Changing constraints on science teaching activity in Icelandic schools

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Abstract

This paper considers the constraints which are to be found on science teaching activity in Iceland. The empirical base is questionnaire and interview data from teachers working in schools in three different communities in Iceland in fall 2006. The data were collected through an electronic survey on actual and preferred situations of science teaching, which builds on a survey developed by Lewthwaite (2005) in which it is proposed that four extrinsic and one intrinsic factor affect the delivery of science. The survey data is complemented by on-site interviews with teachers, principals and pupils on the science curriculum and conditions for teaching science in their schools and data about schools collected during the field visits. Initial findings from these data have been summarised for participating schools and communities in the form of short reports during 2006-2007.

The theoretical base applies cultural-historical activity theory (Engeström, 1987) and sociological theories of Bernstein (2000) to an analysis of Lewthwaite’s factors in order to identify the way in which constraints change or can be changed. Constraints can be conceived of as the difference between an ideal type of rule or division of labour, for example, and the situation in praxis. We suggest that constraints on changes in science delivery are a web of interacting factors. Changing one constraint may introduce another constraint somewhere else in the system though it is only by addressing the constraints that the system can develop.

Aim

This paper reports on one study in a larger science education research and development project1 currently being carried out in Iceland. The focus in this study is on science delivery in schools in three communities in Iceland. The data is drawn from interviews taken during school visits, fieldnotes from visits to schools and a survey on factors identified by Lewthwaite (2005) as those affecting science delivery. The survey questions call for an evaluation by teachers of the capacity of their school to meet requirements for science teaching.

In this paper the factors identified by Lewthwaite are analysed further using activity theory as described by Engeström (1987) and others (see Engeström, Miettinen & Punamäki, 1999) as well as pedagogic discourse as described by Bernstein (2000). These theories are used as a theoretical base to interpret perceived constraints on the teaching of science and the relationship between them and to consider gaps between actual and preferred situations.

The title of this paper is deliberately ambiguous in its meaning. One interpretation points towards a dynamic perspective where theory suggests that the activity system of science teaching is in a state of flux and the components unstable and interactive. The other meaning points towards a linear or directive perspective where agents work towards identifying constraints and then changing them.

1 The Intentions and reality project on science and technology education is being carried out by a team of researchers from the Iceland University of Education and is funded by the national Research Fund in Iceland from 2005-2007.
Background and framework

The starting point for the Icelandic project was the national curriculum from 1999. We were interested in finding out the extent to which the intentions expressed in the curriculum are aligned with realities in schools. A national curriculum does not just appear. It has a history and is the consequence of deliberation and compromise, sometimes over a period of many years or even decades (Reid, 1995, Macdonald, Hjartarson & Jóhannsdóttir, 2005). Bernstein (2000) proposes that the curriculum develops from the dominant principles of society. Nor is the curriculum simply implemented – different forces interact in the pedagogical space in schools and classrooms, such as materials, salaries, teacher education and pupil experience.

The Icelandic national science curriculum from 1989 was short and non-directive. It was extensively revised and essentially rewritten from 1996 to 1999 (Ministry, 1999). Schools were given until 2002 to modify their science programmes. The schools in this study were visited in late 2006. The 1999 curriculum was designed in such a way that assessable aims were set for the end of 4th, 7th and 10th grade in three general areas: the nature and function of science, science content, and skills and methods in science. Detailed learning objectives were then provided for each grade level in three content areas: physics and chemistry, biology and earth science. Teachers interpret the curriculum as being content-led, and this has led to tensions as teachers in some local communities have been encouraged to work towards individualised learning plans for students (Macdonald & Jóhannsdóttir, 2006). Most of the centrally produced textbooks being used in the schools under study are strongly aligned with the approach and content of the national curriculum.

Curriculum planners delocate ‘science’ from its social and economic settings and relocate it as ‘text’ in a national curriculum (Morais, Neves & Fontinhas, 1999). This curriculum is itself then recontextualised (delocated) by curriculum writers as teaching and learning materials which are in turn relocated by teachers for use in teaching and learning in schools. The recontextualisation as a school subject defines the content and form of the ‘pedagogic discourse’ which is constituted by the regulative and instructional discourse (Bernstein, 2000, Macdonald & Jóhannsdóttir, 2006). The instructional discourse is defined by the selection of material, sequencing, pacing and criteria of knowledge, while the regulative discourse is defined by conduct, character, manner and criteria of knowledge (Bernstein, 2000).

In order to describe the system within which teachers themselves work we introduce activity theory which originated from Vygotsky’s idea that tools ‘mediate’ tasks, i.e. a subject uses a tool on an object to perform a task, and in doing so, changes the task (Figure 1) (Engeström, 1987). A teacher works with a class, using a variety of tools, but as they are used the nature of the task and the subject changes in a dialectical relationship.

![Subject-tool-object triad of activity theory](image-url)
Suppose the task or activity is to develop an understanding of density. Different approaches, or tools, might be used to carry out the task. The task itself and succeeding tasks will vary if the topic is approached by looking up densities of materials, by practical work in which volumes and masses of several substances are measured or by a computer simulation in which different levels of support might be offered. Students acquire different knowledge and skills according to the tool and their approach to a new object will vary accordingly. The components of this triad give us an indication of what Bernstein (2000) calls the instructional discourse, i.e. the selection, sequencing and pacing of material and the criteria of knowledge being applied.

Engeström (1987) and others (see Engeström, Miettinen & Punamäki, 1999) have developed cultural historical activity theory in which the subject-tool-object components (Figure 1) are mediated by the cultural and historical setting. Three components are suggested by the theory, including the rules guiding the activity, the community in which it is being carried out and the division of labour being used (Figure 2). We have argued elsewhere (Macdonald & Jóhannsdóttir, 2006) that the contextual components rules-community-division of labour are akin to the regulative discourse proposed by Bernstein (2000) and discussed above. This discourse is one in which the rules of social order are transmitted, which both shapes and is shaped by conduct, character, manner and criteria of knowledge, as indicated above.

What is also important is that Bernstein proposes that the instructional discourse is embedded in the regulative discourse thus no changes can be made to the former if they are at odds with the latter. For example, in a school setting where teachers are subject specialists, it may be difficult to introduce integrated projects across subject lines. Similarly early childhood teachers may find it difficult to teach individual subjects when much of their training has looked at the development of the child. Applying these to the components of an activity system, this proposition would imply that only changes to the upper triad subject-tool-object which are in keeping with the lower triad will be successful.

Consider an example from Australia. Chien and Wallace (2004) used the values of selection, sequencing, pacing and criteria of knowledge in their analysis of the teaching of two science units in a middle school class, i.e. in an analysis of instructional discourse. They found that the principal influenced teachers in a choice of instructional strategies (discourses) that were discipline-based, though teachers were inclined towards more student autonomy and choice. Parents influenced the extent to which transdisciplinary approaches could be used. The unit in which an integrated approach was adopted needed some aspects of a disciplinary approach to ensure acceptance in a culture in which traditional subjects were highly valued. In the integrated unit students were given greater control over selection, sequencing and pacing and some students became more confident.

In the Icelandic research being reported here we consider the activity systems of science delivery in schools and look for the ways in which components of the systems act as constraints or contributors to science delivery. We have suggested an alignment of components of an activity system with relationships between the instructional and regulative discourse (Macdonald & Jóhannsdóttir, 2006). The task of science teaching (instructional discourse) is thus reflected in the subject-tool-object triad where teachers (subjects) use a variety of methods (tools) with students (objects) to achieve a learning ‘outcome’. The task is mediated by aspects of the regulative discourse, i.e. the rules, community and division of labour within which the learning and teaching is to occur.
The core of activity theory is the dialectical relationship between individual and collective activity (Engeström, 1987) and the contradictions that are present within any system. None of the components of an activity system are isolated or stable. Contradictions generally exist within and between components of the activity system and it is only through the resolutions of these contradictions that the system is able to develop. Primary contradictions are found in the conflicts between the use value and the exchange value within each corner (Engeström, 1987, p. 33) and recent work by Pasenen, Toiviainen, Niemela and Engeström (2005) says that we can interpret the primary contradiction as being between an ‘ideal type’ and reality in praxis. This would mean, for example, that we would have in mind a set of ideal tools, rules or division of labour when considering science delivery but that these are not generally found in praxis in schools. Secondary contradictions are those which appear between the corner components, where rules (for example, the timetable and specialist classrooms) prevent the use of advanced tools (for example, easy access to science apparatus or computers).

Using an empirical approach Lewthwaite (2005) identified four extrinsic factors and one intrinsic factor in his analysis of constraints and contributors in the implementation of the science curriculum. We suggest that by exploring these factors and their relationship to the components of science teaching activity and the instructional and regulative discourse, we can explore interactions between the factors identified by Lewthwaite. New forms of activity emerge as constraints or contradictions are identified and addressed, generally as an exception made to the current system (Ilyenkov, in Engeström, 1987, p. 35).

The aim of this paper is thus to consider findings from three different geographical localities in order to identify the ways in which Lewthwaite’s factors interact with one another and constrain or facilitate the science delivery. We choose to call the gap between the actual situation (in praxis) and the preferred situation (the ‘ideal’ type) the capacity gap.

Methods

Participants: Researchers worked with teachers in autumn 2006 in three different communities in Iceland:

- AC, an agricultural community (a central town, one large school, two smaller and one very small schools in rural/outlying areas, grades 1-10, about 540 pupils);
- CC, a coastal community (five small fishing towns, five schools, grades 1-10, about 660 pupils): and
- UC, an urban community (five schools, three participated, grades 1-7, about 850 pupils).
The first two communities, AC and CC, were selected as being representative of those outside the urban south-west of Iceland. The third community UC is representative of a number of smaller urban communities in the south-west. In 1996 the management of schools was decentralised from central government to community level.

**Data:** The data collection was guided by earlier work carried out by Lewthwaite (2005) who developed the Science Curriculum Implementation Questionnaire (SCIQ). This version consists of two 35 item instruments with which teachers assess actual science delivery and preferred science delivery in their own schools. The questionnaires include five sets of seven questions addressing five factors. Four of them are extrinsic: *Resource adequacy, School ethos and the status of science as a subject, Time and Professional support* and one is intrinsic: *Skills, knowledge and professional attitudes.* Each question is answered on a five-point scale: 1= Strongly disagree, 2=Disagree, 3=Neutral, 4= Agree, 5=Strongly agree. Values are calculated for each school, community and factor. The questions on actual science delivery reflect the estimated actual capacity of the school and the preferred delivery as the preferred capacity. The difference between the two measurements is the capacity gap.

The SCIQ was translated into Icelandic using a methodology in which two separate translations are evaluated by a third expert and a final decision made by a fourth. It was pre-tested in three Icelandic schools spring 2006 and modified and is hereafter called ISICQ. All this study draws on data from 75 teachers, 15 in AC, 31 in CC and 29 in UC. Teachers answered the questionnaires on-line, often before schools were visited, and the results processed using SPSS (Statistical Package for the Social Sciences).

The numerical data was analysed using descriptive statistics for combined results from each community. The mean results from the three communities for each factor were presented to schools as radar diagrams (prepared with Excel) showing the capacity gaps, where the actual and preferred situations for each community are plotted. Frequency plots for responses to each individual question within each factor for each community have also been analysed, but are not discussed here.

Interviews with teachers were taken during on-site visits and transcribed. Pairs of researchers also collected information on conditions for science teaching in schools. Interview protocols were developed before the visits in which the views and experiences of teachers on the national curriculum and its implementation at school level were elicited. Interviews were also taken with school principals and older pupils and some lessons were observed. Each pair of researchers prepared reports on individual schools and summary reports were written for each community. This paper does not draw on data from individual teachers or schools, but works with the summaries for each community (Macdonald, 2006, Pálsdóttir, 2006, Thórólfsisson, 2006).

**Capacity of schools to deliver science**

The perceived capacity gaps as measured by the ISCIQ are shown in Figure 3. The difference in the extrinsic factors gaps is most noticeable in the adequacy of resources which is smallest in the UC and largest in the AC. In the other three extrinsic factors, the pattern and gaps are similar. There is not much difference in the perceived gap for the intrinsic factor of skills, knowledge and professional attitudes.

The actual and preferred capacities for each community are shown in Figure 4. Now we turn to the data collected through interviews and onsite visits, starting with resources and time for science delivery..
Figure 3  Capacity gaps for four extrinsic factors and one intrinsic factor (skills, knowledge and attitudes) as measured by ISCIQ in three Icelandic communities. The minimum value for the gap between current and preferred capacity is zero (0) and the maximum four (4).

**Resource adequacy**: In many schools there appears to be a willingness to build up resources. Many opportunities for learning are to be found outside the school, both with regard to natural features of the landscape and nature and in local companies and organisations. When teachers look for learning opportunities beyond textbooks they seem to do it on an individual basis rather than in accordance with the aims of the schools. Theme-based days are an exception. There are few examples of teachers having designated responsibilities for managing science resources. Few teachers have an overview of what is actually available by way of classroom resources. Science classrooms are not always available for timetabled lessons.

**Time**: The traditional timetable with lessons allocated to particular subjects does not necessarily facilitate practical work, in classrooms and in the field. New opportunities have opened up with team teaching, integrated approaches and a coordinated work-day for teachers. The different subject areas within science do not always receive teaching time proportional to the demands of the curriculum. Time is allocated within schools for coordination within yearclasses and grade levels but not often for development of subject areas unless a particular project is underway. Teachers feel that they need more time for preparing and building up teaching than they are getting now. This is both with regard to cooperation between teachers within schools and in other schools.

**Support for teachers**: Local authorities indicate a willingness to provide support for teachers, but practical measures are harder to find. Teachers may in principle be encouraged to attend courses but in practice they need leave of absence and financial support and few science courses have been on offer in recent years. Some teachers felt that there were financial restraints on providing adequate resources. New facilities have however been built or are being built in many of the schools. There have not been enough short courses in recent years and some are not what teachers are looking for. It is difficult to have an overview of what has been on offer since 1996 when the management of schools was moved to local authorities. Teachers are reluctant to attend courses after hours.

Some companies have tried to provide support for teachers. Some schools have some cooperation with local companies though often at the initiative of the companies rather than the teachers themselves.
Figure 3  Teacher views on actual and preferred capacities for science delivery in schools in three Icelandic communities, as assessed by ISCIQ. The value of each factor is the mean of seven questions on a scale of 1 (strongly disagree) to 5 (strongly agree). The lighter area represents views of teachers on the current capacity and the darker areas the preferred capacity.
School ethos and status of science in the school: Science has received more discussion, attention and even support in recent years, though some teachers still feel that there is a lack of understanding about what good science teaching entails. In particular, the demands of preparing for practical work in lessons, ordering and maintaining apparatus are underestimated.

In recent years the development or revision of the school curriculum, in science and other areas, has not been a priority for school leaders. In cases where a school curriculum is available, the extent to which it is being followed is not always clear.

Students have a wide range of understandings when questioned about science-as-research and technology. Science as a subject is not outstanding in any way, it is seldom the most boring or most interesting subject, nor is it the most difficult or easy. Students are frank and sincere in their views but sometimes appear to lack experience and have few connections with the world of science, innovation and technology.

Physics and chemistry are in more trouble than biology, space science and geology though new textbooks have been published in this area. The teaching of physics and chemistry is particularly dependent on the initiative and interest of individual teachers. Some students say that they have more interest in biology as a subject than other areas of science. Several schools emphasise art, technology and innovation education. This presents opportunities for integration with science but requires the support and vision of school leaders.

Skills, knowledge and professional attitudes: Science as a school subject appears to be vast, both with regard to range and detail. Few teachers have an overview of what is required and fewer have specialist knowledge in more than one area. Few teachers have specialised in science or related areas during their training. Several teachers have a biology background and there are examples of non-traditional technology backgrounds.

Teachers are in general confident about their general teaching skills. Students feel that some of their teachers sometimes don’t know enough and that teachers do not take into account their experiences and interests. There is a uniformity of description when students describe their science learning, such as reading chapters at home, completing written assignments and going over them at school.

Teachers have found the learning objectives in the national curriculum to be a useful bank of ideas. Lessons seem however to be built around activities rather than concepts. There is more integration in early years science than in the middle school or junior high years. Practical work seems to be disappearing from grades 8-10. Practical work is not deemed to be as effective for covering material as other types of lessons.

Changing constraints

Time and adequacy of resources: In the schools under study we found that science is typically taught as part of the standard timetable (one or two 40 minute blocks) which is a rule constraining the delivery of science with its demands for practical work and outside activities. In one school the division of labour among teachers was changed so that children took short intensive courses with groups moving from one course to the next and in so doing seemed reduced some of the time constraints. The use of allocated time in the yearly plan was not as much of a constraint when the division of labour was changed so that some class teachers became specialist teachers of science. This change had come about because of school ethos and the willingness of school leaders to strengthen science within the community. The
regulative discourse was changed with a new division of labour and school time became a tool to create new and interesting arrangements.

**Professional support and school ethos:** The regulative discourse affects and reflects school ethos. Active parent advisory committees and local industry can influence community composition thus challenging or supporting the ethos. The absence of nurturing reciprocal responsibilities among the local community, the school and the teacher and a sometimes unspecified division of labour can act as constraints. Some teachers operate as individuals, maybe even unavoidably in small schools. In one case the contribution of a highly interesting but non-systematic approach of one teacher to science delivery in one school turned quickly into a constraint when the teacher moved between schools in the community, leaving behind dissatisfied and suddenly hard-to-please students and an apparently disorganised storeroom. Resources that had been tools in the hand of one teacher became constraints in the hands of the next. An attempt to change the instructional discourse by the teacher, for example, by encouraging students to do practical work at home was met with resistance. For pupils this went against the rules; the conduct of the new teacher was not appropriate.

Professional support is constrained through rules of union agreements which make it difficult for support to be used within school hours and school leaders have recently emphasised group rather than individual courses. This might require new or flexible approaches to division of labour to free up time for teacher support but solutions have not yet been found.

**Skills, knowledge and professional attitudes of teachers:** The capacity gaps within schools with regard to the intrinsic factor of skills, knowledge and professional attitudes of teachers is very similar indicating perhaps that changes in the extrinsic factors, which are mainly to be felt outside the classroom and are part of the regulative discourse, have not been sufficient in UC to lower the gap. The tools for working in the classroom, for changing the instruction discourse, have not changed much. Teachers are the subject of the teaching activity systems, are multi-voiced, and each has a history within the system. Each has a preferred instructional discourse, but in some cases the regulative discourse may be a strong constraint on the exploitation of an inner strength. For example, conduct or manner could ‘override’ the selection of material for science lessons. Another interpretation could be that intensive support could at first undermine the confidence of teachers indicating the need for addressing several constraints at the same time and looking for interactions between the factors.

**Conclusions**

The relocation of the national curriculum has received systematic attention in some Icelandic schools and communities. The relocation for some into a school or class curriculum varies between schools. Important perceived constraints are external factors such as an inadequacy of resources and a shortage of time. Even if these are addressed the intrinsic factor or issue of skills, knowledge and professional attitudes of teachers can be a complicated issue with several ideal types and will not necessarily respond to changes in other constraints. With professional support some schools find ways of using existing resources, in the broadest sense, in new ways, including rules, the community and the division of labour. Generally teachers still feel that schools do not have a strong school ethos in favour of science. The support of principals and communities in developing school curricula in general and science in particular has been weak in recent years.
References


