

Relevancing mathematics and science education: A graduate school for teacher educators (RelMaS)

Objective

The purpose of the graduate school RelMaS is to strengthen research in mathematics and science education, by engaging teacher educators in practice-oriented research aiming to analyze and develop didactic models for relevancing mathematics and science education. The graduate school will: (1) consolidate the research foundations for tackling the challenges of making mathematics and science education relevant to current global sustainability and to the inclusion of diverse student populations; and (2) provide PhD education to nine fully funded students who are already working or will work in mathematics and science teacher education, and thereby increase the number of PhD-qualified teacher educators in these areas.

Theme

We live in a time where education at all levels needs to address local and global challenges such as increased inequality, growing migration, segregation and poverty, radicalized politics, and environmental threats like reduced biodiversity and global warming. Although apparently independent, these challenges are interconnected elements of what Beck (1992) termed a “risk society” and what Latour (2018) recently referred to as a new configuration of “climate change”, defined in a broad sense as the deep modifications of the relationships between humans and their material conditions of existence. The notion of “climate change”, in this broad sense, does not only refer to global environmental transformations, but also to simultaneous and related changes in national populations, migrations of people around the globe, distribution and access to material resources, forms of knowledge, political decisions etc. that both constitute and threaten our life.

There is widespread agreement that education is fundamental for society to respond to new challenges threatening a sustainable future (UN, 2015). Education is commonly expected to provide awareness of dangers as well as action competence. Thus, RelMaS focuses on the challenges of mathematics and science education in educating younger generations to navigate and transform a world in which mathematical and scientific knowledge are needed to deal with wicked problems and socio-scientific issues. This implies that teacher education has to qualify future generations of teachers to engage a diverse population of students with important issues and to provide research-based repertoires for dealing with such issues in ways that go beyond current established classroom practices.

Our argument is that a key to addressing the challenges outlined above is the ‘relevancing’ of mathematics and science education, in terms of providing an educational content that is significant in an era of “climate change”, that is engaging to an increasingly diverse student population, and that is rooted in participatory and practice-oriented forms of research. While these three dimensions are interconnected, they are treated separately for the sake of clarity:

1) *Relevancing the mathematical and scientific content in teacher education and schools for increased action competence.* First, in modernity, mathematics and science, in and beyond school, have been the bearers of the trust in rationality and human control over nature to bring progress and growth (Östman, 1995). Current “climate change” questions such as rationality and calls to develop more critical, responsible and sustainable forms of scientific and mathematical thinking and understanding (Roberts, 2011). Second, the content in science and mathematics curricula rely on a relatively stable core of conceptual areas that are considered fundamental for any citizen to operate in life or to pursue further studies. This contrasts the current dynamic view of mathematics-science in relation to rapidly changing and technology dependent societies. For example, the challenge of dealing with complex socio-ecological systems is expressed in research agendas such as transdisciplinary resilience and interdisciplinary mathematics. In school mathematics and science and in teacher education, this might mean to provide students opportunities to experience the subjects as interconnected, dynamic, powerful, non-neutral spaces of knowledge highly significant for addressing global challenges in ways which connect to students’ lives.

2) *Relevancing mathematics and science content for a diverse student population.* Certain groups of students systematically do not attain expected levels of achievement in mathematics and science (OECD, 2016). This phenomenon, known as the achievement gap (Gutiérrez & Dixon-Román, 2011), is an alarming indicator of educational inequality that points to the failure of mathematics and science education to provide access to repertoires for reflection, action and participation in society, important for citizens’ democratic agency. Students’ success in mathematics and science is related to their socioeconomic status, ethnicity, home language, gender, etc. (Forgasz & Rivera, 2012); and inequalities in achievement among different student groups are connected to the capacity of teachers to effectively deal with students’ multiple diversities and create access to learning for all (Atwater, 2012). As the student population in Swedish schools has diversified significantly, challenges have emerged for teachers to engage meaningfully with a variety of student backgrounds and needs. In teacher education, the population of student-teachers has also diversified raising questions about how teacher education programs respond to increased diversity of experiences and skills.

3) *Relevancing the forms of research-based knowledge in teacher education.* The theory–practice gap is recognized as the persisting lack of connection that teacher-students see “between educational theory taught in university courses and practice teaching” (Molander & Hamza, 2018, p. 507). Thus, a continuing discussion in teacher education concerns the type of

educational research that is important for student-teachers (Wahlström & Alvunger, 2015), and the alignment between didactic and pedagogic content in teacher education and student-teachers' future professional practice (BERA, 2014). In mathematics and science teacher education, this calls to a revision of the forms of research-based knowledge provided to students as part of their studies, and of the possibilities of engaging in on-going research-based initiatives in schools that connect subject matter, educational research and practicum.

Research foundations

It is well documented that mathematics and science teachers receive limited education in dealing with students' diversity, and in devising inclusive forms of pedagogy (Bianchini & Brenner, 2010). They are seldom exposed to newer, complex and integrated forms of subject-matter knowledge in the context of wicked social problems, and to forms of research-based knowledge that connects theory with practice. Thus, the three interrelated areas that RelMaS builds on and seeks to advance are: (1) relevant mathematics and science content through the development of didactic models, (2) relevant equitable and inclusive mathematics and science teaching and learning, and (3) relevant forms of research for school practice.

Research has shown that mathematics and science education can prepare young people for dealing with future individual, social, and political challenges as informed, democratic citizens through, for instance, critical mathematics education (CME) (Ernest et al., 2016), socio-critical modelling (SCM) (Barbosa, 2006), teaching of socio-scientific issues (SSI) (Zeidler et al., 2005), and education for sustainable development (Lundegård & Wickman, 2012). However, changing teaching along these lines constitutes a challenge for teachers (Lundqvist & Sund, 2016). There are at least two issues which require further attention: (1) current research focuses on how to order certain content and how to engage students in reasoning in the classroom (Sadler et al., 2017), rather than offering models for teachers to analyse and transform contents for purposes of relevance and inclusion, and (2) there is a scarcity of research on how to make mathematics and science content interact in CCM, SCM or SSI teaching. One exception is the area of risk education, which has addressed issues of content in order to study how "risk" as content can support teaching for citizenship in existing science and mathematics curricula (Christensen, 2009). More generally, didactic models for choosing and transforming science and mathematics content in relation to particular student populations and teaching purposes exist which may be further adapted to better handle issues of relevance and equity (Johansson & Wickman, 2018).

Research has produced insight into how mathematics and science education contribute (or not) to citizenship, democracy and social justice (Valero & Olander, 2017). Instead of seeing students' failure as a result of individual deficiencies, we now understand how teaching in itself produces failure, and we can propose research-based alternatives of inclusive educational practices (Andrée, 2012). We know that bilingual students' proficiency in the language of instruction limits possibilities to learn science and mathematics (Ünsal et al., 2018). But we also know how students' multiple languages are a resource for learning (Norén,

2008) and how teachers can operationalise them to support both students' conceptual development (Nordin & Boistrup, 2018) and identity work as mathematics and science learners (Chronaki & Kolloosche, 2019). The overall problem of the differential participation of women in science and mathematics has led to questions on how mathematics and science education practices contribute to create certain learner identities (Sumpter, 2016). Students' learning possibilities in mathematics and science are also related to structural class differences that permeate the organization of school and of mathematics and science as school subjects (Joergensen et al., 2014). At the same time, we know that the way science and mathematics are taught can counteract the significance of students' cultural capital, as teachers are able to model "taste" for the subjects in classroom interactions (Anderhag et al., 2014).

Research-based didactic models for analysing and transforming educational content and inclusive practices need to be relevant and functional for both teacher education and school practice. This need is increasingly being addressed through participatory research designs centring around collaboration amongst researchers, student-teachers and schools, such as action research, design-based research, learning studies, and didactic modelling (Wickman et al., 2018). They offer a space for experimentation and modelling of the types of relevant contents and inclusive pedagogies that RelMaS aims to develop. Through participatory didactic research, critical analyses of educational possibilities for inclusion and renewal of contents are made relevant and meaningful for teacher education and school practice, as results are continually being mangled through actual practice.

It is expected that the PhD projects funded will tackle the relevancing of mathematics and science, and take into consideration these three foundations to further develop them.

Research environment

RelMaS is a collaboration between the Department of Mathematics and Science Education (MND), Stockholm University (SU), the Department of Education (EDU), Uppsala University (UU), and the Department of Mathematics, Science and Environment (NMS), Malmö University (MAU). Together, the three environments contribute experienced supervisors to the graduate school, established and well-functioning research groups on areas of relevance for the program, and opportunities for the PhD students to be involved in mathematics and science teacher education.

SU has the largest combined department in mathematics and science education in Sweden, with approximately 120 employees and several active research groups spanning all levels of the educational system. The department has 3 full professors, 1 professor emerita, 13 associate professors, 10 senior lecturers and 14 PhD and 10 licentiate students. Four externally funded research projects provide a foundation for RelMaS: "Teaching through socio-scientific issues in high-school science: Development of didactic models for including risk and risk assessment" (Skolfi 2018-2020), "Industrial initiatives in school – opportunities and challenges for science and technology education" (VR 2018-2021), "Tracing mathematics

teacher education in practice” (VR 2018-2021), and the “Graduate School in Didactic Modelling and Analysis for Science Teachers” (NaNo) (VR 2014-2017) in collaboration with UU. Other research anchoring for the graduate school includes: modelling classroom interactions and science and mathematics curricula to support teachers’ decisions on content and methods (Pansell, 2018; Wickman et al., 2018); inclusion and exclusion in the changing contexts of mathematics and science policy in contemporary societies (Valero, 2018); gender differentiation and gendering (Orlander, 2014; Sumpter, 2016); learning and teaching in multilingual and multicultural settings (Ünsal et al., 2018); the use of socio-scientific issues as a point of departure for democratic science education (Lundegård, et al., 2017); questions on development of scientific literacy and capabilities critical for participation in contemporary society (Wiblom et al., 2017); processes of pre-service teachers’ development (Skog & Andersson, 2015), and forms and processes of participatory research-designs (Hamza et al., 2018).

NMS at MAU has 4 full professors, 5 associate professors, 11 senior lecturers and 6 PhD students. The PhD students are lecturers in teacher education with a specific focus on subject-matter didactics, environmental sustainability and societal challenges in mathematics and science education. Currently there are about 6 externally funded projects, 4 of which are central to the content and methodological perspectives of RelMaS: “Waste work in the sustainability economy: Transforming values of biological waste” (VR 2018-2020), “Education Inc. Exploring conditions, forms and consequences of edu-preneurial engagement in Swedish schools” (VR 2018-2020), “Inclusive teaching in multilingual classrooms – a design study” (NordForsk, 2018-2021) and “Literacy and inclusive subject teaching in multilingual societies” (MAU-strong program, 2019-2023). Other research offering a basis for RelMaS relate to language diversity (Svensson-Källberg, 2018), bodily experiences of learning and inclusion (Chronaki, 2019), learner identity work in relation to gender, race, and social class (Jobér, 2017), privileged curriculum emphasis (Olander, 2013), national and international assessment practices and issues of inclusion and exclusion (Boistrup, 2017; Serder & Jakobsson, 2016); practice-oriented research (Olander et al., 2018), transformative learning, citizenship and sustainability in the global context (Ideland, 2018; Hasllöf et al., 2016).

EDU at UU is a large multi-disciplinary department of education, with approximately 260 employees and research groups spanning, for example, curriculum studies/didactics, special needs education, sociology of education, and interactional practices. The science and mathematics education groups have 3 full professors, 2 guest professors, 4 associate professors, 3 senior lecturers and 5 PhD students. Currently, the groups are involved in approximately 6 externally funded research projects, 3 of which are central to the content and methodological perspectives of the graduate school: “Teaching and learning for action competence in education about antibiotic resistance (Skolfi 2019-2021), “The unlikely scientists: Exploring what has enabled students from under-represented groups to continue to higher education science studies” (VR 2019-2021) and “Comparative didactics and professional development for teachers” (network, VR 2019-2021). The science education



group has a long tradition of research that supports the graduate school: studying science teaching and learning in practice (Lidar et al., 2006), studying teachers' teaching traditions (Lundkvist et al., 2012, practice-oriented research (Almqvist et al., 2017) and research on identity and power relations in science (Danielsson et al., 2018). The mathematics education group has expertise in the research of early algebra (Bråting et al., 2019) and the relation between mathematics and language, especially the importance of linguistic features in problem solving (Dyrvold & Bergvall, 2019). Also, STEM education research is carried out at the Centre for Gender Research and the Faculty of Science and Technology, research environments the groups have collaborations with.

The three environments have a long record of collaboration in individual and inter-institutional projects connected to the theme of RelMaS. This guarantees the stability of the partnership for this graduate school. All three environments have collaborated in the co-supervision of doctoral students in the frame of the NaNo Graduate School (see above) and the Graduate School in Education for Sustainable Development (GRESO), as well as in joint research projects such as "Teaching Traditions and Learning" (VR 2013-2017). SU and MAU have also a strong collaborative record regarding socio-scientific issues in science education. In 2018 SU and MAU co-organized the biannual IOSTE symposium "Future educational challenges from science and technology perspectives". For almost 10 years, there has been individual collaboration of the organisation of PhD courses, resulting in a model of seminar that promotes a high level of academic engagement between students and highly profiled senior researchers. This model is implemented at SU and MAU in doctoral courses, such as the PhD course/seminar "In(ex)clusion and the construction of the 'Other' in math and science education" (RJ F17-1086:1). The model will be used in the core courses of RelMaS. The environments also collaborate in outreach initiatives that involve research partnerships with local schools.

Programme description

In order to constitute a coherent research environment for the PhD students enrolled at 3 different universities, the graduate school is centred around five core courses (utilizing a combination of in-residence and on-line sessions) as well as regular online seminars. The students are also expected to take active part in other seminar series at their respective universities. In the courses and seminars, the students will get the opportunity to develop a capacity for scholarly analysis and synthesis, through presenting their own work and through reading and commenting on others. The core courses consist of highly specialised content of relevance to the theme of the graduate school, to complement other PhD courses offered by the partners.

The graduate school as a whole will consist of a collection of PhD projects that articulate in different ways the relevancing of content, handling student diversity and participatory and

practice-oriented research. The students are enrolled 80% over a five-year period, with 20% teaching in teacher education. This will allow students to gain knowledge and critical understanding of the research foundation, to develop new up-to date specialized knowledge of relevance to the theme, and to gain methodological and analytical expertise in their individual project and overall field. It will also provide experience of teaching in teacher education, while conducting research of relevance for it, so that the research expertise can be incorporated into teacher education. The recruitment base primarily consists of teacher educators without PhDs ('adjunkter') and teachers in school, but also includes individuals working in (inter)disciplinary mathematics/science capacities in, for example, science communication, NGOs and/or museums.

Organisation

Compulsory courses

Five courses (40 credits in total) will be compulsory. The courses will have a main organiser but will be developed and taught collaboratively by all the partners. The courses establish a coherent core of theoretical, methodological, and empirical knowledge related to the theme of the programme.

(CC1) Relevancing mathematics and science education for citizenship and social justice (7,5 credits). The course introduces current scholarship about science and mathematics in relation to wicked problems (e.g. environmental issues, sustainable development, numbers in big data science and security), and how these connect to mathematics and science as school subjects and subjects in teacher education. Special attention is paid to the theoretical foundations and epistemological genealogies of different conceptualizations of mathematics and science education as citizenship education. Organised by UU, in a four-days, in-residence model, with invited international lecturers.

(CC2) In/exclusion in mathematics and science education (7,5 credits). The course offers theoretical approaches to understand and study processes of in/exclusion in mathematics and science education from social and political perspectives. It examines the impact of gender, ethnicity and/or socioeconomic background in mathematics and science education. It explores how reproduction of inequalities is shaped in mathematics and science classroom practices, and how it creates unequal conditions for citizenship. Organised by SU, in a four-days in-residence seminar, with invited international lecturers.

(CC3) Critical and participatory methodologies in didactics research (10 credits). The course provides an overview of critical and participatory research methodology, to support the PhD students in building a research design and making creative, autonomous and appropriate methodological decisions in their research. The course focuses on ethnographic methods, didactic modelling, design research, lesson and learning study and action research. Alleged



tensions between a critical stance and emancipatory participatory stances are problematized. Organised by MAU, in two, three-days seminar sessions, with invited international lecturers.

(CC4) Research ethics in didactics research (7,5 credits). The course examines the challenges of developing ethically responsible research in mathematics and science education. Participatory research, whether it includes young children or teachers, gives rise to particular issues regarding research ethics (e.g. ways in which to include children's perspectives throughout all stages of research). The course will focus on conducting participatory research in ethically sound ways and consider which relations between researchers and participants are enacted related to research objectives, epistemology, the people involved, and the context in which the study is carried out. Organised by SU, as an online seminar series over three semesters.

(CC5) The role of research and researchers in teacher education and professional development (7,5 credits). The course aims to develop the capacity to identify the affordances and constraints for bringing research to inform school and teacher education practices, taking its departure from the four main ways that research can contribute to teacher education identified by the British Educational Research Association (BERA, 2014). This seminar specifically explores these different ways in teacher education and teacher professional development in a Swedish context. Organised by UU, as an online series over three semesters.

Optional courses (OC)

To meet the local requirements, the PhD students will take other courses at the three partner universities or other universities. Combined, the partners offer a variety of courses such as: Didactical traditions: theory and method (15 credits), Math and science teaching and learning in multilingual classrooms (7,5 credits), Perspectives on the philosophy of science and history of mathematics education (10 credits), Pragmatic perspectives on learning (15 credits), and Writing a mathematics or science education academic article (7,5 credits).

Internationalisation

Students are expected to present their work at national and international conferences (e.g. SWERA, MADIF, ECER, IOSTE, PME, MES). They are encouraged to spend a minimum of 2 weeks in a research environment abroad, to interact with researchers of relevance for their work. Contacts will be facilitated by the extensive research network of the partners.

Thesis work

Students will write a compilation thesis comprising four articles of which, on average, 2-3 will be published in international journals at the time of the defence. 10%, 50% and 90% seminars will be organized in connection with the visit of advisory board members so that students can benefit from their comments.



Supervision

Each PhD student will be assigned one main supervisor from the department at which the student is enrolled, and a co-supervisor from one of the two partner departments. This is to secure competent supervision, synergy and research collaboration between the environments. The follow up of student's progression will be handled by the main supervisor in collaboration with the local director of PhD studies, but also be monitored by the managing board (see below).

Electronic collaboration platform

An electronic learning platform will be used to host seminars, to keep track of the progression of projects and to promote conversations between the PhD students and supervisors. This will ensure sustained discussion and collaboration among PhD students and the team of supervisors at the three partners.

Time plan

Year 1 *S1*: Introduction and course start at UU. CC1. Literature review and writing of research plan. *S2*: CC2, CC3-I, CC4-I, meeting with advisory board, 10% seminars, revision of research plan, design of first study. Year 2 *S3*: CC3-II, CC4-II, CC5-I, data collection and analysis. *S4*: CC5-II, OC, writing of manuscript 1, data collection and analysis. Year 3 *S5*: CC4-III, OC, participation in national conference (MADIF), writing of manuscript 2. *S6*: CC5-III, OC, meeting with advisory board, 50% seminars, finalising manuscript 1 and 2, data collection and analysis. Year 4 *S7*: OC, possible short stay abroad, participation in international conference, writing of manuscript 3, data collection and analysis. *S8*: possible short stay abroad, symposia at ECER 2024, writing of manuscript 4. Year 5 *S9*: 90% seminars, finalising manuscripts 3 and 4, writing of wrapping text. *S10*: Finishing wrapping text and thesis, submission, public defence.

Significance

The graduate school will strengthen the research base for mathematics and science teacher education, by a novel take on the relevancing of mathematics and science education as an issue of social justice. By catalysing existing connections between the partners, it will advance research that brings together mathematics and science for citizenship and inclusion in teacher education. The research results will impact teacher education programs through a series of spin-offs, such as projects with in-service teachers and municipalities (what can be called a *professional development effect*), change initiatives within the regular elements of the partners' mathematics and science teacher education programs (what can be called a *pre-service education effect*), and recruitment of the graduated doctors into teacher education in the partner departments, in other departments in Sweden, or in schools and municipalities in units of consultancy and educational development (what can be called a *higher education effect*). In particular, the results concerning the production of research-based, practice-relevant



didactic models will allow dealing with current problems such as the sense of disconnection between different elements of teacher education programs that student-teaches report.

International and other national collaboration

Partners have extensive collaboration networks that will benefit the PhD students, in terms of e.g. guest teachers on courses and the possibility of visiting international research environments.

International networks and projects

Through a three-year network grant (VR 2019-2021) 40 researchers and PhD-students from UU, SU, Gothenburg, and Geneva will meet to discuss research on comparative didactic analysis and teacher professional development. The network aims at creating and supporting new collaborative projects and settings among the participants. In a three-year internationalization of research grant (STINT, Sweden-Chile collaboration), PhD students and teacher educators at SU can take part in discussions on diversity and inclusion in mathematics teacher education with researchers and PhD students from the University of Chile in Santiago, and the Pontifical Catholic University of Valparaíso, two of the most prestigious centers of mathematics education research in Chile. Besides, the students would be able to establish contact with the broad network of collaboration partners of UU, SU and MAU.

National networks and projects

Given the involvement of the partners in different participatory research projects, the PhD students will benefit from a network of contacts in schools, municipalities and teacher educations where further development of the theme of the graduate school is possible. For example: UU, SU, and Gothenburg have a research collaboration with the municipality of Landskrona aiming at developing new forms of participatory research and school development. SU leads the “Stockholm Teaching and Learning Studies”, a platform for participatory research collaboration between SU and school authorities in the region of Stockholm. MAU and Malmö municipality have a network on “Mobility, migration and equality in education”, and also lead the “Malmö Teaching and Learning Studies”.

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