Assessment of mathematical competence using the Estonian national e-tests

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Summary

Since 2000, in assessing the mathematics learning outcomes, in addition to the content topics of mathematics, more attention has been paid to mathematical competence as something more general (Boesen, Lithner, & Palm, 2018). Devlin (2021) points out that such changes are very welcome, because the mathematical skills required in everyday life and in the mathematicians' work have changed significantly. He believes that nowadays we need mathematical thinking rather than, for example, the ability to calculate quickly and correctly.

Mathematical competence has been defined in the national curriculum of Estonian basic schools since 2002 (Põhikooli ja gümnaasiumi riiklik õppekava, 2002), and in the current version of the curriculum, it is part of general competence in mathematics, science and technology (Põhikooli riiklik õppekava, 2021). Assessment of mathematical competence is also a goal in national e-tests of mathematics. At the same time, the structure of e-tests is based on the subject-specific content topics (calculation, data and algebra, geometry, measurement). A similar approach to compiling e-test has continued to this day (e.g. 6. klassi matemaatika..., 2015; Jukk, Mikkor, Pihlap, & Täht, 2020). The level of conceptual and procedural knowledge and the application of concepts and procedures are assessed in different subject-specific content areas. However, such an approach raises the question of the extent to which mathematical competence has been systematically assessed as a general competence. To the authors' knowledge, this has not been analysed before.

Mathematical competence has been defined in various international frameworks (NCTM, 2000; OECD, 2000; TIMSS, 2015), but it was decided to base our study on the Mathematical Competency Research Framework (MCRF)

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developed by Lithner, Bergqvist, Bergqvist, Boesen, Palk and Palmberg (2010) in Sweden, which distinguishes between six sub-competencies of mathematical competence: Problem-solving ability, Reasoning ability, Applying procedures ability, Representation ability, Connection ability, and Communication ability. They largely overlap with the dimensions of mathematical competence in the PISA and TIMSS assessment frameworks but focus more on mathematical competence as a general competence. In addition, the MCRF framework describes three activities for each sub-competence that express its manifestation: interpret, do and use, and judge.

Our study aimed to apply the mathematical competence assessment framework adapted based on the MCRF research framework, in analysing the tasks of the mathematics e-tests in Estonia. Two research questions were formulated:

1) To what extent do the mathematics e-tests conducted in Estonia allow the assessment of the Problem-solving ability, Reasoning ability, Applying procedures ability, Representation ability, Connection ability, and Communication ability that are defined as sub-competencies of the mathematical competence?
2) To what extent do the mathematics e-test conducted in Estonia allow the assessment of the application of sub-competencies of mathematical competence through interpretation, do and use, and judgement skills?

The study used the e-tests conducted in the years 2018–2020 in Estonia. Three mathematics e-tests included a total of 23 tasks. Two researchers categorised all the tasks according to the analytical framework and, if differences emerged, they discussed them until a consensus was reached.

The results of the analysis showed that in the national mathematics e-tests conducted in Estonian, most of the tasks required the Applying procedures ability. This sub-competence was required on all 23 tasks used in e-tests over the three years. There were the fewest tasks in the e-tests to assess the Problem-solving ability, which was also the only competence for the assessment of which there were no tasks in the 2018 and 2019 e-tests. The analysis showed that in the 2020 e-test, the assessment of different sub-competencies was better balanced than in previous years.

In addition, it turned out that students most often have to "do and use" something in case of applying different sub-competencies, but interpretations are also very often needed. At the same time, only one task requiring judgement was found throughout the three years of e-tests.

The results of the study are in line with the analysis carried out in Sweden, where most of the time in school hours is also devoted to the development of the ability to apply different procedures (Boesen et al., 2014). An analysis of the Swedish national math tests (Boesen et al., 2018) has shown that in addition to Applying procedures ability, Communication ability (79% of the tasks designed for different school levels) has been assessed quite often, and Connection ability (36% of the tasks), Problem-solving ability (34%) and Reasoning ability (15% of tasks) have not been assessed so often. At the same time, based on the results of this study, it was not necessary to apply the Problem-solving ability in Estonian mathematics e-test in 2018 and 2019, and other competencies were needed in only one or two of the six or eight tasks used in the e-tests in 2018 and 2019, respectively. One possible explanation of why the Estonian tests cover fewer sub-competencies than the Swedish tests is that in Estonia, we used e-tests in our analysis, but in Sweden, the tests were conducted using paper and pencil. This may indicate that in e-tests, it may be more challenging than usual to develop appropriate tasks for assessing different sub-competencies. One might think that it is particularly challenging to compile computer-assessed tasks for different sub-competencies and that there could be more flexibility in using human-assessed tasks, as people have more flexibility in assessing the answers of, for example, Reasoning, Representation and Communication abilities. However, this assumption was not confirmed by the analysis of the Estonian e-test as in the case of the fully computer-assessed tests carried out in 2020, different sub-competencies of mathematical competence were represented to a greater extent than in the partially human-assessed mathematics e-tests conducted in 2018 and 2019.

However, since the general aim of mathematics e-tests in Estonia has been to assess not only subject-specific content topics as learning outcomes but also mathematical competence as a general competence (e.g. 6th-grade mathematics ..., 2015; Jukk et al., 2020), it can be questioned how well the objectives set have been achieved. Based on the data we collected, it appears that the assessment of mathematical competence as a general competence is generally not guaranteed when compiling tasks but is based on the subject-specific content topics. For a broader assessment of the latter, it may be reasonable to define in the mathematics e-assessment framework that in addition to the Applying procedures ability also Problem-solving ability, Reasoning ability, Representation ability, Connection ability, and Communication ability as defined in the MCRF research framework should be assessed in different content topics (Lithner et al., 2010). Such an approach could well support the development of mathematical competence as defined in the assessment frameworks of the PISA and TIMSS tests (see OECD, 2018; TIMSS, 2015), as they are closely linked to the MCRF framework, which opens up the same ideas more specifically. The MCRF assessment framework also pointed out that all sub-competencies of mathematical competence can be expressed in interpreting, doing and using, and judgement skills. The analysis conducted in this study showed that of the 23 tasks in the math e-tests used in three years, only one focused on judgement. The other dimensions were relatively equally covered. This result again shows that a systematic approach to assessing mathematical competence in the design of tasks could be helpful in a balanced assessment of the different dimensions of mathematical competence as a general competence.

In future research, it would be wise to focus on the individual questions of the mathematics competency assessment tasks, which clearly focus on one dimension rather than several at a time. It would then be possible to assess the possibility of empirically distinguishing the dimensions of mathematical competence and then to assess the development of sub-competencies more systematically. It would also allow for better personalisation of learning, providing each student with individual feedback and suggestions for emphasising further learning, both alone and with other students. In this work, an assessment framework adapted by us based on the MCRF framework could also be suitable for developing new math problems and planning learning activities in schools. Based on the same framework, it is also possible to monitor changes taking place throughout school levels and, based on this, plan activities to support curriculum development and curriculum implementation.

Keywords: mathematical competence, general competence, e-tests, assessment