Regina Soobard has been involved in a national project developing standard-determining testing for the domain of science in Estonia. In 2018, she was awarded a Baltic-American Freedom Foundation Research Scholar Program and was a visiting research scholar at the CREATE for STEM Institute at Michigan State University. Additionally, she is a professional coach, certified by Erickson Coaching International, focusing on personal growth and self-management.

## Discussion about attracting young people towards science studies and science-related careers

The presenters of the seminar are presenting contemporary ideas in science education studies and science-related careers. The discussion session allows participants to express and share their own ideas with peers and a wider audience on how to attract young people to science studies and science-related careers. And even more, how to prepare students for dealing with challenging issues (climate change mitigation), how to increase students' motivation and what the key competences for science-related careers are in the future. The discussion session will be followed by evidence-based presentations on the same topics.

MARIANNE SANTALA

**University of Helsinki, Finland**

Marianne Santala is a meteorologist and designer, who is working as a doctoral researcher in the Education Research and Development Team at the Institute for Atmospheric and Earth System Research (INAR), University of Helsinki. Her research covers the topic of climate change leadership and competences among climate change experts and leaders in various organisations as well as among university students in Finland. She is also involved in teaching and developing multidisciplinary climate change and sustainability courses.

## What are Climate Change Competencies? Views from a climate expert.

The urgent need to implement climate change mitigation and tackle adaptation challenges that are both scientific and social has raised questions about the required competences of a climate change expert. Even though sustainability competences have been a topic of study in the past, a comprehensive framework of competences specifically targeting climate-change challenges have been missing. In order to build such a framework, we have prioritised assessment of societal needs by conducting a survey and interviews with climate change experts and leaders working on the practical implementation of climate goals. Having a better definition of climate change competency and a more holistic approach to climate change education will increase the mitigation and adaptation capabilities at all levels of organisations.

**Weizmann Institute of Science, Israel**

Professor Ron Blonder earned her BSc in chemistry (Magna Cum Laude) from the Hebrew University of Jerusalem in 1993. She then completed her doctoral studies in chemistry at the Hebrew University of Jerusalem. Prof. Blonder joined the Weizmann Institute as Research Associate at the Department of Science Teaching in 2006, and joined the faculty in 2011. She became Educational Director of the Rothschild-Weizmann Program for Excellence in Science Teaching in November 2019.

The goal of Prof. Blonder's research is to bring the chemistry of tomorrow into secondary school chemistry lessons of today. Her research addresses three issues: nano-scale science and technology education, technology integration into science education, and chemistry teachers' professional development. Her research has shown that in order to successfully integrate advanced content into a school, in addition to teachers' knowledge, it is essential to enhance the belief in the ability to teach the material. Thus, her research examines methods, mechanisms, and opportunities for science teachers – and in particular, chemistry teachers – to expand their knowledge and adapt it for use with their students. Her professional development work has reached a large number of chemistry teachers via the National Chemistry Teachers' Center, the Rothschild-Weizmann Program, the professional community network for chemistry teachers, and the Israeli Chemical Society.

Professor  has also been a representative of Israel at the Division of Chemical Education of EuCheMS, the European Association for Chemical and Molecular Sciences (since 2016), Editor of the International Journal of Science Education and on the International Advisory Board of the Journal of Chemical Education. She is a co-inventor of three U.S. patents related to chemistry and chemical analysis.

## Introducing Contemporary Research Topics into School Science Programmes: Impact on Students' Motivation to Become Scientists

Chemistry is continually being developed through research in academia, research institutions, and industry. However, school chemistry and the curricular contents are hardly influenced by developments in chemistry. This gap does not provide an opportunity to expose school students to the beauty and relevance of contemporary chemistry research. Students are unaware of how chemistry contributes to addressing global challenges; they are not exposed to the nature of modern science and to actual scientists who conduct chemistry research today, and who are more likely to be perceived by students as role models [1].

Changing the school curriculum usually takes a long time, and many informal activities and outreach programmes have been developed to communicate contemporary research to school students [2]. However, a deeper approach that does not require curricular changes is to focus on chemistry teachers' professional development (PD) and to update and expand their knowledge by learning and experiencing contemporary chemistry [3, 4]

In my presentation, I will reflect on different approaches to introducing contemporary research topics into school science programmes and present current results on the impact on teachers' and students' outcomes as well as their motivation to become scientists.

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1. Blonder, R., *Introducing contemporary research topics into school science programs: The example of nanotechnology*, in *Long-term research and development in science education: What have we learned?*, A. Hofstein, et al., Editors. 2021, Brill.
2. Tirre, F., et al., *Design of a student lab program for nanoscience and technology – an intervention study on students' perceptions of the Nature of Science, the Nature of Scientists and the Nature of Scientific Inquiry*. Research in Science & Technological Education, 2019. 37(4): pp. 393-418.
3. Blonder, R., *The story of nanomaterials in modern technology: An advanced course for chemistry teachers*. Journal of Chemical Education, 2011. 88: pp. 49-52.
4. Blonder, R., et al., *Nanoeducation: Zooming into teacher professional development programs in nanotechnology in four European countries*, in *Topics and trends in current science education*, C. Bruguière, A. Tiberghien, and P. Clément, Editors. 2014, Springer: Pintforce, the Netherlands. pp. 159-174.

**Weizmann Institute of Science, Israel**

Dr. Rachel Mamlok-Naaman is the head of the National Center of Chemistry Teachers at the Weizmann Institute of Science, and a previous coordinator of the chemistry group at the Department of Science Teaching (until June 2016). In addition, she serves as The chair of DivCED EuChemS, IUPAC Titular member of the committee on chemical education, and executive member of the IUPAC gender gap committee. Her publications focus on the topics which are related to students' learning (cognitive and affective aspects of learning), and on teachers' professional development.

# DR. KATRIN VAINO

**Tartu University**

Katrin Vaino has been working as a researcher and teacher educator at the Centre for Science Education (University of Tartu) since 2011. Her research interests have been related to science teacher beliefs, design-based learning, students' understanding of the nature of technology, and educational assessment. She has been a chemistry teacher in general education for more than 20 years, and a member of the team responsible for the development of the national curriculum (science curriculum) since 2013. Katrin Vaino is the author of a number of teaching-learning materials and since 2017 a test designer of the national science e-test for the 3rd and 4th grades. She has been the principal investigator in several research and development projects, including her post-doctoral project conducted at Umeå University (Sweden, 2015–2017).

## Abstract

In science curricula, more emphasis should be placed on the development of students' scientific attitude, i.e. open-mindedness, curiosity, impartiality, intellectual humility, courage, and honesty. The internalisation of such virtues could be better supported if students' psychological needs for competence, autonomy, and belonging were met in science classrooms, which in turn would be helpful for building stronger science (STEM) identities for students. In the absence of intellectual virtues, science knowledge is not a defense against "post-truth", but could become a weapon in the hands of a future science denialist, conspiracy theorist, or similar. The development of intellectual virtues, but also socially accepted values, has been impeded in science classrooms mainly due to their challenging classroom assessment – a problem that might be actually overcome by strengthening its conceptual base. Both the affective taxonomy by Krathwool et al. and the moral reasoning taxonomy by Kohlberg seem to be promising in that respect. A small step in this direction has been taken by the new version of the national science curricula.

**Tartu University**
**Miina Härma Gymnasium**



Helin Semilarski is a recent PhD holder in science education. She has been working as a researcher and teacher educator at the Centre for Science Education (University of Tartu) since 2021. Her research interests have been related to biology learning, biological literacy, and currently focusing on climate change literacy. She has been a biology teacher at Miina Härma Secondary School, a general education school, for six years.

## Abstract

Being literate is seen as a fundamental personal competence equipping people with the needed knowledge, skills, attitudes, and values to interact effectively within society. Scientific literacy is seen as crucial for students as future citizens in making decisions in their daily lives, such as deciding whether to become a gene or organ donor, determining a healthy diet, selecting suitable medical treatment, or determining ways to protect oneself from Covid-19. The goal of science education is the development of scientific literacy, especially by engaging students in experiencing a range of hands-on and interactive activities. This will help them to develop a caring mentality and critical analytical skills, thus preparing students for further progress and developing their potential to undertake action. Science education in the 21st century needs to be forward-looking and constantly updated to meet the needs of students as future members of a changing society. The following competences are essential for a career in the private sector and in industry: time management, leadership, teamwork, negotiation skills, communication skills, coping with pressure.

# PROF. JARI LAVONEN

**University of Helsinki, Finland**

Dr. Jari Lavonen is a Professor of Physics and Chemistry Education at the University of Helsinki, Finland. He has been researching science and technology or STEM education for the last 34 years and have focused to project based learning, student interest and engagement and teacher education. He is currently a Director of the National Teacher Education Forum and Chair of the Finnish Matriculation Examination Board.

# THE PROJECT "ADDRESSING ATTRACTIVENESS OF SCIENCE CAREER AWARENESS" (SciCar)

SciCar – a science education project – addresses the need to systematically raise the level of expertise among researchers and educators who are involved in science & technology (S&T) education within UT and associated institutions, currently seen as ineffective in making science teaching careers attractive and enabling teaching to adopt more relevant context-based approaches. The project especially addresses, via a Twinning partnership, bringing in expertise from top-level science education countries – Israel and Finland, particularly focusing on enhancing career awareness, enabling a capable workforce, and on promoting science-related careers. The major outcome is envisaged as a centre of excellence at UT in science education, interacting with all STEM teacher education bodies and the science education community e.g. science centres, science teacher associations. This is seen as enabling appropriate models for enacting a change of paradigm related to teacher education and science career awareness. A major focus is put on (1) reducing the gap between scientist and science educator beliefs in the training emphasis of future STEM-related teachers, (2) the involvement of the science education community in making the teaching profession more attractive, (3) thus determining keyways & appropriate models for instituting a paradigm change with a view increasing the number of STEM-related teachers, (4) and giving emphasis to competence development in promoting science-related career awareness. The created centre is to become a platform ensuring that science researchers are guided to embrace science education expertise, making the preparation for science-related teaching careers more attractive while applying excellent knowledge in research (and approaches to undertake research) in coaching the next generations of science education researchers. The project seeks to identify best practice on knowledge transfer between science development and science education.

Twinning partners are Weizmann Institute of Science (Israel) and University of Helsinki (Finland)

# THE CONFERENCE VENUE

The residence of the Estonian Academy of Sciences (built 1865–1868), on the slope of Toompea, is the former city residence of the prominent Ungern-Sternberg noble family and a conspicuous building in Tallinn architecture. The palace on Toompea was commissioned by Count Ewald Alexander Andreas von Ungern-Sternberg, descendent of a highly influential Baltic-German noble family. The architect of the building is the renowned Berlin architect Martin Philipp Gropius.

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