How a local oral examination considers affective aspects of knowing mathematics

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To measure whether and to what extent pupils know mathematics is complicated. The test situation will influence the pupils' work and in addition there are aspects of knowing mathematics that are difficult for a written test to assess. Since the early 1990s, Norwegian pupils undergo a local oral examination at the end of the ten-year compulsory school. Rules and guidelines for this examination has developed over time in accordance with curriculum changes. According to the 1992 national guidelines, the examination has to be based on the pupils' project work or similar. In addition, pupils' creativity and imagination is highlighted. The 2014 national rules are different, the only thing here that a written test cannot reveal, is skills in mental calculation.

Keywords: Assessment, motivation, attitudes, beliefs, creativity.

INTRODUCTION

"Different groups of people can have very different views of what "counts", or should count, in mathematics" (Schoenfeld, 2007a, p. 3), so what it means to know mathematics is far from a simple question. The question of how to assess what pupils know, is even more complicated. Tests or examinations constitute one form of assessment; other forms are for example feedback on daily work. One aim of an examination is to assess what the pupils know; another aim is to assess whether the teaching is successful. Morgan (1999) identified two main strands in research related to assessment in mathematics education. One strand focuses on the design of the tests. The other focuses on critiquing traditional forms of assessment, and often proposes new forms of assessment that are better aligned with the curriculum aims. Norway introduced a local oral examination in 1990 (Ministry of Education, Research and Church Affairs, 1992). This examination highlighted local curricula and pupils' project work; this was a new form of assessment aligned with curriculum aims. The national guidelines for the local oral examination have evolved since the first written guidelines appeared in 1992. The research question is: How do the 1992 national guidelines and 2014 national rules for the local oral mathematics examination consider affective aspects of knowing mathematics?

Because the rules and guidelines reflect the curriculum, an analysis of the curriculum development is presented as an introduction to the further analysis. This paper focuses on the rules and guidelines for the local oral examinations from two perspectives: a) how to facilitate opportunities for the pupils to show what they know, and b) what is assessed. A common problem with tests and surveys is that there are aspects of knowing mathematics that are difficult to reveal in a written test. Affective aspects are among these. The paper first discusses motivation, attitudes, beliefs, and creativity, elements that reflect affective aspects of knowing mathematics and which are found in central documents for Norwegian mathematics education. The following section reveals how Norwegian curricula consider affective aspects of knowing mathematics. Then assessment in mathematics is presented, before the analysis of the 1992 national guidelines (Ministry of Education, Research and Church Affairs, 1992) and the 2014 national rules (Norwegian Directorate for Education and Training, 2014) for the local oral examination.

ATTITUDES, BELIEFS, CREATIVITY AND MOTIVATION

The Ministry of Education, Research and Church Affairs carried out a large project, Quality in Mathematics Education (Brekke, 2002/1995), between 1995 and 2002. The aims were to develop test materials, conduct a survey of pupils' attitudes and beliefs

towards mathematics and mathematics teaching, and describe the spectrum of pupils' performances in different subject areas. During the 1990s, pupils' attitudes and beliefs were accordingly considered important in Norway.

When individuals are doing mathematics, the affective system is not just supporting cognition, but it is playing a central role. Affect as a representational system is intertwined with cognitive representation (Goldin, 2002). Goldin divides affective representations into four sub-domains: a) *emotions*: rapidly changing and usually local or connected to context; b) *attitudes*: moderately stable predispositions towards certain sets of classes of situations; c) *beliefs*: often highly stable, involving the attribution of some sort of external truth or validity; and d) *values,* including ethics and morals, and which refers to deep "personal truths". This paper pays less attention to emotions and values because the Quality in Mathematics Education project highlights pupils' attitudes and beliefs.

Sriraman (2009/2004) identifies creativity as part of mathematicians' work. He points out that creating original mathematics requires a very high level of motivation, persistence and reflection, all of which are considered indicators of creativity. For example, one could be in an environment that is non-supportive of creative efforts, but a high level of motivation may possibly overcome this and pursue creative endeavours. According to Sternberg and Lubart (1999), creativity may not only require motivation, but also generate it. Thus, given the chance to be creative, pupils who might otherwise lose interest in school instruction might find that it instead captures their interest. According to Liljedahl (2013), creativity has more affective aspects than just motivation, because illumination is important in the creativity process. Illumination occurs in the context of trying to work something out.

Self-determination theory proposes that all human beings have fundamental psychological needs for being *competent*, *autonomous* and *related* to others. People are assumed to proactively initiate engagement with their environments. The basis for this activity is intrinsic motivation (Deci & Ryan, 2012). The foundations of self-determination theory reside in a dialectical view, which concerns the interaction between an active, integrating human nature, and social contexts that either nurture or impede the organism's active nature. *Relatedness* concerns the psychological sense of being with others in a secure communion or unity. *Autonomy* refers to being the perceived origin or source of one's own behaviour; it concerns acting from interest and integrated values. Autonomy enables individuals to deal with novelty and generate creative products (Diezmann & Watters, 2000), so autonomy is part of creativity. According to Hannula (2006), motivation is observable only as it manifests itself in affect, cognition and behaviour, for example as beliefs, values and emotional reactions. Pupil-centred classrooms with much teamwork going on may rely on pupils' exhibiting their autonomy and social interactions. According to DeBellis and Goldin (2006), each person constructs complex networks of affective pathways and competencies. These networks have more or less mathematical problem-solving power and their meanings are context-dependent for the individual.

THE THREE LATEST MATHEMATICS CURRICULA IN NORWAY

Three different curricula have been in effect in the Norwegian School during the period from 1990 to 2015. These curricula provide different perspectives on pupils' affect. The 1987 curriculum (Ministry of Church and Education, 1987) focuses on pupils' project work and the schools' development of local curricula. This is interpreted to mean that the curriculum highlights the pupils' autonomy and relatedness, so it is in line with Deci and Ryan (2012). The overarching aims for the subject mathematics in this curriculum, claim that the teaching shall take care of and develop the pupils' logical thought, responsible decisions, imagination and creative enthusiasm. In addition, problem solving is introduced as a separate domain. The curriculum is thus in line with DeBellis and Goldin's (2006, p. 133) point: "The meanings of our emotional feelings are highly context dependent; far more, even, than the meaning of words and phrases." The focus on imagination and creative enthusiasm, shows that the curriculum considers affective aspects of creativity.

The 1997 mathematics curriculum (Ministry of Education, Research and Church Affairs, 1996a) introduces *mathematics in everyday life* as a separate domain. This is interpreted as an explicit focus on context and autonomy. The curriculum points out six main aims for the subject mathematics. One aim is that pupils should develop positive relations with

mathematics, experience the subject as meaningful, build self-respect and have self-confidence. This is in line with self-determination theory (Deci & Ryan, 2012). Another aim is that pupils are stimulated to use their imagination, resources and knowledge to find solution methods and alternatives through investigative and problem-solving activities, as well as conscious choices of tools and instruments. This is interpreted as meaning that the curriculum focuses on the pupils' autonomy, creativity and motivation.

The Danish project Competencies and Learning of Mathematics, (Niss & Højgaard Jensen, 2002) constitutes the basis for the interpretation of mathematical competence in the recent mathematics curriculum (Norwegian Centre for Mathematics Education, 2014). *Competence* is someone's insightful readiness to act in response to the challenges of a given situation. The Danish project describes a set of eight delimited dimensions that together generate mathematical competence: Mathematical-thinking competence, problem-tackling competence, modelling competence, reasoning competence, aids-and-tools competence, communicating competence, symbol-and-formalism competence, and representing competence. No affective aspects of competence are explicitly listed, but Niss and Højgaard Jensen (2002) point out that mathematics-teaching competence includes the ability to motivate and inspire pupils. The overarching aims of the 2006 mathematics curriculum (Norwegian Directorate for Education and Training, 2013) emphasize that both girls and boys must get opportunities to gain experiences that create positive attitudes towards the subject.

Table 1 shows how the perspective on affect has developed according to the overarching aims of the latest three mathematics curricula. The 1997 curriculum's (Ministry of Education, Research and Church Affairs, 1996a) aims, explicitly include the pupils' attitudes and their affective aspects of creativity. "Meaningfulness" is left out in the 2006 curriculum. This is interpreted as suggesting that the pupils' autonomy and self-determination are less important. The greatest difference between the three curricula is that while the two previous curricula present a pupil-centred perspective on the teaching, the 2006 curriculum presents a teacher-centred perspective; the 2006 curriculum has no teaching aim regarding the pupils' affects.

The Core Curriculum (Ministry of Education, Research and Church Affairs, 1996b) states the overarching aims for the education. This part of the curriculum elaborates on the preamble to the Education Act, and it is continued in the 2006 curriculum. The Core Curriculum focuses on creativity, autonomy and relatedness. However, the word "motivation" occurs only once, successful learning depends on the teacher as well as on the pupil. The Core Curriculum highlights the pupils' attitudes by claiming that knowledge, skills and attitudes develop in the interplay between old notions and new impressions. The 1997 mathematics curriculum is in line with the Core Curriculum's perspectives on creativity, autonomy and relatedness, while the 2006 mathematics curriculum is not.

ASSESSMENT

Schoenfeld (2007a) claims that assessments can serve useful purposes for the pupils, but the challenge is to make them do so. According to Wiliam (2007), the use of assessment should support learning in any assessment regime; classroom assessment must first be designed to support learning. Schoenfeld (2007b) discusses how to assess mathematical proficiency: what a pupil knows, can do, and is disposed to do mathematically. He describes four aspects of mathematical proficiency: *Knowledge base* (what does it mean to know a content), *strategies* (ability to formulate, represent, and solve mathematical problems), *metacog-*

	1987 curriculum	1997 curriculum	2006 curriculum
Aims for the pupils	Experience mathematics as meaningful	Develop positive relations with mathematics Experience mathematics as meaningful	Get opportunities to gain experiences that create positive attitudes towards mathematics
Aims for the teaching	Take care of and develop pupils' imagination and creative enthusiasm	Contribute to the pupils' building of self confidence Make the pupils experience belonging	Include playful and creative activities

Table 1: How pupils' affects are considered in the curricula's overarching aims

nition (using what you know effectively), *beliefs and dispositions*. Pupils who experience skill-based instruction tend to succeed on tests of skills, but they do not succeed well when tested in problem solving and conceptual understanding. On the other hand, "[s]tudents who study more broad-based curricula tend to do reasonably well on tests of skills" (p. 63), while on tests of conceptual understanding and problem solving, these pupils succeed much better than those who just exercise on skills. *Beliefs* are important, because if you believe that mathematics is not supposed to make sense, your work will reflect this. The pupils pick up their beliefs about the nature of mathematics from their experiences in the mathematics classroom. That mathematical problems have one and only one answer and that mathematics is done by individuals in isolation are typical pupil beliefs.

Boesen, Lithner and Palm (2010) investigated relations between task characteristics and the mathematical reasoning pupils use when solving tasks in a test situation. Their results show that when solving tasks similar to those in their textbooks, the pupils were mostly trying to recall facts or algorithms. The pupils did not have to construct new reasoning or consider any intrinsic mathematical properties. By contrast, the tasks that were not similar to those encountered in the textbook were mostly approached with creative mathematical reasoning.

THE LOCAL ORAL MATHEMATIC EXAMINATION

As a result of the 1987 curriculum's (Ministry of Church and Education, 1987) focus on local curricula, project work and problem solving, Norway introduced a local oral examination that encompassed these three fields. Pupils may hence undergo two different examinations in mathematics at the end of the compulsory school: A national written mathematics examination and a local oral mathematics examination. Only some pupils undergo each examination.

According to the national guidelines, the 1992 oral mathematics examination aimed to: "... assess aspects of the teaching aims, which may be difficult to show in a written test" (Ministry of Education, Research and Church Affairs, 1992, p. 14, author's translation). The examiner (most commonly the mathematics teacher) leads the talk/discussion with the pupil, while the external examiner determines the grade afterwards. The Ministry designed and published booklets with guidelines and guiding materials for teachers. These guidelines are difficult to access, so they are listed here:

- The test has to include tasks from at least three of the ten main subject areas in the syllabus.
- The test has to give room for use of different methods, creativity and imagination.
- The test has to include tasks where the pupil may explain procedures and rules that she/he uses in solving the tasks. It might be satisfactory that the pupil just sketch how she/he will solve the task.
- The test has to include tasks involving mental calculation and approximation.
- The test might include tasks where the pupils are free to use technical artefacts such as calculators and computers.
- If there is information about project work or similar, then the test has to include questions related to this work (p. 14, author's translation).

In 2014, the responsibility for the local (oral) examination guidelines belongs to the school owners. The Education Act (Lovdata, 2013) regulates the oral examination, and the Norwegian Directorate for Education and Training (2014) has elaborated regulations for the national rules. There is a 24-hour mandatory preparation time, which starts with one day at school with all kinds of aids permitted. In the beginning of the preparation time, the pupil gets a theme or a problem. What goes on in the preparation time is not included in the assessment. Each pupil has a right to pedagogical aid during the preparation day at school. The pupils present their theme or problem during the examination. The examiners then use this presentation as a basis for a mathematical discussion, for which the teacher has prepared questions for the pupil. The examiners cannot ask questions just from a narrow part of the subject. The discussion has to cover at least 2/3 of the examination time. The examination has to be organized so that the pupil can show to what extent the competence aims in the curriculum have been reached. The mathematics curriculum clarifies the meaning of "oral skills":

> Oral skills in mathematics involve creating meaning by ... participating in discussions, communicating ideas and elaborating on problems, solutions and strategies with other pupils ... this development starts with a basic mathematics vocabulary that leads to precise professional terminology ... (Norwegian Directorate for Education and Training, 2013, pp. 4–5)

The schools can make local guidelines for how to carry out this examination. Two examiners assess the pupil, and one of them needs to be a teacher from another school.

ANALYSIS OF NATIONAL GUIDELINES AND RULES

Schoenfeld (2007a) points out that there is more to mathematical proficiency than being able to reproduce standard content on demand. He warns against what he calls "the illusion of competence" by asking: "Have you learned the underlying ideas, or are you only competent at things that are precisely like the ones you've practiced on?" The local oral examination has developed from 1990–1992 and into the 2014 examination form. In order to investigate how the rules and guidelines for these examinations consider affective aspects of knowing mathematics, a framework is built on theories from Deci and Ryan (2012), Hannula (2006), Sriraman (2009/2004), Liljedahl (2013), DeBellis and Goldin (2006) and Goldin (2002). This generates four affective aspects of knowing mathematics: motivation, creativity, attitudes and beliefs. The data in this study consist of the 1992 national guidelines for the local oral examination (Ministry of Education, Research and Church Affairs, 1992) and the 2014 national rules for the local oral examination (Norwegian Directorate for Education and Training, 2014).

The framework leads to three points in the 1992 guidelines: the conversation form, the use of creativity and imagination, and the inclusion of local curricula and pupils' project work. The guidelines explicitly emphasize that the examination shall aim at having a conversational format. This opens up for the teacher to focus on each of the framework's four categories. The use of creativity and imagination directly points at creativity and indirectly points at motivation. The inclusion of pupils' project work is an important aspect of the oral examination; according to the national guidelines (Ministry of Education, Research and Church Affairs, 1992), project work is based on the pupil's interests, ideas or experiences with social practice. Interests are part of the pupil's intrinsic motivation (Deci & Ryan, 2012). Our emotional feelings are highly context-dependent (DeBellis & Goldin, 2006) and thus related to social practice. According to the 2014 national rules (Norwegian Directorate for Education and Training, 2014), the most main point is that the pupils can show their competencies. The examination conversation may consider all the framework categories, but it is explicitly stated that the teacher and the external examiner choose the context for the examination. So the pupil's autonomy is not considered important. The examination aims to assess how the pupils have achieved the competence aims for grade ten in the national mathematics curriculum (Norwegian Directorate for Education and Training, 2013). It turns out to be one single competence aim that a written test cannot assess: to develop, use and elaborate on methods for mental calculations. Based on the competence aims, the teacher can provide each pupil with problems so that the four categories in the framework are covered, but the national rules leave it to the schools to make this choice. Creativity and the pupils' project work are not explicit issues for assessment in the 2014 examination. The teacher may hence provide the pupils with problems that concern the pupils' attitudes, beliefs, motivation and creativity, but the 2014 national rules have no explicit requirement for this, unlike the 1992 National guidelines.

CLOSING WORDS

The overarching aims in the mathematics curriculum have changed since the local oral curriculum for all was introduced. The overarching aims in the mathematics curricula from 1987 (Ministry of Church and Education, 1987) and 1997 (Ministry of Education, Research and Church Affairs, 1996a) present a pupil-oriented perspective, which highlights that the teaching shall provide the pupils with opportunities to show what they know. The overarching aims in the 2006 mathematics curriculum present a teacher-centred perspective with no teaching aims concerning the pupils' affects.

The 1992 national guidelines for the local oral examination (Ministry of Education, Research and Church Affairs, 1992) emphasize that the test has to assess aspects of the subject that are difficult to reveal in a written test. The 2014 national rules (Norwegian

Directorate for Education and Training, 2014) have no similar requirement. In 1992, the pupils' project work was the basis for the examination; in addition, the pupils' creativity and imagination were highlighted. This means that affective aspects of knowing mathematics were considered important. The guidelines point out that the test has to provide the pupils with opportunities to show what they know. In 2014, the teacher provides the pupils a problem or a task, and they get one school day to prepare a presentation of this task. At the examination the pupils discuss this presentation with the teacher and the external examiner. The pupils' social practice is hence not highlighted the way it was in 1992. The 1992 national guidelines explicitly points out that the test has to provide opportunities for the pupils to use creativity, and "to show creativity" was one requirement for achieving the highest grade. The 2014 national rules do not consider creativity; nor do they focus explicitly on affective aspects of knowing mathematics. However, the main point in these rules, is that the pupils can show their competencies. Further research is necessary to provide a more thorough analysis of this issue.

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