

TEACHING better MATHEMATICS: Collaborative inquiry into mathematics learning and teaching

We propose a programme of developmental research consisting of five linked projects in a newly formed consortium of five colleges and associated schools in different parts of Norway. Our proposal sets out the broad aims of the consortium that apply to all the projects, and provides brief details of each project. The programme fits with areas 1 and 3 in the RCN *Praksisrettet FoU i grunnoppl ring og l rerutdanning* programme plan. See also <http://fag.hia.no/tbm/>.

Statement of the main aims and goals of the proposed consortium

We aim to develop and improve mathematics education in Norway through research-based activity with special reference to

- a) improving learning experiences, processes and outcomes for pupils in mathematics;
- b) educating new mathematics teachers; and
- c) building/strengthening research quality and capacity at both college and school levels.

Our first aim is to develop knowledge and practice in the teaching and learning of mathematics, in order to provide learning experiences for pupils to achieve better conceptual understandings of mathematics. Pupils should demonstrate a *fluency* with mathematics, based on deep understandings, and *competence* for independent use of mathematics in different contexts. We will work with teachers to investigate teaching approaches which can achieve these aims.

Secondly, we will work with fellow didacticists¹, teacher educators, teachers and student teachers to build attitudes of inquiry and reflection towards learning and teaching. Student teachers will learn through inquiry and approach their teaching with an attitude directed towards inquiring into forms of teaching that lead to mathematical understanding, fluency and competence in their pupils.

Thirdly, didacticists, teacher educators, teachers and student teachers will inquire into approaches to learning and teaching to develop practice at all levels. Didacticists will draw on areas of theory in the research literature and expect to add to knowledge in mathematics learning and teaching through the research process. Research will both study and contribute to the developmental process.

Mathematics education in Norway

Mathematical achievement in Norway is not as strong as educators or society in general would like to see. This is reflected in both international and national studies such as TIMSS, PISA, KIM and the L97 evaluation (Alseth, Breiteig, & Brekke, 2003; Brekke, 1995; Gr nmo et al., 2004; Kj rnsl  et al., 2004). Pupils in schools are achieving below international averages. National studies show many areas of mathematics to be problematic for pupils (Brekke, 1995). An evaluation of the curriculum introduced in 1997 (L97²) suggested, for some areas of mathematics, that pupils were doing less well than in a review of the earlier curriculum (Alseth et al., 2003).

Until recently (1990), education for teachers in compulsory school (grunnskole) in Norway has included no compulsory study of mathematics, and little associated didactics of mathematics. The situation has improved over recent years, so that teachers at all levels now have basic courses in mathematics and didactics and it is possible for teachers to choose to study mathematics and didactics beyond the basics. However, there are many teachers still within the grunnskole system who have little formal education within the subject and possibly little understanding of and engagement with mathematics didactics. There are many factors which can contribute to pupils' underachievement in mathematics, but it seems clear that teachers' confidence and competence in mathematics (Niss & Jensen, 2002) and in ways to approach the teaching of mathematics is one of the most important. In this programme we will work very specifically with a number of models of teacher development and key topics to learn more about systems and approaches that can achieve the aims set out above.

Inquiry and Community

Our philosophy of learning and teaching in the proposed projects and the proposed consortium is situated within two fundamental theoretical principles, those of *inquiry* and *community*, and we base all our work in development and research on the building of *inquiry communities* involving, “a willingness to wonder, to ask questions, and to seek to understand by collaborating with others in the attempt to make answers to them” (Wells, 1999). We expect to form inquiry communities between didacticians, teachers, student teachers, and pupils, as indicated below.

Building on KUL (Kunnskap, Utdanning og Læring) Projects

The proposed basis of this new programme in a philosophy of inquiry communities builds on what has been learned at AUC in the KUL projects: Learning Communities in Mathematics (LCM) and Information and Communications Technology in Mathematics Learning (ICTML), both seeking to develop new cultures of mathematics learning and teaching³. Factors emerging from these programmes with relation to teachers’ use of inquiry tasks, possibilities for inquiry activity in schools, and issues in learning mathematics (including use of computers) will form important building blocks for the new projects. Both development of methodology and new awarenesses deriving from issues arising in these projects will provide a basis for the new programme.

The Consortium

Didacticians at 5 colleges in Norway (Agder, AUC; Bergen, BUC; Bodø, BoUC; Oslo, OUC and Sør-Trøndelag, STUC) have agreed to work together. Each group has its own proposed project and its own goals, but all are based in the development of learning and teaching mathematics, and in a philosophy of inquiry communities. During work in the individual projects the consortium will meet regularly, share outcomes and issues and address questions fundamental to improving mathematics learning and teaching. We expect to compare and contrast our differing approaches and what we are learning from them, to gain further insights into developmental practice and to use the insights in our ongoing work.

At the outset research questions that can be addressed in all the projects will be refined from our present areas of mutual interest. For example, how do individual projects enable development in learning and teaching mathematics and in mathematics teacher education? How are practicing teachers learning, or student teachers? What development can we see in pupils’ learning of mathematics? What can we learn more broadly, from issues and outcomes reported, about patterns of developmental activity that promote better teaching and learning of mathematics? What is meant by “better” learning and teaching?

The proposed projects are closely linked to the implementation of the new national curriculum, Kunnskapsløftet² which specifies goals for pupils’ learning at all levels but not the methods for achieving these goals. It is a basic principle that each teacher or group of teachers should have freedom in choosing, and studying, their own ways of working with pupils for the benefit of *all* pupils. *Adaptive learning* (tilpasset opplæring), strongly emphasised in the new curriculum, is linked fundamentally to inquiry approaches. The five teams together will develop and study a range of approaches to mathematics teaching, and teaching development, with a focus on the practical realization of learning goals. They will address directly the five basic competences fundamental in Kunnskapsløftet (be able to express oneself orally and in writing, read, calculate, use digital tools) aiming to develop more knowledge about what these mean for mathematics. For example, one focus will be the development of mathematical language and how reading, writing and discussing will lead to improved understanding and skills in mathematics. The projects will foster mutual respect among participants, equal gender opportunities and anonymity in reporting from human interactions. Ethical practices will be of central concern. Relevant permissions to conduct research with pupils will be sought from the Norwegian Social Science Data Services.

The proposed programme and projects

Teaching better mathematics is a two-edged title. It proposes that *teaching* will be *better*, and that *better mathematics* will be taught. We start with the second of these, *mathematics*. Mathematics is known as the language of science, an ideal tool for modelling scientific theories, deriving qualitative consequences from them and forecasting events. We see its uses in areas of international importance, such as the oil industry, civil engineering, weather forecasting, ecological models and high finance. Rapid changes in the world demand a knowledge of mathematics that is versatile and able to respond to new and unanticipated challenges. Mathematics is also a language for everyday life, a central part of human communication, and a means of articulating patterns, relationships, rationality and aesthetics. For all these reasons, mathematics is a central subject in the school curriculum for students at all levels and lends itself as a tool and way of thinking to many other subjects. Pupils need to learn not only to use and apply mathematics rules, processes and formulae but also to develop principled understandings of mathematics, ways of thinking mathematically and ways of tackling a wide range of problems using mathematics. The mathematics should be of use to them in decision-making in important situations in their lives.

It is this that we mean by *better mathematics*. *Better teaching* of mathematics follows: it is teaching that offers pupils rich experiences of mathematics through which understandings can develop and higher levels of achievement result. Teachers must know mathematics deeply and in principled ways themselves so that they can support and challenge pupils appropriately at all levels. The education of teachers must achieve such knowledge as well as knowledge in didactics and pedagogy of mathematics that enables the quality of teaching we expect. Here we see challenges for didacticians who draw on both local experience and the wider literature to achieve these goals.

For example, *activity* and *communication* are central concerns for mathematics learning and teaching. Since the implementation of L97 there has been a considerable focus on student activity in mathematics, possibly due to the constructivist principles on which L97 is founded. The evaluations of L97, both in general (Haug, 2003) and more specifically in mathematics (Alseth et al., 2003) have shown that, despite an increase in levels of activity, learning outcomes are still not satisfactory. International studies, (e.g. Säljö, Riesbeck, & Wyndhamn, 2001) have also documented that activities alone will not generate learning. Recently, one can observe a trend that the value of activities is seriously questioned, and arguments are raised in favour of the view that activities should be replaced by drill and practice (Gradowski & Sigmundsson, 2006). However, activity approaches were introduced due to dissatisfaction with the outcomes of drill and practice (Jaworski, 1994). On a fundamental level this has to do with views of knowledge and learning. It is important to challenge the perception of knowledge as something that can be transferred, as opposed to constructed (von Glasersfeld, 1995) or developed through social participation (Lerman, 2000). Thus, we believe that it is important to try to understand and characterise the learning that takes place through various ways of working. Such knowledge will help teachers to choose ways of working suitable for the specific learning they want to achieve in various situations. It is also important to realise that the endeavour to change/develop classroom practice takes time.

The proposed programme of projects starts from such knowledge and goals. It is a research and development programme such that all participants are researchers and research activity is seen as a tool for development as well as a means of creating scientific knowledge. We explain these ideas further below. It is fundamental that teachers define their own goals and boundaries within the projects and that didacticians respond to teachers' declared goals offering knowledge and expertise according to negotiated agreements (brukermedvirkning). Reporting from the consortium will be a synthesizing of knowledge across and beyond individual projects.

Theoretical background⁴

Mathematics learning and teaching

We draw on knowledge from research in mathematics education in a wide range of areas. First, knowledge of the learning of mathematical concepts and the strategies and errors common to

pupils' work. Second, a wide range of thinking and findings in areas of mathematical problem solving and its contribution to learning of mathematics. Third, we believe that learning is an outcome of pupils' ownership of mathematics questions and ideas, and that ownership emerges from active engagement in the classroom, discussion and negotiation of mathematical ideas with peers and teachers, and critical questioning of mathematical concepts. Problem solving and dialogic inquiry will be central to learning activity for all participants. Fourth, we draw on research in mathematics teaching and teacher education in our construction of activities in which to engage teachers and didacticians for development of common understandings and enhanced practice. Development of teachers' own knowledge of mathematics is a major consideration.

Inquiry communities

To inquire means to ask a question; to make an investigation; to acquire information; to search for knowledge: Thus we see inquiry to be about questioning, exploring, investigating, and researching. In these ways it is central to approaches and heuristics in mathematical problem solving (Polya, 1945). It is also central to practitioner research designed to develop teaching (Elliot, 1991). It leads to metacognitive awareness and ability to take responsibility for learning (Mason, 2002). The essence of inquiry as a basis for effective learning is a position of looking critically, in a positive way, at whatever we are engaged in, asking critical questions that take us deeper into the substance of our activity. We aim to become more knowledgeable about our practice and more able to function wisely and effectively. This applies to doing and learning mathematics, to developing approaches to teaching, and to conducting research.

We recognise that we are people working together to achieve mutual goals, but that we have different focuses and histories. Social groupings such as school, college, family and friends; social structures such as society and schooling; political systems; economic factors; cultural factors; all influence our working lives. We engage in certain forms of practice and these practices are what we seek to understand more clearly in order to develop and improve what we do. If we are to ensure better learning for pupils, we have to explore critically the ways we work with pupils, the kinds of classroom activity we use and the learning outcomes. Similarly with student teachers.

The nature of partnership between teachers and didacticians is central to our research. Ways in which teachers see themselves as inquirers, and their reliance on didacticians have emerged, in our earlier research, as key to development. The roles of didacticians in promoting teacher and teaching development must be a source of inquiry. For example, we have seen that teachers need a more well-founded ownership of developmental goals, in order to stimulate their activity and motivate their sustained involvement despite many demands of school life. It is necessary to form a more equitable basis for teachers and didacticians in motivating and taking responsibility for activity. We want to work together in ways that utilize knowledge and expertise fruitfully for effective development according to all the goals set out above.

Research and Inquiry

We propose to engage in *developmental research*. By this we mean research that both studies the nature and outcomes of the developmental process and also promotes development. Such research has an important *design* element (Kelly, 2003). We plan to design activity at a range of levels, explore the use of what is designed, reflect on its outcomes and feedback to improve the design. This cycle of *design, action, reflection, feedback* applies to teachers' planning for classrooms, to pupils' mathematical activity in the classroom, and to the design of seminars or courses through which to promote thinking of didacticians and teachers in developing teaching. We have research questions in all these areas. The cycle is fundamentally an inquiry process in which questions are explored in creating designs and relative to the outcomes of designed activity. We will collect and analyse data from all aspects of this process according to our research questions.

It is an important principle that both didacticians and teachers are researchers. The research in which they engage can be seen as motivating the kinds of thinking and analysis which emerge. *Both* will be *insider researchers* (Bassegy, 1995): this involves research into their *own* activity and practice for the purposes of learning more about that practice and hence having the possibility to

improve their own practice. The projects will provide support for teachers who are new to engaging in research; providing research training where appropriate. The keeping of records at different levels will be seen as central to the project and teachers will be helped with developing means of writing their reflections and keeping a range of records. Importantly, also, didacticians act as *outsider researchers*, gathering data and exploring development within the project as a whole. In doing so, they look critically not just at their own practice, but also at the activity of others within the project. For example, they might gather data from classrooms or from interviews with teachers or pupils and analyse it with respect to questions about pupils' learning. Insider and outsider research are complementary in enhancing knowledge and promoting development.

Outsider research will employ a variety of methods, qualitative and quantitative, based on relevant research questions. Qualitative methods will include observation in classrooms, with audio and video recordings of classroom activity; audio-recorded interviews with pupils and teachers; written reflections on experienced activity; written documents from lesson planning, classroom materials and pupils' work. Analysis of such data will use techniques including those of data reduction, categorization, and fine grained analysis of discourse. Generalisation will result from critical comparison of findings across projects. Data collected for formal analysis will complement that of teachers in the design cycle. For example, video of lessons, as well as providing data for analysis, will be used as a basis for discussing classroom processes amongst groups of teachers and didacticians to strengthen knowledge of teaching and a deeper awareness of classroom actions and pupils' learning. Quantitative data will be used in an ongoing longitudinal study of students' achievement in grades 1 to 13, starting from existing research and extending to all the new projects.

Teacher education

All the proposed projects include teacher education and student teachers in research and development. First teacher educators are, or will become, members of the didactician community. They will build ideas of inquiry communities into the course material for student teachers. School practice placements will offer activities for student teachers to engage in learning through research. This will take place in various modes, for example: 1) explicit research tasks to carry out in their placement schools; 2) engagement in the schools with teachers' developmental work within the project; 3) designing and using tasks for the classroom in which they develop inquiry activities with pupils. Results from these modes of action will feed into a portfolio for each student teacher that reveals their learning within the teacher education programme, and provides important data within the project. Collaboration between didacticians and practice tutors (mentors) will enhance FoU competence and contribute to a closer connection between formal study and practice teaching.

Relationships with schools

We will work with a number of schools some of which are already partners with one of the colleges in teacher education or research projects (see Attachment_Schools_TBM_HiA.doc). Through their school owners, these schools will bid for their own developmental project in the *Program for Skoleutvikling*. Each school must propose its own goals for developmental work related to mathematics learning and teaching. It is very important for our programme that the schools we work with decide for themselves what they want to develop in the project. Ways of working according to principles of reflective inquiry and participant research will be fostered by didacticians and teachers together and research will document the processes involved.

The activity of the programme and projects

The programme comprises five projects, one at each of the five colleges. Each will develop its own programme and internal consistency while having the common basis set out above. The project in each college, will communicate with similar projects in other subjects, BUC most specifically. The BUC project will be funded at Bergen. Here we offer brief details of what is planned by each college. Further details of the particular background supporting research and development, research questions, references and project implementation can be found at <http://fag.hia.no/tbm/>.

AUC – Inquiry in developmental design

We propose to form an inquiry community between *mathematics education* and *preservice teacher education* at the college and twelve schools (including all of grades 1 to 13) who are partners with one or both of these areas. Each school will have its own goals related to improving mathematics learning for pupils. The use of ICT in mathematics learning and teaching will also be a major focus of development. Some of these schools have been partners in the KUL projects described above, and have started to develop an understanding of inquiry in learning and teaching mathematics. We plan to build on this development to draw the other schools into similar activity. We will build also on schools' experience in working with student teachers to promote a multi-dimensional inquiry process and a new culture of research-based teaching and development throughout our community.

We will begin from schools' own documentation of status (ståstedsanalyser) for developing mathematics teaching and learning as part of their whole school developmental process. Activity will be organized with specific schools and groups of schools. Teachers will identify areas for development and didacticians will work with them to create developmental plans and models for work with pupils based on an inquiry-design process informed by our learning in the KUL projects. Unlike in the KUL projects, we will start from teachers own declared aims and goals.

Our joint activity will start with a conference at which teachers present plans for their projects. Didacticians will encourage questioning and discussion, in large and small groups, to deepen thinking about proposed activity. Together, we will focus on work with pupils and how to promote better mathematical learning in classrooms. We will introduce the inquiry cycle and discuss how it can be utilized according to the various aims in schools. Schools will update their development plans and begin a programme of activity in consultation with didacticians. Groups of schools with similar interests may form a small network: for example, to discuss work with pupils and observations of mathematics learning. We will address, overtly, teachers' roles as researchers, and didacticians' roles in supporting teachers. A schedule of meetings, as a whole community or in smaller groups, at AUC, in particular schools or in regional centres, will be set up. The community will decide on approaches for teachers to upgrade their own mathematical knowledge, ICT expertise and research methods: workshops or minicourses will be mounted by teachers and/or didacticians, web-based materials constructed and existing resources used according to needs.

Teacher education in mathematics will include teaching about inquiry communities and the design cycle in existing courses. School placements for student teachers in project schools will allow student teachers to learn as part of a developmental research process involving their supervisors in the college and teachers in their practice school. They will have specific assignments as outlined above to engage them in the research process as a fundamental approach to their learning to teach.

Eight didacticians of mathematics (at professor and associate professor levels) will be partially involved in the project, initially in parallel with the ongoing KUL research. In addition we will draw in colleagues at levels of associate and assistant professor levels who are currently involved in teacher education. The project will enable competence development at these levels, particularly in research expertise. We wish also to recruit to two doctoral scholarships, a position of associate or assistant professor, and to a project coordinator/secretary position.

STUC – Learning of mathematics through activities and communication

We plan to continue current developmental work with two schools in the Trondheim area and commence work with a third school. Focuses will include: working with mathematical language and communication – in particular for the pupils entering school – and the potential of pupil activities, particularly outdoor activities, for inducing learning of mathematics. The project will develop inquiry communities in and across the three schools and draw on research in the two areas.

The project will bring together work in inservice and preservice education involving didacticians/teacher educators, teachers in the three schools, and student teachers as researchers. The research areas of the project fit very well with central topics in the plan for our recently launched master's programme (Grunnskolen matematikkfag). Masters students will undertake research in the project

schools in which their supervisors collaborate with teachers. Teachers will have opportunity to participate in research training in the master's course.

The project will also contribute to our development of *field studies* for first and second year student teachers– designated tasks for the students to be carried out at the placement schools, outside of the regular practice periods, focusing on a special topic and with clearly defined goals for investigation and learning. Here student teachers will learn from being participants in everyday teaching practice in which inquiry and community are accepted norms.

The work in each school will be directed partly towards the whole school community, and partly towards more specific levels. Each school will enter into a wider community where an inquiry model, using a problem solving and dialogic approach, is developed together with the other schools, didacticians and masters students. This community will run mathematics workshops to raise the level of competence among the teachers both in mathematical and didactical topics, agreed between the participants. In addition, teachers can develop their own mathematics and research expertise through participation in courses, related to their particular mathematical or research background, for which credit points are awarded, some in association with the master's programme. Connections will be made to other research projects within the college.

Five didacticians (one professor, two associate professors and two assistant professors) will work in the project: two with special responsibility towards each school. One didactician with higher research experience and competence will be paired with a less experienced one, and through this model the project will contribute to staff development. We also apply for a research fellow position which would be held by one of the assistant professors. S/he will do research at STUC, and would follow the PhD programme at AUC. Participating in the consortium further strengthens the possibilities of competence development.

BoUC – Understanding adaptive learning

The new national curriculum, Kunnskapsløftet, emphasizes *adaptive learning* for all students. To provide adaptive learning in the classroom, the teacher makes many teaching decisions in each lesson; these decisions are based on the teacher's interpretation of what the students have learned and how they learn. Information is obtained both from formal tests and from other informal ways of assessing mathematical learning. We use the term *revealing learning* (*læringsafdekning*: Niss & Jensen, 2002) to describe these informal methods. We intend to formulate a theory for revealing learning in the mathematics classroom based on a study of teachers' goals, the tools they use, how they interpret information and what decisions are made. We shall investigate how teachers can reveal learning by procedures other than using tests. A further investigation will be about the *validity* of the teachers' interpretations. Our investigation will begin with an exploratory and descriptive phase performed in close interactions with groups of teachers from collaborating schools. The teachers will reflect on their current methods and research new methods for revealing learning. The theory developed will be important for mathematics teacher education. It will provide preservice teachers with analytical tools for their experiences in practice, and it will be an issue for discussion in our inservice teacher education work. We will explore the possibility of student teachers learning theoretically about revealing learning, and then applying this in their placement schools, by collaborating with teachers who are practice tutors and through the practice seminars.

We will work with teachers in two schools collaborating in our *Allmennlærerutdanning* (general teacher education) programme for the *grunnskole* and the proposed master's programme in adaptive learning. The project community will comprise inquiry communities at three levels: the didacticians' community consisting of two teacher educators at BoUC the teachers' communities, one in each school, and the pupils' communities. The didacticians, who have collaborated on several inservice teacher education programmes, will be responsible for the methodological plan and theoretical foundation, organization of meetings with teachers and developing a plan/idea/platform together with teachers. They will collect and analyse data from the project and organize research workshops for teachers. Teachers will engage in activity according to agreed plans, report diagnostic information, maintain research logs and reflections on their activity with

pupils. Pupils will engage in mathematics. A further goal of the project is to be connected to the research community in mathematics didactics through the consortium. This is especially important for our small and young research group in Bodø.

OUC – Making a difference

This project focuses on the attainment targets from Kunnskapsløftet that concern numeracy in grades 1 and 2. The main research goals for the project are concerned with how the establishment of a teacher community on the one hand, and the development of teaching activities addressing specific conceptual targets on the other, can be a driving force in the development of teaching practices. The design of the project is such that teaching development is studied from an intended level (the topic frameworks), to a designed level (the teaching plans) and then to an implemented level (how the teaching is conducted at the schools). The project also aims to produce descriptions at the students' level, and on this basis to discuss in what ways and to what extent better mathematics teaching has been achieved.

We will work with four schools in the Oslo area. Through this project, three communities will be established, one with didacticians and mathematics educators, one with teachers, and one with student teachers. Common to all communities will be their focus on inquiry. Within the project, these communities will be engaged differentially: *The didacticians' community* (comprising one associate and three assistant professors) will develop a conceptual framework, to be presented to the teachers, elaborating the attainment targets from Kunnskapsløftet that concern numeracy in grades 1 and 2. The framework will describe in detail central components concerning how students develop understanding within this mathematical topic. During the project period, together with the teachers, the framework will be developed further based on classroom experiences. Didacticians will also make plans and consult teachers about how the project will proceed, how to organize meetings with the teachers' community, and the inclusion of student teachers in the project. A PhD-student will be a part of this community working mainly at the implemented level, observing teaching and interviewing teachers. Didacticians will collect and analyse data from all parts of the project. *The teachers' community* will meet twice a semester with didacticians at the college where teaching plans will be worked out collaboratively. At the first meeting, the framework from the didacticians will be presented and the participants will discuss and develop teaching plans according to the framework. Teachers will teach their classes, reflect on the outcomes, keep records from their activity and feed back to planning both locally in their school and in meetings of the whole community. *The student teachers' community* will teach and conduct research in the project schools observed by didacticians and teachers. Experiences will be brought back to teacher education seminars and to both the teachers' and the didacticians' communities. Thus, the framework and the teaching plans will be further developed, and teacher education will become more inquiry based.

BUC – Collaborative inquiry : The society as arena for learning mathematics

The focus of this project will be on inquiry, communication and learning mathematics in collaboration between pupils, teachers, student teachers and teacher educators/didacticians. The project is connected to the planned school development project on "*erfaringsundervisning*" in five lower secondary schools in the Bergen area. The schools cooperate with trade industry and organisations in the district. Learning-activities will be developed through visits to trade and industry sites in relation to the implementation of the new curriculum (Kunnskapsløftet). Multicultural and multilingual challenges are recognised especially since one of the participating schools is an *inntaksskole* (school which admits immigrant children). A central issue is to develop investigative mathematical communication as a tool for and part of learning in the context of a variety of environments and languages.

This project will be coordinated across a range of subjects. Mathematical and didactical competency will be an important part of the mathematics strand and will be organized to fulfil the aims expressed in the main proposal above. A PhD candidate will be recruited to the project: if the

focus of research is mathematics, s/he will undertake studies as part of the doctoral programme at AUC.

Outcomes, expectations and implications from the projects

New knowledge and sustainability

The inquiry cycle of *design, action, reflection, feedback* is central to learning in the projects, both for teachers and for didacticians, promoting generation of new knowledge in practice. This supports both critical reflection on current practices and trial and improvement of new practices. We are not proposing to create change for the sake of change, but to educate teachers and didacticians, and the next generation of teachers, to be critically reflective practitioners. As such, they will develop competence in creative design of teaching and critical evaluation of teaching outcomes. We intend to develop research cultures in which research-in-teaching becomes an accepted 'norm', with practitioners growth of understanding of what research in teaching can mean for them and for their students and pupils. Student teachers will experience the inquiry cycle in theory and practice as part of their studies. Pupils learning mathematics will be drawn into a range of modes of activity with encouragement also to become reflective in and of their own learning. Together teachers and didacticians will study the learning of pupils through the designed activities and review critically how different teaching approaches contribute to pupils' development of mathematics understanding. The longitudinal research will provide evidence of pupils' achievement which will feed back to the design process.

A goal of all the projects is that *development of practice* will be closely associated with *development of thinking about practice*. This means that practitioners should grow into new ways of thinking and engagement that make sense fundamentally and can be sustained beyond the life of the project. Research will reveal the issues that have to be faced in achieving these aims. For example, how do pupils respond to particular approaches and what achievements are observable? How do we address teachers' own mathematical needs? How do the wider demands of teaching impinge on the possibilities for engagement in the inquiry cycle? If we apply a credible model, suitably resourced, to enable teachers and didacticians to develop as critically reflective practitioners, what factors have to be recognized and addressed? Thus, sustainability in the project is also a part of its critical dimension, and an element of research.

Dissemination

Dissemination of findings will use traditional means through presentations at conferences and publications of both a scientific and professional form in books and journals. We will explore novel ways of communication in websites, school networks, and the local and national press. Writing workshops will enable teachers and didacticians to develop writing skills at appropriate levels. However, what is learned by participants in these projects will be practical knowledge about teaching and learning that can be described but not handed on through publications. Although the written synthesis will be a valuable communication tool, it is a serious question how this practical knowledge can be communicated. One of the issues we have to resolve as part of these projects is how others can learn from our activity and thinking as it is happening, rather than by reading about it afterwards. In a very real way, what is learned is learned through participation, and to learn one has to participate. We will seek support from the RCN, KD, and NMC to address this conundrum.

Evaluation of ongoing activity

Evaluation of practices will be ongoing with developmental activity. Each project will monitor its own activity and respond contingently. The consortium will act as a monitoring organ through discussion and critical questioning of each of the projects at periodic consortium meetings. An external evaluation of each project will be planned in time to influence project completion.

Programme management

Each project will have its own local steering group including project leaders and representative members from all constituent communities. The Consortium will have a steering group composed of leaders from each of the projects. AUC will be the leading institution and budget holder.

The Consortium and development of mathematics education in Norway

Consortium meetings will focus on issues from practice and from research in the five projects with critical questioning of what we are doing and achieving. We will seek common threads and counter indications, to enable a more general picture of issues in mathematics learning and teaching to emerge, particularly in relation to the new curriculum and pupils' achievement in mathematics. Records from consortium meetings will be an important source of data for analysis in respect of the overall learning across the projects. The doctoral programme and research expertise developed at AUC will support activity within the other colleges. We will open up the consortium debates to others in the field in and beyond the five colleges to aid the dissemination process. Such opportunities, together with presentations at national events will contribute to the development of the mathematics education community in Norway and prepare the ground for a national culture in which achievement in mathematics is raised generally.

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¹ Didacticians are educators (or *teacher-educators*) who have responsibility for the didactics of mathematics – for theory *and* practice in the teaching and learning of mathematics. They are also researchers, just as teachers can be researchers.

² See http://www.utdanningsdirektoratet.no/templates/udir/TM_Tema.aspx?id=148

³ Various publications have resulted so far and others will follow as the projects move into a concluding phase (these can be downloaded from the KUL website at <http://fag.hia.no/kurs/lcm>). In September 2006 a major conference will take place in which we disseminate our activity and findings from the projects.

⁴ Publications here are far too numerous to list in the space we have to write this proposal. Here we refer only to a small number of key texts. If requested to do so we will provide an appropriately expanded list.