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Implementing a multidisciplinary curriculum in a Finnish lower secondary school – The perspective of science and mathematics

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Abstract

Finland has recently reformed the national school curriculum, basing it on so-called 21st century skills. The curriculum prescribes that schools must organise at least one multidisciplinary learning module per year. In this case study, we investigate the implementation of such a module in secondary school (grade 9) from the perspective of the school headmaster and science and mathematics teachers. The data comprise interviews with the headmaster, teachers, and protocols from collegiate meetings. Despite some gains experienced by teachers concerning cooperation with colleagues, the results reveal challenges connected to diffusely defined learning goals, as well as to the vagueness of goals concerning the role of different subjects in the module. The study shows the importance of offering research-based support and time for shared sensemaking for stakeholders to avoid the problems identified when implementing multidisciplinary teaching.

Keywords

Curriculum reform, interdisciplinary learning, multidisciplinary learning, mathematics and science education, Finland

Background

Organisations, educational policy documents and schools in many countries strive to formulate goals in line with the so-called 21st century skills (e.g. McPhail, 2018; Voogt & Roblin, 2012). This is also the case in Finland, where the new national core curriculum describes transversal (generic) competences as a way of meeting future challenges (Finnish National Board of Education [FNBE], 2016). The learning objectives of these competences include the following: thinking and learning to learn; cultural competence, interaction and self-expression; taking care of oneself and managing daily life; multiliteracy; information and communication technology (ICT) competence; working life competence and entrepreneurship; and participation, involvement and building a sustainable future (FNBE, 2016). The objectives of all subjects are interconnected with those of transversal competences, which are claimed to lay the groundwork for an individual's overall development. These objectives will also be evaluated as a part of the subject assessment. Based on their comparison of 21st century frameworks, Voogt and Roblin (2012) show the complexity of applying these competences in practice and recommend interdisciplinary themes to make the connections between the core subjects and competences stronger. Consequently, one of the key ideas in the new Finnish curriculum is obtaining a closer cooperation between different school subjects (FNBE, 2016). This is also considered to enhance competences that will be needed in students' future workplaces. The Finnish curriculum documents do not explicitly state which subjects should interact in a so called multidisciplinary project, leaving it up to the individual schools and teams of teachers to formulate both themes and contributing subjects. However, all subjects in turn must be involved in implementing a multidisciplinary learning module (FNBE, 2016).

While Finnish students' results in science and mathematics have been above average in international evaluations in recent decades, their self-efficacy and attitudes toward these subjects have been negative (Organisation for Economic Co-operation and Development [OECD], 2013). The latest national curriculum can be regarded as a part of the effort to offer meaningful studies for the Finnish students to awaken their interest in studying and learning for the future. As in several other countries' curricula (e.g. Broadhead, 2001; Czerniak, Lumpe, & Haney, 1999; Whitty, Rowe, & Aggleton, 1994), the importance of integration among different subjects has been addressed in the Finnish national curriculum for several decades, but currently, the FNBE (2016) states that all schools must design and provide at least one 'multidisciplinary learning module' per year for all students, focused on studying phenomena or topics that are of special interest to students. Moreover, students are expected to participate in the planning process of these studies, and the phenomena being studied should offer every student the opportunity to work with questions that interest him/her. The ethos of the new core curriculum is grounded in the view that studying will become more inspiring and meaningful if students take an active role in planning their schoolwork, especially in multidisciplinary projects.

The Finnish curriculum can be regarded only as a frame, and local school authorities and teachers are mandated to concretise the goals and contents of the core curriculum (cf. Hemmi, Lepik, & Viholainen, 2013). Finnish teachers are traditionally regarded as highly autonomous professionals 'who are expected to adopt and apply new educational ideas in their own work according to their own judgment' (Pyhältö, Pietarinen, & Soini, 2012, p. 96). However, in Finnish public discussion, there have been doubts concerning teachers' ability and willingness to implement new pedagogical

ideas, such as multidisciplinary themes across different subjects in their classes (Pietarinen, Pyhältö, & Soini, 2017).

The idea of developing and implementing interdisciplinary units at different levels of education has been an international concern in our research field for several decades (e.g. Czerniak et al., 1999; Whitty et al., 1994). Although multiple studies have focused on this issue (e.g. Alexander, Jarman, McClune, & Walsh, 2006; Brand & Triplett, 2011; Broadhead, 2001), there is still little empirical evidence on the determinants facilitating or constraining the successful implementation of such units in different school contexts.

In our research project, we investigate how collective sensemaking concerning the realisation of a multidisciplinary module takes place among different stakeholders. More specifically, we explore how a multidisciplinary module is planned, enacted and experienced by different actors in a Finnish Swedish secondary school[1]. In the context of the overall project we have, during the years 2016-2017, gathered various types of data (interviews with the headmaster and teachers, questionnaires and focus group interviews with the students and protocols from the planning meetings), to shed light on our case from the perspectives of the school headmaster, teachers and students. In this article, we concentrate on the process of sensemaking among the school headmaster and science and mathematics teachers, concerning their interpretations and concretisations of the curriculum reform intentions in their practices. Science and mathematics are especially interesting, as they are traditionally strongly classified as school subjects

[1] There is a Swedish-speaking minority (about 5.3% of the population) in Finland, and they have a right to education at all levels in their mother tongue.

(Bernstein, 2000), and there are indications from earlier research that they are not easily integrated in multidisciplinary modules (e.g. Venville, Rennie & Wallace, 2012).

Our research aims to answer the following two connected questions:

(1) How do the headmaster and science and mathematics teachers conceive and implement a new multidisciplinary module into their practice?
(2) What are the challenges and gains when implementing a multidisciplinary module, especially from the perspective of science and mathematics?

Relevant research and theories

Our study is embedded in the theories of curriculum and curriculum implementation (e.g. Bernstein, 2000; Hemmi & Berg, 2012; McPhail, 2018). We begin by elaborating on the various concepts used by researchers in connection with interdisciplinary working manners, in order to position the target of our case study in relation to these. We continue by reviewing on another important area of research for our study, namely curriculum reform, with a special focus on curriculum integration.

Curriculum integration, multidisciplinary modules and interdisciplinarity

Next, we attempt to bring some clarity to the different concepts used for the working manner where different subjects interact and the characteristics connected to them.

The traditional approach to curriculum design is to allow the individual disciplines, such as physics or mathematics, to provide the structure of the curriculum through the accepted, established knowledge canon of each subject (Scott, 2008). An *integrated curriculum* has no single, accepted definition, except that it tries to break down the strict disciplinary boundaries between subjects, with the often-stated goal of developing a curriculum that better reflects the realities outside the school walls. The

concept of a curriculum integration is broad and vaguely defined, and several different approaches have been suggested and applied (see for example McPhail, 2018). To bring some order to the possible ways different disciplines can interact and be integrated, Davison, Miller and Metheney (1995) have proposed a framework consisting of five models of integration. These five models are; discipline-specific (e.g. integrating chemistry and biology), content-specific (e.g. the use of the concept of scale in mathematics and astronomy), process (using skills like collecting, analysing and reporting data), methodological (using, for instance, the learning cycle model for problem solving in science) and thematic models (choosing a theme, such as the solar system, and teaching other concepts around this theme). According to some authors, the most authentic way to encourage curriculum integration is adopting a project- or problem-based approach, as these methods are congruent with how scientists and engineers work in the real world (Krajcik & Czerniak, 2014).

The concepts of *multidisciplinarity* and *interdisciplinarity* (sometimes *cross-disciplinarity*) are closely related to the idea of curriculum integration. Following the definitions first put forward by the OECD (1972, pp. 25–26), and discussed at length by Chettiparamb (2007), multidisciplinary refers to a juxtaposition of various disciplines, sometimes with no apparent connection (e.g. music, mathematics and history). Interdisciplinary, according to the same authors, is an adjective describing the interaction among different disciplines. This interaction may range from simple communication of ideas to the mutual integration of organising concepts, methodologies, procedures, epistemologies or terminologies. As Heckhausen (1972) noted, the degree of interaction among different disciplines involved in an interdisciplinary exchange can range from the superficial (what Heckhausen calls indiscriminate interdisciplinarity) to deep levels (unifying interdisciplinarity).

The push among curriculum developers toward increased interaction among different disciplines, or toward interdisciplinarity as defined above, has a long history in the field of science education (Czerniak & Johnson, 2014). Although various reform efforts differ in the details, a common thought is that by emphasising interdisciplinary features (of science and mathematics in this case), the curriculum will better reflect the real world, which is integrated by its very nature. Thus, the hope is that by providing students with a more authentic context in which science learning can take place, not only will the students sharpen their critical thinking and problem-solving skills, but there will also be a positive effect on student interest and motivation (Czerniak & Johnson, 2014).

The working manner connected to themes where different subjects interact, no matter what term is used, involves project work and group work in many cases. Project work is seen to facilitate students' independent and active learning, choosing and defining their own problems, self-direction and proactive engagement by the learner. The teacher's role is to be more of a supervisor than a teacher (e.g. Broadhead, 2001). This is also in line with the ethos of the current Finnish national core curriculum that avoids words like *teaching*, while the words *supervise*, *guide*, *support* and *encourage* are commonly used (see Hemmi, Krzywacki, & Partanen, 2017). The Finnish national core curriculum uses the term multidisciplinary in the written curriculum documents (FNBE, 2016), instead of the term interdisciplinary, which is more commonly used in the research literature. We have chosen to use multidisciplinary module when referring to our case as it follows the Finnish national core curriculum. Otherwise, we use the concepts that are used by researchers we refer to or the more general term, interdisciplinary working manner.

Implementing an interdisciplinary curriculum

The interactive and dynamic bottom-up and top-down approaches employed in the Finnish educational policy, should contribute an overall coherence to the curriculum reform among various stakeholders according to the theories of Fullan (1994). Yet, a successful implementation of a reform always entails adaption and applications of the new ideas into new educational practices involving complex *sensemaking* process among those involved. The quality of sensemaking influences teachers' degree of ownership of the new ideas (Ketelaar, Beijaard, Boshuizen, & Den Brok, 2012). A shared interpretation concerning the aim, function, possible outcomes and assessment of the reform, has a potentially positive impact on the success of a curriculum reform (e.g. Pietarinen et al., 2017). It is also important that the teachers understand the need for the change (e.g. Czerniak et al., 1999; Fullan, 2016; Hewson, 2007). Finnish teachers seem to be capable of identifying and analysing what should be changed, but they lack shared and informed assumptions of how change can be brought about (Pyhältö et al., 2012).

The role of the school headmaster is crucial in any change process and his or her active support is important. At the same time, the headmaster can also become an obstacle to change (Fullan, 2016). When the headmaster has a solitary vision of how he or she wants to implement a reform, it can result in failure because the teachers do not experience ownership of the reform. In Finland, the role of the headmaster has traditionally been different from that in many other countries (e.g. Erss, Kalmus, & Autio, 2016). Headmasters are also teachers, and they often teach some lessons each week in parallel to their work as school leaders. Yet, this role is changing, and headmasters now sometimes act as agents for educational administration; thus, they do not always share the same values as teachers (Erss et al., 2016). When implementing a curriculum reform in the school, the headmaster is not only responsible for allocating

the resources, but also for translating the ideas behind the reform to the local school level, adapting the reform and ensuring that it will be carried out (Soini, Pietarinen & Pyhältö, 2016). Soini et al. (2016) point out that the headmaster's view of how the reform should be implemented ought to focus on collective professional learning. The headmaster can develop local aims, based on the big ideas behind the reform, in cooperation with the teachers. A dialogue for reaching a shared understanding of the objectives of the reform and its implementation is important throughout the process (Soini et al., 2016). Pyhältö, Soini and Pietarinen (2011) found that the headmaster's perceptions about the aim of a change in the school were clearer than their perceptions of how the reform should be concretely realised.

Broadhead (2001) investigated the implementation of a new Norwegian curriculum that addressed thematic approaches, ideas of an active and cooperating learner and meaningful learning. Despite the attempts to implement these ideas in the school curriculum over a long period, teachers – especially at the secondary level – continued working within their own subjects rather than making meaningful connections. Broadhead's (2001) study shows that a continuing shared sensemaking that strives to interpret the links between the ideological origins of the reform and reality of the practice is needed. The greatest challenges for the teachers comprise the planning and teaching of 'cross-curricular' topics and finding the resources and equipment to promote active and investigative approaches. Indeed, research has drawn attention to the important roles of the teaching materials and in-service education in fostering the feasibility of reforms (e.g. Ball & Cohen, 1996; Davis & Krajcik, 2005; Hemmi, Krzywacki, & Koljonen, 2017). Further, the teachers in Broadhead's (2001) study also found it challenging to analyse the intentions of the curriculum. Broadhead (2001) concludes that, although making connections across subjects is intellectually

demanding, it can be developmental for those who participate in it. Concerning students' active engagement in planning and participation, Broadhead (2001) advocates the creation of a clearly articulated and theoretically founded rationale exploring 'the perceived relationships between a method of planning the curriculum and a way of delivering that curriculum that engages pupils in certain kind of activities' (p. 34).

The balance between the development of an understanding of a traditional school subjects' central concepts and making connections, has been identified as an important consideration (e.g. McPhail, 2018; Whitty et al., 1994). In Whitty et al.'s (1994) study, science teachers especially experienced that cross-curricular themes polluted their subject or interfered with their pupils' subject learning. Moreover, teachers did not feel confident in dealing with other subjects (Whitty et al., 1994). Secondary school teachers are usually subject teachers, and subject matters dominate their thinking (Lang & Olson, 2000; Mason, 1996; Meier, Cobbs, & Nicol, 1998). Integrating different subjects implies that they, as teachers, must abandon the safety of teaching their subject and engage with subjects that they have not necessarily mastered as well. This sense of a lack of safety is usually deepened when teaching according to an integrated curriculum, which often is something they do not have any previous experience with or models for (Mason, 1996). In a study by Alexander et al. (2006), science teachers expressed positive experiences working with a cross-curricular theme where literacy (English) was integrated into science teaching. The teachers could participate from the standpoint of their subject mastery and had the autonomy to plan learning according to their own judgement and the students' knowledge. The teachers appreciated being treated as professionals rather than technicians. Brand and Triplett (2012) followed elementary school teachers who had received special education in interdisciplinary teaching in their preservice education. The teachers maintained a

positive view of the benefits of interdisciplinary teaching, but contrary to their preferences in their preservice education, they restricted their planning to themes involving only two school subjects, such as science and mathematics. The constraints that the teachers experienced were comparable to those in many other studies connected to the federal and local mandates, such as testing and pacing guides.

Based on earlier research, McPhail (2018) stresses that a thoughtful utilisation of interdisciplinary approaches, where inquiries naturally move across disciplinary boundaries and are supported by an awareness of conceptual progression, could provide a model for future-focused learning modules. Yet, as McPhail (2018) points out, knowing and determining what progressions and cognitive development may look like in varied integrative contexts remains a great challenge, even for experienced teachers. Extra time and assistance are needed to develop evaluative criteria 'to ensure learning moves beyond common sense knowledge to interdisciplinary insights' (McPhail, 2018, p. 71). These as yet unresolved challenges are one of the reasons why Venville et al. (2012) states that curriculum integration still remains a contentious issue.

Methodology

The study context

The Finnish school system consists of nine-year-long compulsory basic comprehensive schooling common for all students, starting at age 7 and ending at age 16. Teachers in grades 1–6 (primary school) have a master's degree in education, while teachers in grades 7–9 (lower secondary school) have a master's degree in a specific school subject. However, it is extremely common for science and mathematics teachers in lower secondary schools to have a minor subject that they also teach. The combination of a major in mathematics and a minor in physics or chemistry is common. A headmaster in

Finland must have a national educational leadership certificate (25 ECTS study points), which includes educational leadership for school development and administrative management (Uljens & Nyman, 2014).

As stated in the core curriculum, all students should be involved in (at least) one multidisciplinary module during the school year. The core curriculum does not specify which subjects, or how many different subjects, should form a multidisciplinary module. Thus, the curriculum leaves this decision up to each school. The core curriculum only states that, during the three-year period of lower-secondary school, students should encounter each subject in at least one multidisciplinary module. In our study, many subjects were included and many teachers involved in the planning and implementation of the module.

The multidisciplinary module in grade 9 (theme: *Energy*) consisted of two 60-minute long sessions each week for a total of seven weeks. In spring 2016, 63 students participated in the multidisciplinary energy module under study. The teachers involved in the module taught mathematics (2), science (3) and humanities (8), and all 13 teachers had five years of teaching experience or more. Before the start of the module, students answered a short, written questionnaire probing their interests and wishes concerning the upcoming module. The activities making up the module were then chosen and developed by the teachers, with the stated aim of focussing on transversal competences and giving students the opportunity to acquire a broader understanding of the meaning and uses of the concept of energy. The activities chosen by the teachers were deliberately diverse. The module began with two lectures by invited speakers on sustainable energy production (solar and wind) that all students attended, followed by study visits to a waste-to-energy plant and a business forum for energy companies. There was also a laboratory session, a visit to a fitness centre, an interview (planned and

executed by the students in English) with a non-Finnish person working in the local energy sector and an activity focussing on the everyday and literary uses of the term energy. Each activity was the responsibility of a subset of two to three teachers. To obtain a passing grade for the module, each group of three students had to pick three activities and write or record a report on these activities for a class e-paper. Each student group also had to select one favourite activity and present it to the other students at the final session of the module.

Methods of data collection and analysis

This case study (e.g. Bassey, 1999) investigates the implementation of a multidisciplinary module in grade 9 in lower secondary school, in line with the change in the national core curriculum (FNBE, 2016). In this article, we especially focus on how the headmaster and mathematics and science teachers experienced and related to the module.

The data collection that this paper is based on consisted of the following:

(1) A recorded, semi-structured interview with the school's headmaster;
(2) Video recordings of three collegial meetings concerning the planning of the multidisciplinary module;
(3) Two (pre and post) recorded, semi-structured focus group interviews carried out with three of the science and mathematics teachers involved in the planning and implementation of the multidisciplinary module; and
(4) Complementary data – written notes and student material.

Interview guides for the interview with the headmaster and focus group interviews with the teachers were developed by the researchers. The themes for the interviews with the teachers and with the headmaster were the background to the multidisciplinary module

and the planning of it, learning goals and assessment, and the implementation of the module. Two semi-structured focus group interviews were conducted with the three science and mathematics teachers. Focus group interviews were used in order to get a wider variety of different views in relation to the topic through the interactions between the teachers interviewed (Gibbs, 1997; Bryman 2001). Two researchers were present at both focus group interviews and the sessions were video/audio recorded and transcribed. A qualitative open approach to the data was used (see e.g. Bryman, 2001). The data were organised and categorised using NVivo as a software tool. The transcribed material was analysed inductively using thematic analysis (Braun & Clarke, 2006). Based on the transcribed interviews and planning sessions of the teachers, keywords were identified via repeated reading of the transcribed material. These keywords were then used to identify important themes in connection to our research questions. Using the themes identified we describe the planning and implementation of the multidisciplinary module from the perspective of the headmaster and the teachers. These perspectives formed then the basis for the analysis of the challenges and the gains (our second research question). The final coding scheme is presented in Table 1.

Insert Table 1 about here.

The analyses of the data were initially conducted by one research group member and checked by the others. Additional and contradictory items emerging from the data were considered. During this process, the categories were iteratively refined in a collective meaning-making process. We had a long-term contact with the object of study, both the topic and the school and general knowledge of the settings that made it easier for us to gather and interpret the data (see for ex Bassey, 1999).

We conceptualize individuals' cognition and talk situated within, and as part of, culturally established ways of talking and thinking and reflecting their experiences and views that can change during interaction with others (see for example Hemmi & Ryve, 2015). Yet, the talk reflect a reality as experienced by the individuals although (e.g. Pring, 2000). The aim of this case study is not to generalise the results to all schools in Finland, but rather, to provide a deep perspective on one case to find critical features that are important to consider for comparison with other cases, not only in Finland but in other countries. In reporting the results, we offer authentic extracts from the headmaster and teachers to make our analysis transparent. For ethical reasons, we consider the five mathematics and science teachers as a group and do not distinguish the specific teachers when exemplifying our results.

Results

The first two parts of the results are organised according to the themes and sub-themes created in our analysis (see Table 1). In the first part we deal with the sub-themes connected to ownership of the module and shared sensemaking. The second part focuses on the sub-themes connected to how the headmaster and the teachers understood the interdisciplinary working manner. In the last part of the result section, we high-light the challenges and gains, as identified in the analysis of the themes.

Ownership of the module and shared sensemaking

Top-down / bottom-up project

The multidisciplinary learning module was initiated by the headmaster one year before the new curriculum was to be implemented. The headmaster motivated her active participation in implementing a multidisciplinary module with her knowledge about pedagogy and the new curriculum:

> I consider my pedagogical knowledge sufficient to have been able to drive this. I also know the new curriculum, have taken part of education concerning it and I think I know it well. Therefore, I have been able to drive this.

The headmaster recognised that there were earlier intentions to engage in multidisciplinary work, and that these had been unsuccessful. She also stated that there was a need to change the school and working manners to make the school better for the students. Yet, the headmaster acknowledged the possible problems of driving her vision too strongly:

> I see the problem of top-down steering, but somehow, I see that the headmaster must be the motor […]. I am totally conscious of the disadvantages when I'm driving in the race.

According to the headmaster, this could have a negative effect on the teachers involved in the realisation of the vision:

> It's a problem if one is too inspired and believes too much [in the idea], so it's not easy.

She also acknowledged some teachers' fear that 'the sovereignty and the quality of the Finnish school' were being spoilt, but she stressed that this represented an opportunity for the teachers to learn from testing and mistakes.

Regarding the question how the multidisciplinary project was initiated, the teachers all answered that the idea came from the headmaster, who had been motivated by the new curriculum. The teachers were basically positive to multidisciplinary projects, as long as the scale was sufficiently small; 'on a small scale I personally think its welcome, but absolutely not on a large scale'. In the first interview the teachers use the word "scale" to refer to the idea of teaching subjects as separate on one end, or a completely thematic and multidisciplinary way of teaching on the other. Thus "large scale" is interpreted by

the teachers as abandoning subject boundaries for a completely thematic way of teaching. Some teachers also expressed a fear of losing their autonomy and control over how they taught their subject.

Although the implementation of the multidisciplinary module under study was conducted on the initiative of the headmaster, the teachers were responsible for the module's planning and implementation. Energy as an organising theme for the multidisciplinary project was chosen because an 'Energy Week' involving grade 9 had been part of the school's curriculum for the previous two years. Thus, the teachers had some material and ideas about what could be a part of the new, multidisciplinary module. It should be noted that the teachers did not receive any in-service teacher training focused on multidisciplinary teaching and learning before starting the planning of the multidisciplinary module.

There was only a few collegial meeting with the headmaster concerning the visions for the new curriculum. Hence, the shared sensemaking concerning the curriculum intentions mainly took place among the teachers when they planned the module. The headmaster was not involved in this work.

Practical arrangements and teachers' workload

When planning the multidisciplinary module the teachers experienced that their opportunities to influence the practical arrangements, such as time schedules, were extremely limited. In fact, they were critical of how the school's management solved the problem of freeing up time from ordinary lessons to be dedicated to the multidisciplinary module. The contribution of each participating teacher in the module was to be in proportion to how much that teacher's lesson time had been shortened. In practice, this freed-up time did not match the time that most teachers had to invest in

planning the module, resulting in a feeling among many teachers that they did a lot of unpaid planning work. One teacher expressed this approach to planning as ‘practical from the management’s point of view, making resources magically appear from nowhere’. The teachers found the collegial planning of which activities should be included in the module and who should be responsible for what activity extremely time consuming. One teacher commented that ‘the time for planning was 8–10 times greater than usual, and planning of individual activities was not included in it’. In addition, the process of reaching a consensus, with 13 teachers involved in the planning process, was viewed as problematic.

According to the headmaster, the main reason for these problems was that the wage system for teachers in Finland is mainly built on the number of lessons taught, making it difficult to make room for large new projects.

Teachers’ cooperation

The headmaster’s view was that the close cooperation between teachers when planning multidisciplinary modules implied, among other things, that not only did they acquire a greater understanding of other subjects, but they also picked up ideas that were applicable to their own teaching. There were also teacher voices in our interviews that emphasised the positive experience of having the opportunity to cooperate more closely with colleagues, even if it took extra time as she usually worked alone: ‘I appreciated working with colleagues. Usually you are quite alone. But now you got to sit together and plan together. I liked that’. Some teachers also experienced that they were exposed to new ideas about teaching, although it was too early to say whether these ideas would influence their ordinary teaching.

Understanding of multidisciplinary teaching

The role of specific subjects in multidisciplinary teaching

The headmaster's view was that multidisciplinary teaching is a way to let students encounter each subject 'in reality', not just to study them theoretically, but to see them in a societal context, transcending the school and connecting different subjects:

> To work with the subjects as one really meets them in real life – not only theoretically studying them but experimenting with them, going beyond the school to the society, connecting different subjects and letting students see the connections between theory and reality.

According to the headmaster, multidisciplinary teaching does not imply that the individual subjects disappear; rather, the teachers had responsibility for their subjects in the project: 'We should not forget the subjects, but work with the subjects in a manner whereby you encounter them in a real way'. The headmaster also stressed that it is not possible to develop transversal competences without subject knowledge, and that it is the teachers' responsibility to connect the subject to the module:

> Competences and subject knowledge go hand in hand […]. The school subjects do not vanish, the teachers have the responsibility […]. Without subject knowledge, [there are] no competences.

At the beginning of the planning of the module, the teachers' expressed intentions were that different subjects involved in the multidisciplinary module should contribute to a broader view and understanding of the energy concept. For instance, physical education would contribute with the perspective of the human body and its energy use and needs. The role of mathematics in the module could involve introducing energy statistics and

working with spreadsheets. After the module, however, the teachers expressed quite clearly that multidisciplinary teaching implies that the individual subjects should not be visible in the whole: 'I guess it's the intention that you should not be able to distinguish the individual subjects'.

Mathematics was a subject that was viewed as especially challenging for incorporating into the multidisciplinary framework in a meaningful way:

> [Mathematics] is a subject that is hard to incorporate when you are doing practical things. Of course, you can calculate a lot of things, but still, the things that they calculate become somewhat artificial. However, I do not have to have mathematics in the module; if it is multidisciplinary, you put in the subjects that fit.

The teacher in the extract above states that there is no need to involve subjects that do not fit in naturally. The teachers yielded and stated that the subjects are still in the ordinary curriculum, while multidisciplinary teaching is something done outside the ordinary lessons.

Learning goals and assessment

The module's overall goal was to focus on the transversal competences and offer students the opportunity to acquire a broader understanding of the meaning and uses of the concept of energy. Concerning the deeper learning goals of the module, the headmaster emphasised the development of transversal competences, without losing sight of subject knowledge, and seeing the connections between theory and reality. Further, the headmaster stressed the importance of making students conscious of the goals concerning the transversal competences in the module.

Still another goal stated by the headmaster was having students work differently than they ordinarily do, motivating them and contributing to a positive experience of being in

school: ‘It should be more fun coming to school than staying away’. Hence, in line with the curriculum intentions, the headmaster considered this working manner as enhancing students’ enjoyment of school and joy of learning.

On questions concerning more specific learning goals asked both before and after the module, the teachers had difficulties formulating a clear answer, and they stated that they had not had time to think about the learning goals because of all the practical arrangements. They mentioned the learning of energy as a whole:

> To learn about energy and so. It’s in the curriculum, a whole.

The weak presence of the subjects was visible when the teachers talked about goals: ‘I have not thought about it from the perspective of chemistry’. One teacher even stated that students should learn to leave their ‘subject thinking’ behind, something that he/she sometimes had found disturbing during ordinary lessons:

> I think that it’s good if they learn to come away from the subject thinking. If we have now dealt with energy in physics, it is fully possible to talk about energy in biology and chemistry as well […]. I sometimes feel that it is like that in ordinary teaching; as soon as I talk about atoms in a physics lesson, they say that this is physics, why are we talking about chemistry? That they would realise that things are not divided into boxes […] I think this is the idea.

One explicit learning goal connected with the energy concept that the teachers identified in relation to planning the module, was that the students should be able to understand the difference between the everyday use of the word energy and its scientific use.

> And then I think that it would have worked better if one would have separated everyday talk about energy … and that you expend energy from this really scientific concept.

The teacher admitted that they failed in this effort, and that next year, the focus would be on only the scientific meaning and use of the energy concept.

There were also some self-critical reflections among the teachers concerning the separate parts of the energy module. The teachers felt that how the different sub-themes within the module fit together to make up the whole, became unclear to the students. In this way the activities making up the module became in some sense free-standing and thus not providing the deeper understanding of the energy concept, that was one of the stated goals of the multidisciplinary energy module.

Ultimately, the teachers stated that the development of the transversal competences was the main learning goal: 'I think, looking in the rear-view mirror, and what they were expected to learn, it was the work-life competences'. They stressed, for example, students going outside the school and meeting people who work with energy, as connecting to the competences entrepreneurship and social skills. In addition, learning to cooperate was also viewed as an important learning goal of the module: 'From the students' perspective, it is about learning to work more in groups, an important learning goal in itself '.

Concerning assessment, the headmaster's expressed view was that there should be no traditional exam in connection with a multidisciplinary module, but one still needs to assess student learning in some way. In addition, the focus should be on the students' perceptions concerning which competences they had developed during the module, but as she stated, this aspect needs to be developed further in the future by focusing more on the students' documentation of the learning process.

The teachers saw the assessment of the students' learning as problematic, and they did not reach a satisfactory solution on how it should be done. Their interpretation of the headmaster's guidelines was that there should be no summative assessment of the module, only a formative assessment. This interpretation was partly because the teachers conceived that formative assessment plays a central role in the new curriculum:

> There is something in the new curriculum that states that summative assessment should not be used in multidisciplinary teaching. I have not, however, read the whole curriculum in detail, so I cannot be fully sure, but I do not think that [summative assessment] is prohibited in any way. I think that [the headmaster's] thought is that formative assessment should be used, as the new curriculum encourages one to use formative assessment.

Meanwhile, the teachers reflected on how they could ensure that the students would care about formative assessment and take it to heart, as the students did not see it as relevant to their final grades in their subject courses. The teachers also saw the assessment of a student's transversal competences as difficult. One teacher expressed that the question concerning the competences was forced, as the competences are automatically involved in a lot of activities. This teacher also asked, if one is to test for the different competencies, what should one test and how?

On questions concerning what the teachers considered that the students had learned during the module, the answers were somewhat vague: 'I think that they [the students] definitely got something out of the module'. This quotation should be put in the context that the teachers, based on the students' answers to a written questionnaire, perceived that the average students' knowledge concerning energy was relatively shallow before the module.

The roles of the teachers and students

The headmaster saw the multidisciplinary modules as a way of introducing change into the teaching practices, which would imply a change in the roles of both the teachers and students. More cooperation was required from the teachers, as well as a transition from a more teacher-directed learning style to one where the teacher was more of a coach:

> I would like to bring in some new ways of thinking in line with the new curriculum, where the teacher's role is changed from being this mediator of knowledge, to a teacher that is more of a coach.

Also the teachers stated that they should learn to have a new role as a teacher, meaning supervising instead of direct teaching of students. Multidisciplinary teaching, however, implies that the roles of both the teachers and students change. When a teacher becomes more of a coach, and less of a person directly telling the students what they should do, the students also need to take more responsibility and make independent choices. Before the planning of the multidisciplinary module started, the students were asked to write down suggestions concerning what they would like to learn more about in connection with energy and how and in what way they would like to learn and work. When asked the question of how the students' preferences were taken into account in the later planning of the module, the teachers responded that most planning had been done without directly considering the suggestions made by the students. However, according to some of the teachers the students were free to choose more than they could 'in traditional teaching'. The teachers also stated that they tried to enhance the students' sense of responsibility:

> I think that we do try to put quite a lot of responsibility on the students, so that they think about what they want to do and work on and how they would like to produce their texts and the multimodal…

Hence, according to the teachers, the students were given a greater responsibility and opportunities to make choices in the multidisciplinary project, as compared with more traditional schoolwork. However, the headmaster did not consider the freedom of, for instance, students making a choice between three preselected laboratory themes as a case wherein the students were given a real opportunity to influence what they would do:

> But it was the teachers who planned everything; they [the students] have been able to choose among different experiments, but there have not been so many choices.

The headmaster also emphasised the challenges involved in including the students in the planning, partly because they are not used to it, or asked to, and partly due to the lack of time:

> We are not good at incorporating the students' wishes, something that this project also shows, but it is certainly the lack of time in the school system.

The students were expected to do much of the work in small groups (three to four students per group) during the multidisciplinary module. The task of putting together the different student groups, was carried out by the teachers based on their evaluation of which students would likely work well together. However, according to the teachers, there were several groups that did not work well together and that had difficulties taking responsibility for their joint tasks. The teachers, who were to guide groups that consisted of students not previously known to them, also faced some

difficulties: ‘It’s different if you don’t know the students. It was easier with those you know. To go there and make suggestions if you know how they function’.

The headmaster noticed the problems students had working in groups and raised the question with the students of what constitutes good group work. According to the headmaster, teachers (including herself) are not adequately prepared in guiding group work, and there is a real need for in-service teacher education about using and implementing cooperative learning in the classroom.

Challenges and gains

The lack of a shared sensemaking between the headmaster and the teachers of what constitutes multidisciplinary teaching and its practical implementation, was one of the key challenges in planning and implementing the multidisciplinary module. Although the teachers were free to choose the theme of the module, they did not feel an ownership of the project. One reason was the practical framework for the module provided by the headmaster, which according to the teachers only resulted in a substantial increase of their workload. The number of teachers and subjects involved in the multidisciplinary module, also contributed to the perceived lack of ownership and difficulties of creating a meaningful whole.

The view of the role of different subjects within the multidisciplinary project was also not shared. While the headmaster’s view was that each subject should remain visible, teachers considered that the whole point of a multidisciplinary theme is that the individual subjects should be invisible. The latter viewpoint contributed to the fact that clear learning goals for the module were missing, thus also resulting in difficulties developing appropriate assessment tools.

Yet another challenge was the new roles of teachers and students within the module. There was an agreement between the headmaster and the teachers that the students should learn to take a greater responsibility for their and their group's work. However, the shift from being a teacher, towards being more of a coach, was seen as challenging, especially when working with students that they did not encounter on a daily basis.

The major gains identified in planning and implementing the multidisciplinary module, was the opportunity for the teachers to interact with colleagues. As subject teachers they were all used to working independently and alone. The module gave the teachers an opportunity to cooperate and gain insights into other teachers' way of working, thus providing the opportunity for gaining new insights and ideas.

Discussion and conclusion

Our case study has focused on how the headmaster and science and mathematics teachers conceive and experience the implementation of a multidisciplinary module and what challenges and gains can be identified in the implementation process. The term "multidisciplinary" is vaguely defined in the Finnish curriculum and does not completely overlap with the term "interdisciplinary", the term most often used by the international research community. The results are important, not only for the Finnish educators and curriculum authors, but also for the international research field, as a lot of questions remain to be answered concerning the implementation of interdisciplinary working manners.

Next, we discuss the mismatch between the headmaster's vision and the teachers' views and experiences revealed in our study, and more generally, the challenges and gains when implementing a multidisciplinary module based on the results of this case study.

How, for instance, the development of the transversal competencies in multidisciplinary modules are to be developed is not clear. Hence, a successful implementation of a module that develops the competences demands a throughout shared sensemaking among the stakeholders involved in the implementation. This was not the case in our study. The view of the multidisciplinary module was not negotiated at a conceptual level. The headmaster in our study had a clear but quite abstract vision, while the realisation of the vision was left to the teachers. This seems to be typical for the Finnish contexts (Pyhältö et al., 2011). The teachers did not receive any concrete support, for example, concerning the principles of how to plan and enact the contents, goals and assessment of such a module (cf. Pyhältö et al., 2012). Beyond the importance of the headmaster's support for a successful educational reform to take hold (Fullan, 2016), it is also vital that the teachers feel an ownership and active participatory role in the process (Hewson, 2007). The teachers in our study related positively to the idea, and they were given the freedom to choose the theme and plan the multidisciplinary module. Yet, it seems that many important decisions about the character and organisation of the module were made without a collective sensemaking, involving both the teachers and the headmaster. In addition, the organisation and solving of the practical problems took a lot of time. Therefore, there was not enough time for concretising the contents, goals and assessment of the module – something that previous research has identified as creating a great challenge for even experienced teachers (e.g. Broadhead, 2001; McPhail, 2018). Hence, the question of what constitutes a multidisciplinary module, how to involve the transversal competences, and the roles of the individual subjects in that module, remained partly unexplored and unanswered by the teachers. Yet, thinking thoroughly through these questions should be the natural starting point in planning and sharing the same vision of any multidisciplinary module (cf. McPhail, 2018). Inclusion

of many subjects in one module made its organisation even more time consuming. Interestingly, such broad subject integrations have been advocated by teacher educators and researchers (e.g. Brand & Triplett, 2012).

The teachers in our case study chose to organise the multidisciplinary module around the theme of energy, which is in line with Davison at al.'s (1995) fifth model of integration and a crosscutting concept (see the first part of the literature and National Research Council [NRC], 2012). However, the great number of subjects and loose connections between the different disciplines making up the studied multidisciplinary module in our case also overlaps with the definition of multidisciplinarity in the OECD documents (1972). McPhail (2018) stresses the importance of placing the subjects first before the transversal competences to maintain a high level of intellectual challenge in interdisciplinary work. However, it takes time to plan themes and criteria for the assessment of a theme concerning both the development of the conceptual subject knowledge and interdisciplinary insight. The hope expressed by the participating teachers was that, by participating in various activities highlighting different aspects of the energy concept, the students would gain interdisciplinary insights in the form of a broader understanding of this concept. In this context, one important aspect was the difference between the everyday use of the term energy and the more scientific use of the same word. To achieve this goal, the student activities in the module also represented different aspects of energy and its use. As different teams of teachers were responsible for only a subset of activities, the integration between different activities were not actively pursued. The teachers also realised this at an early stage and decided to exclude certain activities next time and focus more on the scientific–technical aspects. The difficulties the teachers experienced in trying to have students build a

bridge between their everyday use of the energy concept and the more exact and scientific concept of energy have been identified also in other studies (Duit, 2014).

Opposing the headmaster's vision, according to which the transversal competences should be developed hand-in-hand with the subjects, the role of science and especially mathematics became downplayed in the enacted module, although there were initial efforts to use and focus on them somehow in the module. Instead, the teachers ultimately assumed that it was more important to develop the transversal competences expressed in the core curriculum. Thus, the teachers explicitly expressed the tension between the learning of disciplinary concepts (i.e. forms of energy) and a more 'holistic' and interdisciplinary view of learning in science (Venville et al., 2012). This tension was especially apparent in the problematic role of mathematics in the multidisciplinary module. Several teachers involved in the module expressed that they saw no natural way of including mathematics in the theme, and thus, they abandoned their efforts to make mathematics an integral part of the module. Some teachers even saw it as a goal for students to learn not to think about specific subjects. Because of the lack of shared sensemaking with the headmaster, lack of time and all the practical problems to be solved, several teachers started to consider the multidisciplinary module as something outside their 'ordinary teaching', where the students would learn the subject matter.

The teachers identified the assessment of the development of transversal competences as challenging. This was partly connected to learning goals that were vaguely formulated. The teachers' comments show that they had no clear picture of exactly what should be assessed during or after the multidisciplinary module or how it should be evaluated. Some of the teachers expressed that formative assessment, but not summative assessment, should be included in the module. This opposes the national

core curriculum, which states that the students' knowledge and competences in a multidisciplinary module should be assessed, and the results of this assessment should be reflected in the grades given in the subjects involved in the module (FNBE, 2016). How this should be done, however, is not explicitly stated. Hence, it is not plausible that students could 'recognise' and 'realise' (Bernstein, 2000) the evaluative codes of this module.

A major motivation for introducing multidisciplinary modules into the Finnish curriculum was to offer all students an opportunity to investigate problems that are of interest for them. It would also facilitate students' involvement in self-directed group work, where the teachers would take on more supervisory roles. While the teachers made some efforts to meet students' interests in the form of pre-questionnaires and some alternative activities to choose, they planned the programme in a detailed way, something that the headmaster pointed out as a problem. Both the teachers and headmaster identified cooperative learning as an important work-life skill that is not given enough space in today's schools. The teachers were not satisfied with how this worked out in practice, with many students failing to take responsibility for their work or that of their groups. The headmaster stated that this may be one part of the Finnish school that needs developing, for instance, by encouraging teachers to participate in in-service training in cooperative learning. Even here, we see similarities with the study by Broadhead (2001), who advocates the creation of a clearly articulated, theoretically founded rationale for how to plan and deliver the curriculum in a way that engages students. This work remains to be done. In line with the intentions of the Finnish curriculum, both the headmaster and teachers stated that teachers' roles should shift toward supervising rather than teaching. However, dichotomising teachers' roles and actions can lead to downplaying valuable teacher knowledge in science and

mathematics that is needed to support students' conceptual development (cf. e.g. Hanna, 1996).

Finally, the headmaster saw the project as an opportunity for testing and learning, and some teachers stated that planning the module with colleagues was instructive. Hence, in line with Broadhead's (2001) study, making connections across subjects with colleagues can somehow be developmental for those who participate in it. An important question is if this could be done in a more productive manner so that the challenges revealed in our study could be overcome.

Conclusion

We cannot generalise the results to all Finnish schools. However, given the relatively homogenous school culture in Finland (e.g. Andrews, Ryve, Hemmi, & Sayers, 2014), we can assume that teachers in other Finnish schools struggle with similar issues as those in our study. The study is important, not only for those responsible for the Finnish national school policy, but also for the international research field, as many countries aim at implementing curricula in line with the 21st-century skills, where teachers will meet the tension between the development of knowledge about the traditional school subjects and simultaneously developing students' transversal competences.

Firstly, our study reveals similar challenges in the Finnish context as identified in other countries (e.g. Broadhead, 2001; Gresnigt, Taconis, Keulen, Gravemeijer, & Baartman, 2014; McPhail, 2018). an important aim with interdisciplinary working manner is to provide students with a more authentic context in which learning can take place and enhance student interest and motivation (e.g. Czerniak & Johnson, 2014). Moreover, when students can choose and define their own problems, while teachers act

more as a coach, it may facilitate students' independent and active learning. To be able to realise this conceptualisation of critical factors should be developed further in our research field. Through empirical case studies in different cultural–educational contexts, it is possible to eventually discern general features and continue the important work of theorising the issue. This could help the work of implementation and the shared sensemaking between stakeholders by offering a more structured way of working.

Secondly, opposite of what some researchers advocate (e.g. Brand & Triplett, 2012), it seems more favourable to restrict the number of subjects in a multidisciplinary module, especially if there is no supportive material available for planning and implementing the module. Although not explicitly mentioned by the teachers during the interviews, the lack of available teaching material and teacher guides, combined with the lack of in-service teacher training focused on multidisciplinary teaching, obviously made the teachers work even more time consuming and inefficient. According to Broadhead (2001) the greatest challenge that subject teachers experience when working in an interdisciplinary contexts, beyond the lack of time, is the lack of curricular resources and equipment for promoting students' active and investigative approaches. The importance of teaching material, especially teacher guides for the quality of teaching, has recently been raised as important factor for the quality of education by several researchers (e.g., Ball & Cohen, 1996; Davis & Krajcik, 2005; Hemmi et al., 2017). Research-based teacher guides could support teachers' learning concerning what to especially pay attention to when planning and enacting an interdisciplinary module based on the conceptualisations by researchers.

Finally, this case study is part of an ongoing research project on multidisciplinary teaching and learning, with a specific focus on how science and mathematics are integrated in a module on energy. At the time of writing, the

multidisciplinary module has been through two cycles, and our future research will focus on both the students' experiences and the development of the multidisciplinary module during these two cycles.

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