LOCAL CULTURE FOR UNDERSTANDING MATHEMATICS AND SCIENCE (LOCUMS)

1. Relevance relative to the call for proposals

The project addresses FINNUT priorities B (practice, professional practice and competence development) and A (learning processes, assessment forms and learning outcomes). LOCUMS has an action component addressing (B) and a research component addressing (A).
It will address priority A by increasing the quality of learning in science and mathematics at lower secondary level, through linking it to local cultural contexts and practical work related to science and mathematics. In order for teaching and learning to be effective, it is essential that students are engaged and motivated, that their learning experiences are authentic and that their previous knowledge and understandings are recognised. LOCUMS will investigate whether students' cultural backgrounds can situate and contextualize their learning in Science and Mathematics, thus enhancing achievement, motivation and engagement.

It will address priority B by developing teaching models and materials for this context, and by working directly with teachers and school leaders in the Research and Design process. This will constitute capacity building and competence development for these stakeholders. Although Norway is not challenged to the same extent as (e.g.) France or the UK in terms of cultural difference in schools, the cases chosen for the project will provide useful learning at an international level, as well as informing Norwegian policy and practice, due to the openness of the Norwegian system to research and design activities, which are not possible in other contexts.

A school based professional development program for in service teachers will be developed and put into practice by Skolelaboratoriet at NTNU, an organization that has engaged in this type of activity since 2006.
The research participants will be located in Finnmark and in Oslo. Our project will investigate the use of practical activities based on students' life experiences and cultural backgrounds as a starting point for the learning of concepts and basic skills. The localities included in this research investigation have a rich and varied cultural heritage, which needs to be considered when teaching (amongst other things) mathematics and science. Several studies show that students' learning can be facilitated when the starting point and focus of teaching is rooted in local culture (Aikenhead 2010; McKinley, 2006). We believe that this is relevant to all kinds of cultural backgrounds, whether indigenous or migrant. The study will, therefore, explore the notion of a culturally responsive science and mathematics education. This is relevant to the situation in Norway, but also connects to the wider context of global change in education systems, which need to become more responsive to student diversity whilst delivering better literacy, numeracy and science-related skills (OECD, 2013).

2. Aspects relating to the research project

Objective 1: To develop more culturally responsive teaching and learning methods in secondary school science and mathematics, involving local knowledge and cultural identity, in order to engage students, raise their achievement and reduce school drop-out.
Objective 2: To collect data from contrasting case studies in three locations in Norway, in order to evaluate the effectiveness of these teaching and learning methods and to provide a basis for research studies in the field culturally responsive science education.

Objective 3: To develop state of the art professional development activities in order to support the implementation of more culturally responsive teaching and learning methods in secondary school science and mathematics.

Objective 4: To provide a strong evidence base for the implementation of culturally responsive science and maths education, in order to strengthen Norwegian and international education policy in this area.

Background and status of knowledge

Cultural identity in science and mathematics education

Western science represents a specific worldview (Cobern, 1996), from which students may feel alienated. Minorities may be particularly affected, although this phenomenon can also be identified in other groups of students. In order to improve the engagement and learning of young people, their cultural identity must become an integral part of their schooling. When this identity is not considered, learners may experience dissonance between their own culture and that of the school, especially in science and math, where increasing levels of abstraction may become a problem. Barriers to engagement are thus created, and these are hard for learners to overcome (Aikenhead, 2001, 2010) without changes in pedagogy and lesson content.

Science educators have been preoccupied for some time with making science education more culturally inclusive. The Framework Programme 7 project, SiS-CATALYST, has been working on the relationship between young people and science, and has developed the concept of 'locally-defined minorities'[1]. This concept refers to the fact that across the world, minorities are circumstantial rather than being fixed entities, and can be defined across a range of factors such as ethnicity, religion, class, gender, sexuality, language and so on. Often these factors combine to produce a local minority, such as white working-class boys in the UK, who are at risk of underachievement and disengagement from education. Locally defined minority groups can reinforce their own isolation or they can overcome it, through positive action by all members of the relevant community. These groups may not be minorities in specific locations where they are the main group, but might be minorities in wider national contexts.

In Norway, there are several cultural groups, including the Sami in the North, and migrant communities in cities. The status of the Sámi people, as indigenous to the area, is well known and documented. During the last decades, however, people from other cultures outside Norway have settled and are now a part of our society. Very few studies pertaining to cultural identity have been undertaken in the area of mathematics and science education, though there are some recent studies in the area of mathematics (e.g. Chronaki, 2008). According to Aikenhead (2006, pp.107-108), culture-based clashes in science classrooms occur when discordant worldviews create an incompatibility between, on the one hand, students' established self-identities (e.g. who they are, who they want to be), their views of Western science or school science, and their perception of who they should become in order to engage in science. LOCUMS, therefore, supports a move towards more student-centred education.

Working with non-Western minority students in Canada, Aikenhead (1996) has described how acquiring scientific knowledge can be facilitated by explicitly speaking of science as a subculture of Western or Euro- American society. O'Donoghue (2013) further claims that indigenous people might have difficulties seeing the richness in their own culture. By using local cultural artefacts linked to a specific topic in science, students can research and explore the topic as contextualised in their home culture. This cultural richness will thus enhance science education.

Culturally Responsive Education

According to Gay (2000), culturally responsive teaching is best defined as *using the cultural knowledge, prior experiences, and performance styles of diverse students to make learning more appropriate and effective for them; it teaches to and through the strengths of these students*. Culturally responsive teaching is based on the supposition that, when academic knowledge and skills are situated within lived experiences and used as frames of reference for students, they are more

[1] See: http://www.siscatalyst.eu/tartu

personally meaningful, have higher interest and appeal, and are learned more easily and thoroughly (Gay, 2000). In their book, *Literacies in Place,* Comber, Nixon and Reid (2007) describe experiences and outcomes of place-based inquiry combined with literacy practices. They claim that place-based pedagogies highlight people's relationships with places and non-human life forms, and the reciprocal responsibilities that people in one place and time have for people in other places and times. In the LOCUMS project, we wish to further develop the concept of *culturally responsive science* and include the notion of how to embrace and incorporate students' different cultural backgrounds into science and math, in order to enrich the experience and link the learning of science to the students' local environment.

Links between science and math education

School science includes mathematics as a working tool, to make models of, for example, population growth or physical forces. The current focus on Norwegian students' problems with school mathematics and science, due to disappointing PISA and TIMSS results, has not only increased efforts to improve education in these subjects, but has also stimulated the use of science to contextualise mathematics learning, and mathematics as a natural part of investigating science phenomena. In fact, science facilitates the use of many basic skills. Even though our investigation will focus on students' learning of mathematics and science, it is also inevitable that other skills, such as literacy and use of information and communication technology (ICT) will be developed through students' work. All these skills will provide a basis for assessment, and will be the subjects of our interventions within the study.

In addition to research-based knowledge in this field, a local reference group, including school leaders and teachers, will be formed to (1) assist in identifying appropriate practical activities, and (2) assess these activities according to locally adapted curricula. The locally linked and research based projects will have a wider impact on teaching practice with the results being transferable and applicable to other areas of the school curriculum.

Inquiry-based teaching linked to cultural heritage

Inquiry-based science teaching has been promoted as a way forward for science education for many years (Rocard et al., 2007; Hoveid & Gray, 2014). Its effects have been mediated by variations in understandings of inquiry, inconsistencies in its application, and incompatibilities between inquiry-based methods and existing curricula and assessment systems (S-TEAM 2012; INSTEM, 2014). The basic principle of inquiry is that the student should be involved in formulating and solving questions regarding observed phenomena, rather than being presented with units of knowledge in which phenomena are already fully described.

Inquiry-based teaching therefore promotes understanding of scientific processes and concepts (Keys & Bryan, 2001; Crawford, 2007). It includes elements of practical work, problem solving, critical thinking and student autonomy, and is thus capable of building a wide range of student skills, as mentioned above. With regard to mathematics, Skovsmose describes a paradigm, characterised by providing *landscapes of investigation,* that provides an investigative approach, supporting the learning and application of mathematics in action rather than dealing with prescriptions (Skovsmose, 2001).

The Norwegian PISA+ study (Ødegaard & Arnesen, 2009), however, reported few observations of science lessons that included inquiry elements, whilst other recent reports (Technopolis-Fraunhofer, 2012; INSTEM, 2014; McKie, 2014) have indicated that adoption of inquiry on a wide scale is problematic, and represents an ideal situation, rather than the reality of science lessons, in most countries. We suggest that this is not because of inherent problems with the concept of inquiry, but because implementing inquiry requires careful consideration of its cultural context in order to build on the pre-existing attitudes, beliefs and conceptions of students. When this dimension is added to the elements of student cooperation, critical thinking and autonomous working, already present in many indigenous cultures, there should be a major increase in student engagement. In other words, inquiry is being enhanced by culturally-responsive teaching and learning, rather than the other way around.

Furthermore, inquiry constitutes a learning method based on open narratives rather than on closed, conceptual schemas. This means that inquiry is more compatible with culturally formed identities, and the narratives that make up those identities, than the supposedly neutral formulations of conventional science texts. In carrying out project activities, students enact narratives of discovery, but within an overall environment in which scientific knowledge is available and in which there are opportunities to access it. Because this has parallels to their own experience, these narratives resonate with the students and provide motivation.

Our objective is therefore to help teachers support their students in culturally relevant, inquiry-based activities in science that facilitate their understanding of scientific facts and the nature of science, and which also promote mathematical and other skills. Findings in several areas are important here. Increasing the amount of practical work in science education (Anderson, 2007; Jenkins, 1999), is intended to provide students with insight into the process dimension of science (KUF, 2006), and because it enriches student learning about scientific phenomena and systems (Scott, Asoko & Leach, 2007). Wiske (1998) points out the importance of having progression in activities in order to obtain deep understanding. Students start with "messing about" activities, followed up by with "guided inquiry", and then ending with "culminating performance", where students work autonomously and demonstrate their understanding.

Berland and Reiser (2008) identify three goals of engaging in scientific practices: (1) sensemaking, (2) articulating, and (3) persuading. However, they found that persuading others of an understanding in science requires social interactions that are often inhibited by traditional classroom environments, but are promoted by inquiry.

Bybee et al. (2006) incorporates five stages in a learning cycle: Engagement, Exploration, Explanation, Elaboration and Evaluation. Our student projects will be evolved according to these five stages. The project *Budding Science and Literacy* (Ødegaard, 2010) links inquiry-based science and literacy in order to improve teaching and learning in science. Multi-modal teaching activities (do it; talk it; read it; write it), and systematically switching between first-hand and second-hand investigations (Palinscar and Magnusson, 2001), create synergies between science and literacy (Pearson et al., 2010).

Letting literacy play a role in scaffolding and structuring inquiry activities (Knain, Bjønness and Kolstø, 2011; Ødegaard, 2011), energises and directs students and teachers in the inquiry process. By making inquiry a common theme for students, and by helping teachers situate science, mathematics and literacy, students are provided with profound tools for learning and managing future challenges. The LOCUMS project will therefore adopt and adhere to these principles.

Approaches, hypotheses and choice of method

We will be informed by international and national studies, whilst further developing the notion of culturally responsive science and math education. We will design learning resources in parallel with a teaching model that links local culture to science and math education. We will also develop theory linked to this approach. The study will therefore address the following overall research question:

How can the engagement and achievement of locally defined minority students in science and mathematics education be better supported?

We will answer this research question through the analysis of data from our partner schools, where the following sub-questions will be addressed:

1. What are the learning needs of locally-defined minority students, based on their cultural identity, local knowledge and prior abilities?

2. What kinds of culturally responsive teaching and learning **activities** increase the engagement of these students in science and maths education?
3. Which **aspects of culturally based knowledge** and understanding can enrich science and maths teaching?
4. How do we **assess** culturally responsive science and maths learning?
5. What kind of teacher professional development activities are needed to support culturally responsive science and maths activities?

Research design

A design-based research methodology will be utilised in this project. Within the design- based research methodology, a wide range of "interconnected interpretive practices" (Denzin & Lincoln, 2000, p.3) will be utilized, with the goal of developing robust theory about culturally responsive science and mathematics education. In accordance with Cobb (2001) *cases* with student projects will be developed and trialled in lower secondary schools in Finnmark and in Oslo. The projects will be designed by teachers from the participating schools, in cooperation with the research group, to ensure a common approach.

We will use an iterative design cycle to develop this teaching model and to better embody the localised elements of science lessons. Most student projects will be developed by the research group, in cooperation with teachers in the participating schools, with one project being developed in Finnmark and one in Oslo. All the student projects will start with a local artefact or craft related activity, and inspired by these, students will be challenged to develop knowledge from the available local resources. A typical student project will last for one week, during which most of the available teaching time will be dedicated to the project. The topic in all cases will be the link between nature and natural resources, and the related effort to make a living in the area. We will focus mainly on math and science in our study, whilst recognising that many school subjects can benefit from the overall principles and specific student project activities.

The design of student projects will be inspired by the latest work from our advisory researchers (see for example Aikenhead 2010), as well as from previous work undertaken by the members of the research group, for example the research on teaching and learning within technology by Lysne and colleagues (see Lysne, Nykvist & Lloyd 2009; Lysne 2011; Hoveid & Hoveid 2013; O'Donoghue, Shava & Zazu, 2013; Ødegård 2011, Fyhn 2014, Fyhn & al in press). Likewise, Chronaki (2008) and Nykvist (2008) have worked extensively with online communities and authentic student collaboration. In this project, their function will be to assist in designing professional development courses for teachers, based on our results and their experiences in the same field. Starting points for student projects might be patterns, constructions or shapes found in traditional handcrafts or in activities related to local cultures or communities. Based on this, students will engage in practical projects and will be challenged to describe these artefacts, activities and/or processes, using their everyday language and concepts. Examples of these might include activities connected to traditional and modern Sami handcraft or food traditions related to Norwegian immigrant cultures.

The next step will be to develop a scientific understanding of the chosen artefacts or activities, in the local context, and combine this understanding with mastery of more advanced language and concepts related to science and mathematics, enabling generalisation of the principles and processes at work. Whilst this will be done in an inquiry-based way, the students will be given sufficient scaffolding to ensure that they move beyond so-called 'folk understandings' of science, or common misconceptions.

The participating schools will be chosen in collaboration with school owners. The Arctic University of Norway has binding agreements with a number of school owners in the region (RSK vest and RSK mid Finnmark) and NTNU with Trondheim municipality. These agreements cover student teacher practice, as part of their education, and R&D cooperation on projects.

The research methodology will be based on experiences from two earlier research projects, one at Finnmark University College (*Technology and design makes the future in Northern Norway*) (see

Byrkjeflot *et al*, 2010) and one at NCSE (*Budding Science and Literacy)* (Ødegaard, 2011). In order to collect rich and meaningful data, the project will combine different sources of data, including observation and video of classrooms, and interviews with students, teachers, student teachers and school leaders. When students explore local nature and society outside the school, selected student groups will carry head-mounted video cameras in order to gather data. In previous projects on technology, for example, the research group video filmed teaching in the classroom over three days for each student project. At each session, both selected student groups and the whole classroom were filmed. Interviews with students and teachers were also filmed.
The videos will be transcribed and categorised based on criteria developed from our theoretical framework. This method will cause only minor disruption to the teaching situation at school and, in previous projects, has proven to be a cost effective way to collect large amounts of solid research data. Research staff will do the filming and observe the teaching, but they will not intervene in teaching activities. In addition to these films, student communication about projects with international partners on social platforms, and their video blogs, will be included in the research data.

Data Collection

The aim is that this data will illustrate:

- student communication, their use of concepts and everyday language within the activities
- student-teacher communication
- levels of activity, including interaction between students
- input from persons other than teachers and students
- development of students' language, use of concepts and understanding following these activities

The data will be analysed using e.g. Transana software and phenomenological analyses of the transcriptions texts (Moustakas 1994) followed by open coding as described by Strauss and Corbin (1998) in order to categorise the data. These categories will be quality assured through research triangulation (Robson 2002).

3. Project management, organisation and cooperation

During the first six months of the project, members of the research group will plan five to six student projects in cooperation with teachers in participating schools. These projects will be repeated in an iterative cycle design, with an average of three trials, in order to develop each project over the project period. This will result in a total of fifteen to eighteen student projects across Norway.
The data collection period will be from January 2016 till December 2017. Data analyses will start during the third quarter of 2016 and will run throughout the project period. Scientific publications, and publications for our target audiences of teachers, school owners, parents and other stakeholders, will be produced in parallel with the analyses, as results emerge, in order to provide feedback into the research and design processes.
The major tasks that need to be developed during the project are:

- To develop and facilitate the student projects and data collection;
- Develop knowledge on culturally responsive teaching and learning;
- Explore comparable research data together with our international research partners
- School based professional development for teachers

There will be three workshops, where the advisory researchers will be invited to Norway, funded by the project. The aim of the first workshop will be to discuss research methods and to set up the details of the research schedule, including its relationship to similar student projects run by the members of the research group. During the first workshop, the research questions will be finalised and the research plan and related methods will be discussed in detail, in order for the partners to come to a common understanding of all aspects of the project. This process will draw on the extensive experience and expertise of the advisory board.

The second workshop will discuss data analyses and collaboration on scientific publications where student projects from different parts of the world will be compared. The final workshop will discuss conclusions and further progress in the area in light of the knowledge developed in the project.

The project is run by the Norwegian University of Science and Technology (NTNU), and collaborating institutions in the project will be the University of Oslo and the Arctic University of Norway, at the national level, and Queensland University of Technology (QUT), Department of Early Childhood Education, University of Thessaly, Volos, Greece, and Environmental Learning Research Centre (ELRC), Rhodes University, South Africa at the international level.

Research group

Project leader: Associate Professor Per-Odd Eggen The Norwegian University of Science and Technology, (NTNU)

Professor Marianne Ødegård, ILS, University of Oslo, (UiO)

Associate Professor in Biology and Natural Science Didactics, Dag Atle Lysne, Programme for teacher education, The Norwegian University of Science and Technology (NTNU);

Associate Professor Halvor Hoveid Programme for teacher education, The Norwegian University of Science and Technology (NTNU);

Senior Lecturer Shaun Nykvist, Queensland University of Technology (QUT);

Professor Rob O'Donoghue, Environmental Learning Research Centre (ELRC) Rhodes University, South Africa;

Professor Anna Chronaki at Department of Early Childhood Education, University of Thessaly, Volos, Greece;

Associate Professor Anne Birgitte Fyhn, the Arctic University of Norway (UiT).

Advisory researchers

Professor Emeritus Glen Aikenhead, Aboriginal Education Research Centre, College of Education, University of Saskatchewan;

Professor Rene Dubay, Salish Kootenai College, University of Montana

Their tasks will be to participate in the scientific part of the project, including data gathering, data analysis and subsequent discussion and publication. The advisory researchers will also be invited to the three scheduled workshops in order to discuss progress in the project and the links to projects run by the members of the research group. Finally, they will be involved in the teacher professional development aspect of the project.

Local reference group

Local reference groups will include school leaders and other members of the local community, such as parents. Their tasks will be to bring in information on local culture and current community issues, to participate in the development of student projects in lower secondary school and to inform the local community about the project and its results. The local reference groups will meet with the research group at the start of the project and then once each semester during the project period.

PhD and Post.Doc.

The project will include one Post Doc position (two years) located at the University of Oslo and one PhD student at NTNU. The PhD will apply for the NTNU/PLU PhD program on professional research with a focus on teacher training and schools. The main supervisor will be at NTNU, with a co-supervisor at UiT. The post doc and the research team will cooperate closely with the PhD candidate.

Budget

See grant application

4. Key perspectives and compliance with strategic documents

This project is a continuation of the work of the research project *Technology and design makes the future in Northern Norway*, financed by The Research Council of Norway (2008 – 2012). LOCUMS will build the necessary research base, and related national and international networks, in order to improve research in natural science and mathematics didactics in and beyond the partner institutions, with a specific focus on culturally responsive science and mathematics education. Teacher education is one of NTNU's top priorities in professional education, and the focus on natural science and math didactics links the project to NTNUs main profile.

At the national level the project is well rooted in the plan *Science for the Future: Strategy for strengthening Mathematics, Science and Technology (MST)* 2010-2014; especially through its focus on student motivation and the importance of concretizing key concepts in order to provide students with the possibility of scientific understanding in their own cultural contexts.

White Paper no 22 (Ministry of Education, 2011) focuses on the need for an increase in student motivation at lower secondary level. It is argued that schools need to recognise the value of practical work, both in order to make teaching practices more varied, but also to concretise the teaching of abstract concepts and to value practical knowledge as equal to academic knowledge. The project will meet these challenges by developing new teaching practices and models, and by developing new theory within the research area.

Relevance and benefit to society

Studying culturally responsive science education fulfils four purposes. First, and most important, it will increase our knowledge about how teaching can be 'localised', or fitted to cultural contexts, in order to accommodate diverse student identities. Secondly, and more broadly, it will make science and mathematics more relevant through the use of local perspectives within a global society. Thirdly, there will be benefits for students, who will become more responsible and environmentally aware citizens, with an aptitude for lifelong learning. Fourthly, communities will become more cohesive and sustainable, through better educational engagement.

Environmental impact

The implementation of this R&D project and/or the utilisation of project results will provide significant positive environmental impacts, through better awareness and sensitivity.

Ethical perspectives

All data collection, storage and accountability of data will be carried out as required by good research ethics practice and approved by the Norwegian Data Protection Authority. The project will be based on mutual collaboration in developing knowledge, with the ambition of benefitting all involved parties; students; teachers; local schools, researchers and national authorities. Communication with student's parents will be prioritised before commencing research activities in schools, in order to ensure acceptance and to avoid tensions related to e.g. religious beliefs or established cultural issues/practices/traditions. However, students' own voices and rights will be the main driver from an ethical perspective. The ethical process will be an integral part of the research process and informed consent will be obtained through dialogue to supplement the usual method of signing a form, in order for the participants to gain an understanding of research methods in general, and this project in particular.

Gender issues (Recruitment of women, gender balance and gender perspectives)

The gender balance of the research team is approximately 50/50. Recruitment policies will reflect the need to maintain gender balance. The research itself will be sensitive to local gender sensitivities, bearing in mind research findings regarding the different interests of boys and girls.

5. Dissemination and communication of results

Dissemination plan

Teachers and school leaders not involved in the project will have the opportunity to discuss the results at regional and national conferences where they are the target groups. Examples at the regional level are: the yearly research days, conference for teachers (Læringsdagene) and every second year (IKT-konferansen). On the national level, examples are the Naturfagkonferansen and Realfagkonferansen at NTNU.

Furthermore, student projects will be published at the web site naturfag,no, which is frequently used by teachers.Researchers will publish results in popular science journals which are read by teachers and school leaders, for example Naturfag and Bedre Skole. A project web site, with links to wikis with student projects and a project blog, will make it easier for teachers and school leaders, as well as researchers, to follow the development of the project and its results. Project information and video from student projects and teaching demonstrations will be distributed via social media, subject to the necessary ethical permissions being obtained.

There will be an international network with members of the research group and the reference group. Within the project period the members will meet at three workshops where the project's progress and results will be discussed. The members of the research group will present the results of the project on national and international scientific conferences from early 2017 and throughout the project period. Examples of conferences that will be considered are;- at the national level; *FOU i Praksis* ((R&D in Practice) - Trondheim- at the international level; NFSUN 2011 - *Nordisk forskersymposium om undervisning i naturvitenskap* (Nordic symposium on teaching natural science) and ESERA (European Science Education Research Association).

During the same period scientific publications will be a major focus for the research group. The goal is that each member of the research group will be first author at at least two articles in national and international scientific journals, based on the results of the project. An important part of the dissemination plan will be the incorporation of project results in teacher training, school development and school leadership programs at PLU and elsewhere, in cooperation with school owners at county and municipality level. We will also use student teacher R & D projects, and masters' theses, at PLU and elsewhere, to further exploit the project findings. Finally, we will link our findings to the ProTed project, which is a centre for Excellent Teacher Education, a collaboration between the University of Oslo and the University of Tromsø[2].

Communication with users

Close collaboration and communication between researchers, teachers and school leaders is necessary throughout the project period. During the development phase, the trials and the evaluation phase, the teachers will participate in the evolution of the student projects. During the period of data analyses and publication, teachers and school leaders will be invited to (at least) two one-day seminars to discuss the project results and their consequences for school practice.

School leaders involved in the project will also have the opportunity to discuss student projects, results and the consequences for school practice in the meetings of the local reference group.

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[2] see: www.uv.uio.no/proted

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