AIM
The aim of this inquiry is to review and evaluate the process of systemic innovation involved in policies and practices designed to promote science and technology education in one school district in Iceland. It aims at understanding how the process works, and which factors, including local management and financing, influenced its development. A definition of innovation suggested by the OECD is used (OECD, 2007).

Innovation is any kind of change that is introduced with the aim of improving the operation of educational systems, their performance, the perceived satisfaction of the main stakeholders, or all of them at the same time.

We look for connections between research evidence and innovation, whether innovation is driven from the centre, the openness to bottom-up innovation, the channels for development and the roles of stakeholders, time scales and monitoring and evaluation (OECD, 2007). In a related study we evaluate the process of systemic innovation involved in policies and practices designed to promote science and technology education in Iceland (paper submitted to NARST 2009). We will also use the concept of the Zone of Feasible Implementation developed by Rogan and Grayson (2007) and the self-evaluation of the actual and preferred delivery of science in schools, using the Science Curriculum Implementation Questionnaire SCIQ (Lewthwaite 2006). The ZFI draws on theories of school development, on Vygotsky’s concepts of the zone of proximal development and the importance of social interaction for development, and on the zone of tolerance i.e. the space given to institutions by communities in the change process.

PROCEDURE
Both authors have been involved in a research project Intentions and Reality since 2005 on the status of science and technology education in compulsory and secondary schools. The findings build on an analysis of interviews with teachers and administrators, students, curriculum writers and other stakeholders, for example, producers of curriculum materials.

In the research project researchers collected data from schools in five districts in Iceland 2006-2007 visiting four to five schools in each district. Data are collected on science provision from documents, questionnaires, on-site visits, interviews with principals, teachers, pupils and district leaders. The capacity of the schools with regard to science teaching was assessed by using the SCIQ (Lewthwaite 2006; Authors, 2007). The questionnaire calls for the evaluation by teachers of the actual and preferred capacity of their own school in implementing the science curriculum. Four extrinsic factors (resource adequacy, time, professional support, and school ethos and the status of science as a school subject) and one intrinsic factor (Skills, knowledge and professional attitudes) are assessed. In Lewthwaite’s approach, the SCIQ results can form the basis of discussion and further development within schools (Wood & Lewthwaite, 2007); (McMillan, Lewthwaite, & Hainnu, 2007).

The SCIQ results showed that there was a clear capacity gap between actual and preferred situations. According to the teachers, the biggest gaps were in the area of resources and of the knowledge, skills and attitude of teachers. An analysis of the interviews and questionnaire data provided some ideas on activities which might change some of the constraints on science in these schools. To further analyse these constraints in one of those areas we developed two approaches.
First, we focused on teacher motivation and identity in science teaching and analysed the extent to which collective and individual interests of science teachers are met in schools. To do so we used Roth`s proposition (2007) that motivation in the workplace is only high when one realizes both individual and collective interests in the same action. Based on Roth`s ideas, Macdonald (2008) designed a two dimension framework to map teacher motivation and identity.

Further, with teacher response to challenging situations in mind the theory of curriculum implementation (Rogan and Grayson, 2003; Rogan, 2007) was used to discuss with teachers how much curriculum change is appropriate in a given context. The theory was introduced to and discussed with two focus groups of science teachers. It is based on three major constructs: A. Profile of implementation (in the classroom), B. Capacity to support innovation and C. Support from outside agencies. For each construct it is possible to create a matrix (rubric) of relevant factors and the levels of development schools have reached in working towards the long-term goal of implementing the national curriculum. Schools can find themselves positioned at different levels on different factors, both within and between constructs. The rubrics were adapted to cover the Icelandic national curriculum guidelines, the capacity of those who participate in the school system and support from outside agencies. Here we use Rogan and Grayson`s idea of identifying the “zone of feasible innovation” for planning development, which suggests that innovation should not exceed current practice by too large a gap between existing practice and the demands of the innovation.

Rogan and Grayson (2003) defined six propositions with regard to the theory of curriculum implementation. These are:

- Innovation should be just ahead of existing practice. Implementation should occur in manageable steps
- Capacity to support innovation should be concurrent with efforts to enrich the profile of implementation.
- Outside support should be informed by the other two constructs, matching outside support with capacity, and capacity with desired implementation
- All role players need to reconceptualise the intended changes in their own terms and context.
- Changing teaching and learning is a change of culture not a technical matter.
- There should be alignment between the three constructs and the primary level (e.g. the learning experience).

**CONTEMPORARY OVERVIEW**

*The municipality of Gardabær*

Gardabær is a town about 10 minutes drive from Reykjavik, the capital city of Iceland. The total population of Gardabær is around 10,000 residents and it is more homogeneous than in many communities in the southwest of the country where most of Iceland’s population is located. The income per capita in Gardabær is higher than average, relatively little welfare accommodation is provided and there are few immigrants. At the town the centreright conservative party has dominated local politics. Local leaders state on the town website that a high level of services for residents is provided and in the school policy an

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**Figur 1. Mean teacher assessment of the actual situation within schools.**
emphasis is put on progressive education including taking steps to have well educated, interested and skilled teachers (Skólastefna Garðabæjar 2006-2009). Icelandic children must attend school between the ages of 6 and 16 years old (grades 1–10). There are four public schools in Gardabær; Hofsstadaskóli (grade 1-7), Flataskóli (grade 1–7), Sjálandsskóli (grade 1-9) and Gardaskóli (grades 8–10). There are also three privately operated schools; the Hjalli Method Primary School (grades 1–4) and two small international school (taught in English).

FINDINGS

Local innovation
Since the decentralisation of schools in Iceland in 1996 the educational authority in Gardabær has tried several approaches to innovation in order to strengthen science education in their schools.

For the past 10 years they have sought ideas and support far and wide to strengthen science teaching in the public schools. For example, a private company in the municipality has provided money to buy expensive equipment for science teaching in all the public schools; innovation in organising physics teaching material (tool kit boxes) was carried forward; teaching advisers were hired to support teaching in IT, Icelandic language and science; courses in science from specialist science teachers from University of Education have been provided for the teachers and they have willingly participated in large scale research projects.

The teachers, school administrators and educational authorities have consistently followed the national curriculum, and elaborated their educational policy and school curriculums in accordance with the law. They have collected information about how they are doing, and, based on information from external and internal evaluation, scores in national exams and a determined will to provide high quality education, the local educational authority has worked at improving science and information technology education within their district. In general it can be stated that the role of the local educational authority has been a kind of catalyst or broker, where they did many different things hoping it would motivate changes and strengthen science teaching. The teaching advisor in science functioned as a broker between local authorities and teachers, and between the privat company and teachers. However,
these actions have been more top-down than bottom-up. We wondered why the district had not done better and experienced more systemic and persistent changes in science education despite support for innovation.

**Research on practices in Gardabær**

In 2006-2007 the three elementary schools in Gardabær participated in a research project called *Intentions and Reality*. The answers of science teachers to the SCIQ questionnaire indicate a clear gap between actual and preferred situation (Figure 1) similar to other districts that were researched. The biggest gap was in the area of *Skills, knowledge and professional attitude* of the teachers but this was the second biggest gap in other areas, where the area of *Resources* showed the biggest gap. The three Gardabær schools are different in how they organise science teaching and this among other things affects how the teachers perceive their situation.

A first analysis of the interviews with teachers and the questionnaire data provide ideas on activities which might change some of the constraints on science in these schools. The results indicate that teacher motivation is an important factor in teacher capacity to deliver the science curriculum. Thus, using Roth’s (2007) idea on motivation and Macdonald’s (2008) graphical representation teacher motivation and identity were evaluated according to what extent the teacher meets the needs of the school (collective interest) and to the extent to which she meets her own needs (individual interest). Competent teachers in Gardabær show high motivation and strong identity but coerced teachers show low motivation and weak identity. We then discussed the Zone of Feasible Innovation with nineteen science teachers in two focus groups (not from Gardabær). We felt that the theory of the ZFI is an useful idea to evaluate the levels of implementation and identify developmental aspirations and potential contributors and constraints to implementing the national science curriculum. These teachers felt that the ZFI was practical to map the landscape and plausible, but that external help could be useful in developing the indicators.

We then developed indicators for use with the Gardabær data and found, for example, that the science teachers in the three schools in Gardabær could be positioned mostly at the first and second level within the construct *B Capacity to support innovation* (Figure 4). According to the ZFI the next feasible step would be to aim for third level but not the fourth, to not overreach existing capacity. By this, the changes would be manageable and be of more immediate value in the teaching situation. Also, it is important to remember that the theory suggests that a school should try to keep in step across all factors. We concluded that the input of teaching resources may have been out of step with provision of many other factors in Gardabær. The professional development of teachers however lagged behind this activity.

In spite of all actions undertaken by the local educational authorities in Gardabær there was still a considerable gap in the perception of teacher skills, knowledge and professional attitudes. The gap in the area of resources is smaller than in other districts but still in place supporting the notion about teachers having traditional idea of what is science. And how can that be explained? According
to our results the approach to changes has not had systemic effects, since the factors that influence science teaching development and what kind of change could be appropriate to undertake were under-estimated. Teacher skills, knowledge and professional attitudes in science teaching need more attention and further innovation needs to address the capacity of all stakeholders to support that innovation and to be driven more bottom-up.

REFERENCES