Centre for Research, Innovation and Coordination of Mathematics Teaching: MatRIC

1. PROFILE AND VISION

The proposed Centre for Research, Innovation and Coordination of Mathematics Teaching (MatRIC) will focus on mathematics teaching and learning within the study programmes of other subjects such as engineering, natural sciences, economics and teacher education. MatRIC will:

- Create, lead and support networks that enable sharing and development of effective use of video, digital and web-based technologies in teaching, learning and assessing mathematics.
- Initiate, support and disseminate research into teaching, learning and assessing mathematics to identify, understand and evaluate effective innovation in practice.
- Bring together mathematics educators, scientists, engineers, computer scientists and economists in cross-disciplinary teams to produce workplace simulations and realistic tasks for mathematical modeling.

Vision: *The Centre will lead innovation, research and excellence in mathematics teaching and learning within higher education 'user programmes'.*

This vision will be achieved through:

i. Networking mathematics teachers and users (engineers, scientists, economists, teachers, etc.).

ii. Coordinating research into innovation in teaching, learning and assessing mathematics.

iii. Developing teaching resources that simulate applications of mathematics in the workplace and a student laboratory for developing competencies in mathematical modeling.

iv. Disseminating research, innovation and excellence in mathematics teaching.

MatRIC will address a national priority area set out in the Norwegian strategy for science and technology (Ministry of Education and Research, 2010). Mathematics is a requirement in the Norwegian national frameworks for the education of engineers, economists and teachers, and is an indispensable element of studies in natural sciences and health care. However, national and international tests reveal disappointing levels of performance of Norwegian students as they transfer from school to higher education. The Norwegian Mathematics Council's test of basic skills exposes severe weaknesses in students' fluency and reliability in elementary mathematical procedures as they embark on studies in economics, engineering, and teaching (Nortvedt, 2012). Also, the TIMSS-Advanced Study revealed Norwegian upper secondary students' performance in mathematics to be below the international average (Grønmo, Onstad, & Pedersen, 2010).

Context: Mathematics education at the University of Agder (UiA) is provided within the Faculty of Engineering and Science, and is mostly concentrated within the Department of Mathematical Sciences (hereafter referred to as the 'Faculty' and 'Department' respectively). Mathematics education at UiA is organized in two 'genres': (1) in mathematics courses and (2) in

courses and research on mathematics education. In the first genre mathematics is taught within degree programmes in engineering, natural sciences, economics and finance, and teacher education to the extent that 30% of the Faculty's 'production' (i.e. students x ECTS points) consists of mathematics education. The Department has also worked with colleagues in Healthcare to improve the performance of students in the compulsory course in medical calculations (Leland & Tollisen, 2009; Omland, 2008). In the second genre, the Department has well-established masters and doctoral programmes in mathematics education (114 masters and 13 PhDs completed), and a large internationally recognized research group in mathematics education. Research focuses on teaching and learning mathematics at all levels from pre-school to university. Mathematics education research at UiA has a substantial record of collaboration (local, national and international) and innovation stretching back over several decades. Over the last five years, national and international collaborations have included several large research projects funded, for example, by the Research Council of Norway (RCN) and NordForsk.[1]

At UiA the integrated community of mathematicians, mathematics education researchers, mathematics teacher educators, and scholars from disciplines and professions that use mathematics reflects the priority given to achieving high quality teaching and learning in mathematics. Mathematics teaching at UiA is based on several fundamental principles: Learning is a social and interpersonal activity and the consequent effectiveness of group work, collaboration, peer-tutoring, and teacher-student engagement. Personal control over learning is achieved through active engagement, inquiry, reflection, and students' willingness to be challenged. Teaching and learning are dynamic social processes that can be developed through innovation, the use of modern technologies and critical implementation of research findings. The following examples illustrate the extent and integration of mathematics, teaching, mathematics education research and innovation.

Mathematics teachers at UiA have developed the use of digital technology in teaching (e.g. Fuglestad, 2009), net-based assessment, and computer based simulations to incorporate video lessons, video streaming, video simulations, interactive simulations, exercises and applications (e.g. Brekke, & Hogstad, P.H., 2006, 2010). Research at masters and PhD levels, supervised by mathematicians and mathematics education researchers, focuses on these developments (e.g. Hogstad, N.M. 2012; Raen n.d.), and using the products in school (e.g. Curri, 2012). Mathematics teaching developmental research projects funded by RCN have generated knowledge and experience about incorporating 'inquiry' in teaching and in learning mathematics (cf. footnote #1). This knowledge is now being applied in innovative ways in the mathematics teacher education programme (Berg & Grevholm, 2012). The masters' programme in mathematics education

[1] Information about research projects in mathematics education and publications can be found at: http://www.uia.no/no/portaler/om_universitetet/teknologi_og_realfag/forskning/institutt_for_matematiske_fag

incorporates students' research in addition to their dissertation work. For many years the masters' research course included classroom based inquiry, but for the last three years this has evolved to integrate inquiry into teaching and learning in school, university and (industrial) enterprises (Cestari, 2011a,b,c; Cestari & Vos, 2013). Master students and PhD fellows focus on teaching and learning mathematics at all levels. In addition to those mentioned above, recent masters' researches inquire into teaching and learning mathematics in programmes for economics (Eilertsen, 2008, Rømteland, n.d.), health care, (Omland, 2008) and teacher education (Storebø, n.d.). Recent doctoral research includes studies into engineering students' use of their mathematics textbook (Randahl, 2012), and didactical issues of learning algebra in inquiry-based group work in teacher education (Måsøval, 2011).

The application of technology is aimed at supporting students' learning and enabling more efficient and effective use of teacher time. Mathematics teachers are supported by UiA's efforts to develop the use of digital technologies in teaching and learning in the university's developmental programmes such as "Learning Arena 2020" (LA2020)[2] and "The Digital University" (investment in each of these to date: 6,5 and 10 million NOK respectively). Funding has been secured by mathematics teachers within the Faculty to develop a 'teaching studio' for the production of video episodes that will reduce dependency on technician support. A two day seminar is planned for June 2013, to develop the science, technology, engineering and mathematics (STEM) teaching/research agenda within the Faculty and with colleagues from other Norwegian institutions.

The mathematics education group is well-connected to a wide international network of scholars and researchers and regularly invites highly regarded researchers to present their work in seminars and spend time at UiA within the university's guest stipend scheme.[3] Events with international guests are open and advertised nationally.

2. QUALITY IN ESTABLISHED EDUCATIONAL ACTIVITIES

MatRIC will build on excellence recognized in the external evaluations of UiA programmes carried out by the Norwegian Agency for Quality Assurance in Education (NOKUT, 2006, 2008, 2010 & 2011); and The Research Council of Norway (RCN, 2012).

2.1 Summary of basis for claiming excellence in mathematics teacher education at UiA.

> *The Committee appreciates that Agder University gives importance to the quality of teaching in mathematics* (RCN, 2012, p. 23)

Evaluations of UiA's programmes, a recent survey of UiA graduates, and national data provide consistent evidence of the quality of mathematics education at UiA. MatRIC will be founded on

[2] See http://www.uia.no/no/div/prosjekt/la2020/om_la2020 (In Norwegian).
[3] For the seminar programme see: http://www.uia.no/no/portaler/om_universitetet/teknologi_og_realfag/-_matematiske_fag/--_seminarer_og_foredrag

established quality in teaching, research, innovation and students' experience in mathematics.

2.2 Result factors: Student flow, graduation rates, quality assurance, external evaluations, etc.

The Norwegian 'state of higher education' report for 2012 observes "*Among the universities Agder and Stavanger have the highest completion rates …*' (Ministry of Education and Research, 2012, p. 45, author's translation). This observation is consistent with the report of the national evaluation of engineering education (NOKUT, 2008), which noted that UiA is one of the larger institutions of engineering education and has "*good progression rates compared with other engineering institutions, with monitoring among many good features*" (p. 287 author's translation). The NOKUT evaluation of engineering education also reported "*additional teaching resources have been provided for mathematics … failure rates have reduced from 36% to 19%"* (pp. 291, 292 author's translation). Special effort to improve students' progress has also been made in other programmes, for example, a mathematics course for economics students was restructured so that students could select a track that suited their needs best (Eilertsen, 2008).

Progression rates data published by the Norwegian Social Sciences Data Service (NSD, 2013) reveal that UiA lies above the average for Norwegian Universities. The data also reveals that progession rates in programmes within UiA that have a compulsory mathematics component provided by the Faculty are above the UiA average. Progression rates for courses with a compulsory mathematics component (i.e. engineering, natural sciences, economics and teacher education) at UiA over the last five years range from 83% to 93,5%.

Quality Assurance system and internal evaluations: In 2010 NOKUT evaluated the quality assurance systems at UiA and found the quality assurance system to be satisfactory:

> *The system is known throughout the (university's) operation … It is evident that through the system, the university obtains the knowledge which is necessary to evaluate the quality of education. The committee has in the documentation seen good analyses and discussions that give the foundation for improvement in education* (NOKUT, 2011, p. 5 & p.11).

Mid-way and terminal course and programme evaluations provide evidence of a dynamic cycle of improvement. Students' evaluations of their experiences are considered in Study Programme Advisory Committee and contribute to annual course, programme, Department and Faculty reports. Thus students' satisfaction with their experiences and their suggestions for improvement are well documented within the system. Nevertheless, the basis of excellence rests on the close relationship between students and teachers, which facilitates *continuous* feedback, adjustment and improvement.

Reports from alumni - Graduate Survey 2010: The survey of graduates from years 2007, 2008 and 2009 (Rambøll, 2010) although not focusing directly on mathematics courses, reveals that about 75% of graduates were satisfied with the education they received at UiA. Mathematics is a significant component of the basic analytical skills that students need in their studies and thus it is

relevant to note from the report: "*The results show that it is the basic academic skills of analysis … that graduates evaluate most positively*" (Rambøll, 2010, para. 9.9, author's translation).

2.3 Process factors: teaching, working methods and assessment

> *The Committee will emphasise that the institution also has specific strong subject didactics milieus which succeed in dissemination of research and have good and relevant research and development projects linked to compulsory school, where teaching practice supervisors and students participate. Especially, this applies to mathematics* (NOKUT, 2006, p. 13).

Teaching and assessment: Students meet a variety of teaching approaches ranging from more traditional style lectures through to innovative digital-simulations and collaborative problem-solving in small groups. Approaches to teaching and learning support students' development as independent learner-inquirers who contribute to, and learn from, their participation in an active learning community. Assessment approaches are chosen to suit the learning objectives and students' learning needs. These include: traditional examinations, oral presentations, reports from individual and group activity, observation in work place settings, and interactive web-based approaches through which students are provided with immediate feedback and targeted support.

Integration of research and development in teaching:

> *The research base and orientation of the teaching is more evident than in many other institutions* (NOKUT, 2006, p. 19).

Students are introduced to and engaged in research in bachelor and masters courses, examples are included above (Section 1). Students are invited to research seminars, and *all* masters and PhD students present their research in the same seminar series as international visitors. Research, as systematic inquiry, and evidence permeate teaching and learning at all levels. The University has developed a large international research group in mathematics education (described below in Section 2.4), which is engaged in many directions of research activity in mathematics education. This facilitates the dynamic synergy between research and teaching, described briefly in Section 1. Opportunities are taken for masters and doctoral students to research innovative practice within mathematics teaching at UiA. Additionally they can engage in developmental research to apply innovations which they have experienced at UiA. Reciprocally, researchers both enrich teaching from their own research agenda as well as designing new, innovative courses at all levels.

2.4 Input factors: Academic resources, staff competence and leadership.

Academic resources: MatRIC will be located within the Department of Mathematical Sciences.

> *The university college's*[4] *leadership reports that to a large extent international resources are brought in for teaching and supervision in the doctoral programmes for specific milieu, especially mathematics education* (NOKUT, 2006, p. 13).

[4] UiA was awarded the 'University' title in 2007, it was formerly Agder University College.

These 'international resources'[5] combine with the strong national resource in mathematics education. The Department comprises 26 permanent teaching staff[6] including mathematicians and statisticians, mathematics education researchers, mathematics teacher educators, and informatics and ICT educators. Mathematicians and mathematics teachers are also employed within other departments in the Faculty (about 10). Teachers from different fields within mathematics collaborate closely, especially through joint supervision of dissertation work (at masters and doctoral levels) and the moderation of students' assessment. Mathematics courses and students at all levels benefit from the integration of academics and researchers in different fields.

> *The Committee notes also that in specific subjects there is a clear focus on subject didactics. Mathematics and Norwegian are outstanding in this respect* (NOKUT, 2006, p. 14).

Teachers within the Department are experienced in higher education and schools, they are highly and appropriately qualified (18/26 with PhD), many with a PhD in mathematics education (9), and most are actively engaged in research within their own field (average 36% of assigned work is research and development[7]). The Department emphasizes the importance of the didactical competencies and knowledge of academics, for example, in 2010 the appointment of a professor of mathematics included a demonstration lecture which was required to focus on teaching. Teachers serve on national and international committees representing the subject at a variety of levels.[8]

3. POTENTIAL FOR INNOVATION AND DISSEMINATION

MatRIC will support effective mathematics teaching and learning that results in:

- Motivated students, who enjoy mathematics and appreciate the relevance of mathematics.
- Students who understand fundamental mathematical ideas so that they can apply relevant mathematics to resolve non-routine problem situations.
- Students who have strategic knowledge and awareness of mathematics that enables effective problem solving and self-regulation.
- Students who have procedural fluency and reliability in routine operations and calculations.
- Students who possess competencies in mathematical modeling and the application of mathematics in the problems encountered in the work place and applied research situations.

3.1 Strategic plan for development and innovation: rationale and description

MatRIC will have four interdependent work packages (WP) focusing on networking (WP1),

[5] Scholars from Algeria, Brazil, France, Germany, Sweden, the Netherlands, UK and Ukraine
[6] Not counting PhD fellows.
[7] Based on R&D allocation together with project work, doctoral supervision, and research leave. This is low because UiA is funded on the model used for the university colleges.
[8] Carlsen, M. - Faggrupperepresentant for matematikk i FLU - member of the subject group of kindergarten teacher education representing mathematics.
Fuglestad, A. B. – Board member - Norwegian Mathematics Council.
- International Commission on Mathematics Instruction (ICMI) representative for Norway.

research (WP2), innovation (WP3) and dissemination (WP4).

WP1: Networking mathematics teachers and user groups. One main concern addressed by MatRIC is the coordination of innovative effort invested in teaching mathematics. MatRIC seeks to connect teachers to facilitate exchange of ideas and experience.

Objectives: Stimulate, share and coordinate good, innovative practice and experience and enhance teaching through collaboration and exemplary practice. Bring together mathematics teachers with specialist teachers and specialists from the workplace within engineering, science etc. which focus on specific applications of mathematics and learners needs (Special Interest Groups – SIGs).

Task 1.1: MatRIC will develop a web-site as a 'virtual competence centre'. The web-site will be MatRICs resources bank and notice board. MatRIC will work to establish links to the MatRIC web-site from universities, research institutes etc.

Task 1.2: MatRIC will establish an annual conference that will bring together teachers of mathematics and user disciplines to present exemplary cases of innovative approaches in teaching mathematics from other countries and within Norway. The conferences will facilitate the formation of SIGs (WP3) – initially one for each study programme - and dissemination (WP4).

Task 1.3: MatRIC will organize regional workshops that will serve an outreach function, to connect teachers of mathematics and user subjects into the Centre's network, and make the activities of the Centre known (WP3 & 4).

Task 1.4: MatRIC will support visits to international centres of excellence in teaching mathematics and provide opportunities (in all WPs) to share the knowledge gained through publication and action.

Competence: The Mathematics Education Research Group has established collaborative research projects with other institutions. Members of the Group have organized national and international conferences. Teachers within the Department and Faculty are connected into national and international professional networks.

WP2: Research: Evaluation of innovation of teaching and learning. Another main concern of MatRIC is the knowledge base that supports mathematics teachers experimenting with, or exploring the use of video, digital, web-based and other technologies.

Objectives: Enable the replication of innovation leading to the coordination and validation of knowledge gains and eliminate 'blind' repetition that occurs due to inadequate means of sharing. Support the development of a research-informed knowledge base in the use of innovative approaches in teaching and learning, and share this with teachers and users of mathematics.

Task 2.1: MatRIC will survey sources of research evidence related to innovation in teaching, learning and assessing mathematics at university, and make this available on the Centre web-site.

Task 2.2: MatRIC will survey current efforts to improve the teaching, learning and assessment

especially in the use of video, digital and web-based technology to establish a data base of practical information, insights and contacts for others interested in introducing similar innovations.

Task 2.3: MatRIC will support research effort by providing small grants ('seed money') to enable pilot studies and the development of proposals for external funds to support research and innovation in teaching.

Competence: The Mathematics Education Research Group is already engaged in this research field, including masters and PhD students' research. The network established by MatRIC will enable the development of this research activity and the distribution of the knowledge accumulated.

WP3: Student modeling laboratory and workplace simulations. This WP is the core component of MatRIC as a centre of innovative practice. MatRIC will establish a network (WP1) and a research base (WP2) that can be exploited to develop innovative approaches to teaching and learning mathematics through the collaboration of teachers and users in SIGs (WP1).

Objectives: Improve students' enjoyment and motivation in mathematics. Develop students' competencies in mathematical modeling in situations related to their 'user' programmes. Develop students' awareness of how mathematics is applied in the workplace and thus motivate their engagement in mathematics. Contribute to students' understanding of the mathematics as a subject where abstract relationships are related to 'concrete' objects of the application. Develop competencies in group work, collaboration, sharing responsibility, and communication skills. Reinforce the need for accuracy and self-monitoring when using mathematics in real contexts.

Task 3.1: MatRIC will support SIGs to develop workplace simulations in which video, digital and web-based resources are used to create contexts in which students apply their knowledge of mathematics to the real world problems and challenges of the work place and research laboratory.

Task 3.2: MatRIC will support SIGs to create "Student laboratory" workshops in which students learn mathematical modeling 'in-vitro' through specially structured and focused tasks, and then apply their learned competencies 'in-vivo' as they are required to create mathematical models of 'real-world' contexts, related to their programmes of study.

Competence: This WP builds on the integrated community of mathematics teachers, mathematicians, scientists, engineers, computer scientists within UiA, and institutions and Centres (national and international) with which MatRIC will collaborate. Mathematics teachers within the Faculty have a national reputation for the integrated use of video and digital simulations (cited above, cf. attached cv-s). Tasks within WP3 are framed within the principles of mathematics teaching outlined in Section 1.

WP4: Dissemination of knowledge. MatRIC will communicate the knowledge gained through the other WPs through the annual conference (Task 1.2), and regional workshops/seminars (Task 1.3).

Objectives: Make the activities and outcomes of the Centre known to all 'stakeholders' and

stimulate collaboration in innovation and research in teaching and learning mathematics (WP1).

Task 4.1 MatRIC will produce a Newsletter each half year and make this available through the MatRIC web-site (Task 1.1). The Newsletter will be aimed at teachers, user groups, policy makers, students and other stake holders of innovation in teaching and learning.

Task 4.2 MatRIC will establish a professional journal for university mathematics teachers to share their experiences and insights from innovation. Papers in this journal will provide a 'launch pad' for developing articles for publication in international peer-reviewed scientific journals. MatRIC will also support presentation of results from WP2 and WP3 at national and international conferences.

Competence: Mathematics teachers and mathematics education researchers within the Faculty have extensive experience in publishing in professional and scientific journals and conferences, and dissemination of research outcomes in 'popular media'.

4. ORGANISATIONAL PLAN

4.1 Organisation

A Centre Management Board (CMB) will have responsibility for budget, oversight, policy and strategy of MatRIC. The Board will be chaired by a Vice-Rector (assistant vice-chancellor, or substitute) with members representing teachers and students from mathematics and user subjects and external members from other universities and employers. MatRIC's leader will be a member of CMB. The Centre Executive (CE) comprising the Centre Leader and administrator will have responsibility for ensuring MatRIC's policies and work packages are carried out. CE will provide CMB with monthly progress reports. An International Advisory Board (IAB) will be appointed to provide CMB with advice and evaluations of MatRIC's policies, strategies and implementation. IAB will comprise international authorities in mathematics education for engineers, scientists, economists, health workers and teachers. IAB will meet once each year, during the annual MatRIC conferences (Task 1.2), IAB will also receive the monthly reports from CE and have direct lines of communication with CE and CMB. Tasks in Work packages WP1 and WP4 will be carried out directly from the MatRIC-CE. Tasks in Work Packages WP2 and WP3 will be devolved to coordinators and groups, for which CE will have responsibility for monitoring and ensuring efficiency and effectiveness.

4.2 Centre management

MatRIC will be led by a Professor who is employed by UiA on a 100% permanent contract. MatRIC will account for 50% of the leader's workload. The person identified to lead MatRIC has extensive international experience in teaching mathematics, leadership, consultancy and research. A Centre Administrator will be appointed on a 100% contract. Coordinators to carry out the tasks for WP2 and WP3 will be appointed from SIGs (WP1). Coordinators will lead the tasks in WP2 and WP3, and will report to the Centre Leader.

4.3 Impact of MatRIC

MatRIC will directly address the challenges for higher education set out in the national strategy for mathematics and science (Ministry of Education and Research, 2010). MatRIC's research into innovations in teaching and opening up new opportunities for innovation, coordination of effort and dissemination of knowledge will raise significantly the quality of teaching mathematics and improve students' learning experiences. MatRIC will contribute towards improved recruitment to occupations in mathematics, science and technology, and better progression and completion rates in programmes that require a significant level of mathematical maturity as a foundation competence.

Additionality: Many are exploring the use of video and web-based technologies to teach, learn and assess mathematics. Much of the effort is uncoordinated and under-researched; consequently there is a lot of repetition and little progress in the systematic accumulation of knowledge about effective and efficient approaches to teaching and learning with these technologies. MatRIC will fill this gap by combining networking (WP1), research (WP2) and dissemination (WP4). The network will also create opportunities to establish groups of mathematics teachers and users that will work on design of simulations and modeling tasks that focus on specific applications of mathematics (WP3).

5. COLLABORATIVE PARTNERS

MatRIC will collaborate with and learn from the experience of the award winning Mathematics Learning Support Centre (of Excellence) at Loughborough[9] (contacts: Director Dr. Carol Robinson, & Professor Barbara Jaworski). MatRIC will also seek links with the UK National Centre of Excellence in Teaching Mathematics, until recently directed by Professor Celia Hoyles. Prof. Hoyles has recently been elected President of the Institute of Mathematics and Its Applications (2014-2016). Also, MatRIC will collaborate with the Science Education and Communication research programme at Delft University of Technology (contact: Director Prof. Marc de Vries). Leaders of these international centres will be invited to participate on the IAB.

Within Norway, the proposers of MatRIC have agreed to collaborate (independent of the award of Centre status) with colleagues at the Norwegian University of Technology and Science (a letter of intent is attached) and The Norwegian University of Life Sciences (UMB). Professor Frode Rønning, NTNU, and a representative from UMB will contribute to the management of MatRIC. Mathematics Educators at UiA and Norwegian Centre for Mathematics Education (NSMO) have been collaborating for several years in the development of courses. MatRIC will work with NSMO to exploit the synergy between the two Centres. MatRIC will seek to collaborate with other Norwegian Centres of Excellence, recognition of the potential for mutual benefit exists between the proposers of MatRIC and the leaders of ProTed.

[9] See: http://mlsc.lboro.ac.uk/