Assessment of Secondary School Students' Transversal Skills in Optimal and Highest-Level Mathematics

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ABSTRACT

Aim. The aim of this study is to assess secondary school students' transversal skills in mathematics at the optimal and highest level to determine whether education reforms have been implemented successfully.

Methods. In total 512 students from grades 11 and 12 participated in the research. Data was gathered by survey. Students transversal skill assessments from optimal and highest level was compared. The data was analysed with descriptive statistics to summarise and describe collected data (Vetter, 2016). Correlation between each transversal skill was made and Mann–Whitney U tests were conducted to determine whether there is a statistically significant difference between the self-assessments of students learning at the optimal and highest levels.

Results. The analysis shows that students have adequate transversal skills. However, students self-directed learning skills and civic skills are evaluated lower compared

to other transversal skills. Students who learn mathematics at the highest level have assessed their transversal skills higher compared to students who learn mathematics at optimal level.

Conclusions. Even though results indicate that students have well developed critical thinking and problem-solving skills, digital skills and collaboration skills, there are some gaps in students' transversal skills such as self-directed learning and civic participation. Transversal skills more connected to mathematical content or learning methods that promote subject learning are better developed, while other transversal skills that were not included in the previous curriculum should be promoted. This indicates that the recently implemented education reform has not yet been fully implemented into practice.

Keywords: transversal skills, secondary school, school mathematics, optimal level, highest level

Introduction

In the 21st century, globalisation and economic interaction between countries have contributed to the necessity of transversal skill development. These skills are essential for worldwide employment and are not specific to one particular job or industry (Karapetjana et al., 2017). In today's world, students need to develop transversal skills that allow them to solve everyday challenges to ensure competitiveness in the global economy (Rehman et al., 2021). Qualitative and inclusive education is the foundation of a stable and sustainable country. Latvian citizens have lifelong access to education, creating a sustainable democratic society, internationally excellent science, innovative enterprises, and a competent workforce. Latvia's education system at all levels not only meets today's requirements but is also open to the challenges of the future, preparing critically thinking, emotionally intelligent and digitally skilled specialists (Pārresoru koordinācijas centrs, 2020). One of the possibilities for promoting the objectives set out in the National Development Plan of Latvia is to promote the development of transversal skills, starting from pre-school and continuing in further education. Transversal skills are an essential component of the learning process as they help students gain knowledge in different contexts and use divergent thinking and self-driven learning techniques (Skola 2030, 2019b). These skills include cognitive, affective and social aspects that apply to all directions of human activity.

Transversal skills, alongside multilingual skills, are also highlighted as an essential component in European Commission documents (European Commission, 2019, 2021). The main objective of this initiative is to support labour mobility across Europe, thereby making the labour market more integrated and efficient. The Transval-EU project was launched in 2023, and as part of the project, a conference was held to discuss

policy activities and share experience on the development of transversal skills (Making all Skills Visible: Tools and Methods for Assessing Transversal Skills, 2023).

Education reform is also taking place in Latvia, as a result of which the following transversal skills to be acquired in secondary school were defined: critical thinking and problem-solving skills, creativity and entrepreneurship skills, self-directed learning skills, collaboration skills, civic participation skills, and digital skills (Ministru kabinets, 2019). As a subject in secondary education, mathematics is versatile and fundamental, as it not only provides practical skills in everyday life but also promotes intellectual, professional and personal development, making it an integral part of education. In Latvia, secondary school students can learn mathematics at the optimal or highest level.

The assessment of transversal skills is essential, as it enables students to recognise their strengths and weaknesses, fostering personal growth and targeted skill development. Assessment also promotes self-reflection, which is necessary for effectively planning one's learning process and making informed career choices. By monitoring reflection, teachers can more effectively support the development of transversal skills in mathematics at secondary school.

Theoretical Background

Since the 2010s, transversal skills such as critical thinking, collaboration, creativity, and learning skills are vital at all levels of education, as well as at work and in life. The development of these skills plays an important role as they contribute to sustainable economic growth, social inclusion and competitiveness. In the EU, employers, employees and education institutions are encouraged to develop these skills (European Commission, 2024). Transversal skills are generic skills that are not specific to a particular profession or activity. They can be used in different situations, regardless of a person's technical knowledge. These skills are an essential part of modern and future education. They help students develop capacities that can contribute to more efficient and more productive lives in the future (Terol Pastor, 2020). The best course of action to prepare students for an unknown future in times of uncertainty is to promote the development of transversal skills (Maunsell, 2023). The labour market requires specialists with transversal skills adapted to modern conditions, capable of adapting and developing to the needs of the workplace. Unlike technical skills, transversal skills are more sustainable because they are less affected by technological advances. Technological development presupposes the development of transversal skills (Lāma, 2020).

One of the challenges facing higher education is developing students' transversal skills (Jussila et al., 2023). They therefore need to be realised in previous levels of education – pre-school, primary school, and especially secondary school – but

the lack of a coherent approach may become an obstacle to the development of these skills and the transition from learning to work (Tam & Trzmiel, 2018), as at this stage, secondary school students are about to realise the immediate objectives of continuing their education in higher education institutions. The results of previous studies indicate the need to improve pupils' transversal skills in order to meet labour market requirements, cooperation between all actors involved in the process (policymakers, industry and educators), and, from an educational point of view, the need to introduce new learning approaches to implement and assess the acquisition of transversal skills (Lopez & Rodriguez-Lopez, 2020). Motivational methods and learning techniques, such as learning through role-playing games (Sánchez Quinto & Vives Abril, 2022), virtual reality (Villarejo Muñoz, 2022) or cooperative learning (Larraz et al., 2017), are sought to foster the development of these skills.

Mathematical education includes many skills, including planning and organising learning and thinking critically. Students' self-assessment determines the accuracy, reliability and relevance (or usability) of the materials provided (Holmes & Hwang, 2016). The purpose of mathematical learning content is to promote students' critical thinking. Analytical and critical thinking includes data screening, drawing conclusions, formulating ideas and evaluating claims. Mathematics develops students through cognitive processes related to mathematical problem-solving (Schoenfeld, 2014), providing them with a meaningful understanding of the mathematical concepts behind the issues to be addressed (Friedlander & Arcavi, 2017) and thereby fostering critical thinking and problem-solving skills.

In recent years, educational reforms have taken place in many countries, leading to the development of new curricula and an interactive learning environment that promotes active learning, cooperation and interdisciplinary learning and enables the development of transversal skills (Guilland, 2016). Educational reform is currently underway in Latvia at all levels of education, reviewing, supplementing and restructuring training content and improving the course of the learning process (Skola 2030, 2019a). In Latvia, the acquisition of transversal skills at the secondary school stage is specified in Cabinet of Ministers Regulation No. 416 on general secondary education standards and programmes (Ministru kabinets, 2019). However, how and when these skills can be identified and developed is a challenge for educational institutions (Maunsell, 2023). The creation and assessment of this skills assessment tool is also a challenge (Reynolds et al., 2020).

Students who learn mathematics at the optimal or highest level in grades 11 and 12 in order to monitor their transversal skill development were surveyed. The design of the questionnaire took into account the skills and definitions of transversal skill content, as well as the planned results to be achieved by secondary education students. Both the definitions and the intended outcomes in this study are used in accordance with the Regulations on national general secondary education standards and general secondary education programme samples. (Ministru kabinets, 2019). Table 1 shows

the content of the transversal skills and the corresponding statements that reveal the content of the skill.

Table 1

Transversal Skill Framework

Transversal skills	Questionnaire statements
Critical thinking and problem-solving skills – formulate and critically analyse complex situations and abstract ideas, obtain comprehensive and accurate information about them, employ situational problem-solving strategies, propose different solutions and choose the most appropriate target, adapt flexibly to unforeseen changes.	1. When I address problem-solving tasks, I understand the information given and what I have to find out. 2. I interpret or explain the solution to the mathematical task. 3. I examine the result and opt for a different solving method if necessary.
Creativity and entrepreneurship skills – looking at the situation with interest and from different perspectives, sees new opportunities and offers different, original solutions, proactively seeks opportunities to improve his or her quality of life and that of others, knows how to manage the process from creating an idea to implementing, uses errors as an opportunity for growth, and maintains calmness and openness in atypical situations.	4. I accept new challenges in mathematics, maintaining an emotional balance. 5. Looking at the situation or the task from different angles, I notice new opportunities in mathematics. 6. In mathematical lessons, I develop ideas both individually and in a group to use in the future. 7. I use mistakes and difficulties in mathematics as an opportunity for growth.
Self-directed learning skills – analyses the relationship between activity and emotions, personality traits, and behaviour. Sets short- and long-term objectives, draws up a plan for the achievement of the objectives and adapts them to the achievement of the objectives, uses criteria for evaluation and improvement of the work, gathers lessons learned, and uses them in the future. Independently selects, customises and applies learning strategies appropriate to the task to be performed.	8. I set personal goals for mathematics lessons. 9. I set out the criteria for determining whether a goal has been achieved in mathematical learning. 10. I independently and regularly analyse my work toward achieving the stated goal in mathematics.

Transversal skills	Questionnaire statements
Collaboration skills – successfully collaborates in both homogenous and heterogeneous groups, supports and promotes constructive group collaboration, involves and utilises the diverse knowledge, skills and experience of the student's classmates to achieve the best possible outcome, focusing on the common good and the objectives of the group.	11. I use respectful verbal, non-verbal and digital communication with others to achieve my goals in mathematics. 12. I collaborate in groups to perform tasks in mathematics, accepting a diversity of opinions and experiences. 13. I can represent my own interests and respect the interests of others in mathematics lessons when the group's and my needs differ.
Civic participation skills – describes interactions at different levels, explains his/her involvement in and the consequences of multifaceted processes, assumes responsibility, offers ideas and actively engages in societal challenges. Engages in activities based on their values and respecting the values of others. Justifies the need for rules, respects them and encourages change by justifying their necessity.	14. I use mathematical knowledge and skills in the local community (school, interest groups, etc.) to improve quality of life. 15. I take responsibility for data-based arguments by expressing my opinion in public.
Digital skills – effectively exploits digital technologies for different purposes, analyses the benefits and risks of digital communication, critically analyses the credibility of information in the media. Respects privacy, ethical and legal conditions when creating content. Assesses and adapts to his/her needs and follows healthy and safe technology usage habits.	16. I purposefully choose and effectively use appropriate digital technologies to accomplish tasks in mathematics learning. 17. In mathematical lessons, I learn the skill of respectfully communicating in the digital environment according to my own interests and those of others. 18. In mathematics lessons, I learn the skill of respecting privacy and legal conditions in the digital environment.

Source. Ministru kabinets, 2019 – Table 1 left column.

Research Methodology

Aim of the study: To comprehend and compare the assessment of secondary school students' transversal skills in optimal- and highest-level mathematics.

Research question: How do secondary school students assess their transversal skills in optimal- and highest-level mathematics?

Transversal skills self-assessment survey was used to assess secondary school students' transversal skills in mathematics. The questionnaire was developed based on transversal skill framework of a secondary school mathematics curriculum. In Latvia there are 23796 students from grades 11 and 12 (Latvijas Atvērto datu portāls,

2023). In total, 512 students from grades 11 and 12 participated in the study (Table 2). Therefore, with a 95% confidence level, the margin of error is 4.29%.

Table 2

Characteristics of Study Participants

Grade	**N**	**%**
Grade 11	299	58%
Grade 12	213	42%
Gender	*N*	*%*
Male	210	41%
Female	288	56%
Other gender or unwilling to specify	14	3%
School type	*N*	*%*
Gymnasium	87	17%
Urban school	339	66%
Rural school	86	17%
Level of learning	*N*	*%*
Optimal level	384	75%
Highest level	128	25%

Source. Own research.

The questionnaire consisted of statements measured on a 5-point Likert scale (5=very good, 4=good, 3=acceptable, 2=poor, 1=very poor). In total, six transversal skills were measured: critical thinking and problem-solving skills (3 statements), creativity and entrepreneurship skills (4 statements), self-directed learning skills (3 statements), collaboration skills (3 statements), civic participation skills (2 statements), and digital skills (3 statements).

To involve participants in the research, the following steps were taken:

- A list containing all Latvian secondary school names and official email addresses was acquired from the Ministry of Education.
- An email with a proposal to participate in the study was sent from the researcher's official university email address to all Latvian secondary schools, and after a week, a reminder email was sent. The email contained instructions on how to organise a survey and a link to the questionnaire itself.

The questionnaire was distributed using QuestionPro and was available from March 25, 2024, until April 12, 2024. SPSS and Excel were used for data analysis. Approval for conducting this research was obtained from the Research Ethics Committee of Social Sciences and Humanities of the University of Latvia (14.03.2024. Nr.71–43/41).

To determine the Likert scales' reliability, Cronbach's alpha values were calculated for each transversal skill (Table 3). For all six transversal skills, Cronbach's

alpha is over 0.6; therefore, the Likert's scales' internal consistency is satisfactory (Taber, 2018).

Table 3
Likert Scales' Internal Consistency

Transversal skill	Cronbach's Alpha	N of Items	Transversal skill	Cronbach's Alpha	N of Items
Critical thinking and problem-solving skills	0.772	3	Collaboration skills	0.784	3
Creativity and entrepreneurship skills	0.851	4	Civic participation skills	0.687	2
Self-directed learning skills	0.859	3	Digital skills	0.766	3

Source. Own research.

The data was analysed with descriptive statistics summarise and describe collected data (Vetter, 2016). Cronbach's alpha values were calculated for each transversal skill separately to determine each Likert scale's internal consistency. Spearman rank correlations between each transversal skill were calculated to determine whether transversal skills are connected. Mann–Whitney *U* tests were conducted to determine whether there was a statistically significant difference between the self-assessments of students learning at the optimal and highest levels.

Research Results

Students who learn mathematics at the optimal level self-assessed their collaboration skills (M =3.58, Mdn = 3.67, SD = 0.78), digital skills (M = 3.57, Mdn = 3.67, SD = 0.78), and critical thinking and problem-solving skills (M = 3.46, Mdn = 3.33, SD = 0.77) as more developed compared to other measured transversal skills (Table 4).

Table 4
Optimal-level Mathematics Students' Transversal Skills Self-assessments

Transversal skill	Mean	Median	Standard deviation	Skewness	Kurtosis
Critical thinking and problem-solving skills	3.46	3.33	0.77	-0.18	0.15
Creativity and entrepreneurship skills	3.29	3.25	0.81	-0.30	0.05
Self-directed learning skills	3.10	3.00	0.86	-0.05	-0.12
Collaboration skills	3.58	3.67	0.80	-0.48	0.34
Civic participation skills	3.15	3.00	0.93	-0.29	-0.08
Digital skills	3.57	3.67	0.78	-0,40	0.48

Source. Own research.

Optimal-level mathematics students' transversal skills that are perceived as more developed are in line with previously conducted studies (Lāma, 2022, 2023). It is possible that this collaboration is manifested in students handing their already completed homework to other students, who then automatically copy it without understanding the process. However, collaboration skills are revealed in the interaction resulting from the pedagogical learning activities of teachers and students, systematically progressing through the planning, implementation and evaluation phases. Learning does not happen immediately but moves forward at certain stages. Teachers help students learn effectively during the process by promoting the desired collaborative learning process (Putri et al., 2023).

Students self-assessed their creativity and entrepreneurship skills (M = 3.29, Mdn = 3.25, SD = 0.81), participation skills (M = 3.15, Mdn = 3.00, SD = 0.93), and self-directed learning skills (M = 3.10, Mdn = 3.00, SD = 0.96) as less developed. The previously mentioned skills' data dispersions are also higher compared to other measured transversal skills, indicating higher skill self-assessment diversity.

Students who learn mathematics at the highest level self-assessed their transversal skills similarly (Table 5).

Table 5

Highest-level Mathematics Students' Transversal Skills Self-assessments

Transversal skills	Mean	Median	Standard deviation	Skewness	Kurtosis
Critical thinking and problem-solving skills	3.85	4.00	0.73	-0.23	-0.61
Creativity and entrepreneurship skills	3.70	3.75	0.87	-0.44	-0.19
Self-directed learning skills	3.19	3.00	1.05	-0.13	-0.59
Collaboration skills	3.84	4.00	0.89	-0.70	0.24
Civic participation skills	3.44	3.50	0.91	-0.34	-0.22
Digital skills	3.76	4.00	0.90	-0.51	0.00

Source. Own research.

Highest-level students self-assessed their critical thinking and problem-solving skills (M = 3.85, Mdn = 4.00, SD = 0.73), collaboration skills (M = 3.84, Mdn = 4.00, SD = 0.89), and digital skills (M = 3.76, Mdn = 4.00, SD = 0.90) as more developed compared to other measured transversal skills. For all these transversal skills, the medians are equal (4.00). Students self-assessed their creativity and entrepreneurship skills (M = 3.70, Mdn = 3.75, SD = 0.87) slightly lower. However, the results for all four transversal skills are quite similar. Highest-level students self-assessed their civic participation skills (M = 3.44, Mdn = 3.50, SD = 0.91) as less developed and their self-directed learning skills (M =3.19, Mdn = 3.00, SD =1.05) as least developed.

Students who learn mathematics at the highest level self-assessed all their transversal skills higher than those who learn mathematics at the optimal level. To determine

whether there is a statistically significant difference between students' transversal skill self-assessments, Mann–Whitney *U* tests were conducted (Table 6).

Table 6

Mann–Whitney U Test Results for Optimal and Highest-level Mathematics Students

Transversal skills	Level	N	Mean Rank	Sum of Ranks	Mann–Whitney U	Z	Asymp. Sig. (2-tailed)
Critical thinking and problem-solving skills	Optimal level	384	238.12	91439	17519	-4.91	<0.001
	Highest level	128	311.64	39890			
Creativity and entrepreneurship skills	Optimal level	384	238.92	91745	17825	-4.68	<0.001
	Highest level	128	309.25	39584			
Self-directed learning skills	Optimal level	384	252.92	97123	23203	-0.96	0.340
	Highest level	128	267.23	34205			
Collaboration skills	Optimal level	384	243.97	93684	19764	-3.35	0.001
	Highest level	128	294.09	37644			
Civic participation skills	Optimal level	384	245.40	94236	20316	-2.98	0.003
	Highest level	128	289.79	37093			
Digital skills	Optimal level	384	247.68	95111	21191	-2.36	0.018
	Highest level	128	282.95	36218			

Source. Own research.

Comparing both student cohorts, it can be concluded that there is a statistically significant difference for five out of six transversal skills: critical thinking and problem-solving skills ($Z = -4.91$, $p < 0.001$), creativity and entrepreneurship skills ($Z = -4.68$, $p < 0.001$), collaboration skills ($Z = -3.35$, $p = 0.001$), civic participation skills ($Z = -2.98$, $p = 0.003$), and digital skills ($Z = -2.36$, $p = 0.018$) are all more developed for students who learn mathematics at the highest level. The biggest mean value differences are for critical thinking and problem-solving skills and creativity and entrepreneurship skills. This can be explained by mathematics' specificity. Critical thinking is closely linked with mathematics and is necessary in solving most problems. Similarly, creativity is connected with the skill of combining

different learning methods and requires in-depth mathematical knowledge. There is no significant difference in students' self-directed learning skills. However, both optimal- and highest-level students' self-directed learning skills are insufficient; therefore, teachers should concentrate on tasks and learning structures that promote self-directed learning skills.

To determine whether transversal skills are connected, Spearman's rank correlation tests were conducted (Table 7).

Table 7

Spearman's Rank Correlation Between Transversal Skills

Spearman's rho	Critical thinking and problem-solving skills	Creativity and entrepreneurship skills	Self-directed learning skills	Collaboration skills	Civic participation skills	Digital skills
Critical thinking and problem-solving skills	1.000	0.696**	0.476**	0.524**	0.524**	0.499**
Creativity and entrepreneurship skills		1.000	0.614**	0.599**	0.590**	0.584**
Self-directed learning skills			1.000	0.472**	0.570**	0.518**
Collaboration skills				1.000	0.489**	0.605**
Civic participation skills					1.000	0.553**
Digital skills						1.000

** = correlation is significant at the 0.01 level (2-tailed).

Source. Own research.

The results indicate that all the measured transversal skills are connected. There is a statistically significant correlation for all transversal skill pairs. The correlation between most of the transversal skill pairs is moderate, but for three pairs, the correlation is strong (Akoglu, 2018). Therefore, critical thinking and problem-solving skills and creativity and entrepreneurship skills (r = 0.696), creativity and entrepreneurship skills and self-directed learning skills (r = 0.614), and collaboration skills and digital skills (r = 0.605) are more connected.

Discussion

The development of transversal skills is widely recognised as a crucial component of high-quality, inclusive, and contemporary education. In recent years, educational reforms in many countries, including Latvia, have led to the creation of new curricu-

la and the establishment of interactive learning environments that foster active learning and the enhancement of transversal skills.

Students at both optimal and highest levels rated their transversal skills similarly. They identified their digital skills, collaboration abilities, and critical thinking and problem-solving competencies as the most developed, while self-directed learning skills were assessed as less advanced. This suggests a need to focus on activities that enable students to set and achieve goals, develop actionable plans, and utilise criteria for evaluating and improving their work. The average ratings for all transversal skills across both groups of students were above the scale average and were deemed to be relatively strong. Among students studying mathematics at the optimal level, collaboration skills were rated as the most developed transversal skill, likely due to peer collaboration on homework. In this context, collaboration is often understood as sharing completed assignments without engaging in the detailed problem-solving process. Students and their teachers have assessed students' collaboration skills in secondary school mathematics as well developed also in previous studies (Lāma, 2022).

Students studying mathematics at the highest level rated their critical thinking and problem-solving skills the highest, indicating an improvement in these areas. In the school mathematics focus are usually more on critical thinking and less on problem solving (Helmane & Vigule, 2023). To further promote these skills, teachers could offer real-world mathematics problems for students to solve collaboratively in pairs or small groups (Brannon, 2016).

The average transversal skills assessment among students at the highest mathematics level were higher than those of students at the optimal level, with statistically significant differences in assessments of critical thinking and problem-solving skills, creativity and entrepreneurship, collaboration, civic participation, and digital skills. However, the difference in self-directed learning skills was not statistically significant. This highlights the importance of transversal skills in learning mathematics at higher levels. Critical thinking, problem-solving, creativity, and entrepreneurship are crucial for addressing complex challenges and combining problem-solving methods (Lavrinoviča, 2021), which may explain the differences in assessments. The difference in digital skills could stem from the advanced mathematical knowledge of higher-level students, which allows them to better assess the appropriateness of digital solutions for performing tasks. However, further research is needed to explore the gap in transversal skills between students at the optimal and highest levels.

All transversal skills in mathematics learning are closely interconnected, with at least a medium statistically significant correlation observed between all pairs of transversal skills. This suggests that the development of transversal skills is interdependent, and the underdevelopment of one skill may impact the level of others, ultimately affecting the overall learning outcomes.

Conclusions

In this study transversal skills of secondary school students in mathematics at both optimal and highest levels are measured. In result of education reforms transversal skill development have been implemented in Latvian secondary school mathematics as independent learning outcome. To determine whether schools have successfully implemented a new mathematics curriculum survey measuring students' transversal skills was conducted. Survey results indicate that students have well developed critical thinking and problem-solving skills, digital skills and collaboration skills, while self-directed learning and civic participation are transversal skills that students have self-assessed lower and, therefore, should be promoted.

Limitations

Self-assessments cannot be fully representative of actual students' skills development level as they tend to be connected with perception. Other methods, such as objective skill tests and observation, could be applied to further explore students' transversal skills in secondary school mathematics. The study is also limited by the assessment of civic participation skills, as it often relies on self-perception and personal experience, which can be subjective. Moreover, the evaluation criteria may vary depending on context and interpretation, making data comparability more difficult. These factors can restrict the generalisability and accuracy of conclusions regarding manifestations of civic participation.

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