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New Examination Approach for Real-World Creativity and Problem-Solving Skills in Mathematics

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Abstract: This paper presents a new and innovative examination method designed to foster creativity, problem-solving, and collaboration in mathematics education. Traditional assessment practices often focus on rote memorization and fail to engage students in the exploration of mathematical concepts and connect the content to real-world problems. In contrast, the proposed examination approach requires students to invent and solve their own mathematical tasks based on their personal interests and experiences. By actively engaging with mathematical concepts and relationships, students deepen their understanding while developing essential skills such as communication, self-assessment, and peer feedback. Anonymized peer correction is also introduced as a means of minimizing bias and promoting objectivity and a wider understanding. The study investigates student perceptions of the examination based on their experiences regarding its effects on creativity and problem-solving skills. The findings suggest that the new way of examining may not only enhance students' mathematical understanding and problem-solving abilities but also foster a collaborative learning environment that encourages communication and peer support. The paper concludes that the adoption of this new method has the potential to transform traditional assessment practices and promote more engaged, creative, and collaborative learning experiences for students in a wide range of subjects.

Keywords: education; mathematics; examination; student-centered learning; peer-correction; problem-solving; creativity; assessment; remote learning; COVID-19



Citation: Nilimaa, J. New Examination Approach for Real-World Creativity and Problem-Solving Skills in Mathematics. *Trends High. Educ.* **2023**, *2*, 477–495. <https://doi.org/10.3390/higheredu2030028>

Academic Editor: Carla C. Johnson

Received: 11 May 2023

Revised: 6 July 2023

Accepted: 10 July 2023

Published: 17 July 2023



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1. Introduction

In the ever-evolving landscape of education, the need for innovative approaches to teaching and assessment is becoming increasingly important. Traditional methods of teaching and examination in mathematics have long been criticized for promoting rote learning and memorization [1] rather than fostering the creative and critical thinking skills necessary to navigate the complex problems of the real world [2].

In response to this challenge, this research paper investigates a new form of examination that emphasizes creativity, problem-solving, and collaboration in a basic mathematics course in higher education. The proposed examination method deviates from conventional assessment practices by requiring students to invent, solve, and explain their own mathematical tasks in a series of four examinations throughout the course. Every student is thereafter assigned to another student's examination for anonymous peer assessment. This approach aims to engage students more deeply in the learning process by encouraging them to actively explore mathematical concepts and relationships while also fostering essential skills such as creativity, problem-solving, communication, self-assessment, and peer feedback. The anonymity of the peer correction process aims to minimize bias, increase the student's understanding of how their peers think, and promote objectivity in the evaluation process.

This paper will first review the theoretical underpinnings of this innovative examination approach and its alignment with current research on mathematics education. It will explore how the integration of creativity, problem-solving, and peer assessment supports

a more holistic understanding of mathematics and the development of creativity, critical thinking, and problem-solving skills. Furthermore, it will analyze the potential benefits and challenges associated with the implementation of the proposed examination method in the higher education classroom. By investigating the student-perceived efficacy of this novel examination approach, this paper seeks to contribute to the ongoing dialogue surrounding the enhancement of mathematics education and the promotion of creativity, critical thinking, and problem-solving skills for students. Ultimately, it aims to provide valuable insights for educators, policymakers, and researchers as they continue to explore and implement innovative strategies for improving mathematics education and fostering the development of well-rounded, creative problem-solvers. The study, however, only focused on the context of the new examination method compared to the current state-of-the-art in mathematics education. Furthermore, it only focused on the personal perceptions of the students and did not investigate the actual impact on the course results.

2. State of the Art in Mathematics Education

2.1. Traditional Approaches to Mathematics Education and Assessment

Mathematics education has historically been dominated by traditional approaches that emphasize the mastery of mathematical procedures, techniques, and algorithms through direct instruction, practice, and repetition [3]. These approaches tend to prioritize the memorization of facts, formulas, and standard algorithms while neglecting the importance of creativity, critical thinking, and problem-solving [2,4]. The main features of traditional approaches to mathematics education and assessment include teacher centered instructions, a focus on procedural knowledge, rote learning and memorization, standardized testing and examination, and a limited focus on creativity and problem-solving.

Traditional mathematics education typically involves teacher-centered instruction, where the teacher delivers knowledge and demonstrates procedures to students who are expected to listen, take notes, and practice the techniques provided [5]. This approach often limits the opportunities for students to actively explore mathematical concepts, engage in discussion, or collaborate with their peers. The traditional instructions emphasize procedural knowledge, which refers to the ability to carry out a series of steps or actions to solve mathematical problems [6]. While procedural knowledge is essential, this approach often overlooks the importance of conceptual understanding, which is the comprehension of the underlying principles and relationships that govern mathematical concepts and gives them a clear context for the students.

A key aspect of traditional mathematics education is the reliance on memorization and repetition [1]. Students are often expected to memorize formulas, definitions, and standard algorithms without fully understanding the underlying concepts or reasoning. This approach can result in a superficial understanding of mathematics and a lack of flexibility when it comes to real-world challenges and more advanced problem-solving. Traditional assessment methods in mathematics primarily involve standardized tests and examinations that assess students' knowledge of facts, formulas, and procedures. These assessments tend to prioritize the recall of information and the application of standard algorithms, rather than evaluating students' ability to think critically, reason, and solve problems creatively [1,2].

The old approaches to mathematics education often fail to engage the students, and they typically do not prioritize the development of creativity, critical thinking, and problem-solving skills. Students may become proficient in applying standard procedures and techniques but struggle when faced with unfamiliar or open-ended problems that require flexible thinking and more innovative approaches. The traditional approaches to mathematics education and assessment have been criticized for their limitations when it comes to fostering the essential real-world skills required for success in modern society. Consequently, there has been a growing movement towards more student-centered learning [7], inquiry-based approaches [8,9], and alternative assessment methods that emphasize creativity, critical thinking, and problem-solving in higher education [10].

2.2. *The Shift toward Student-Centered Learning and Inquiry-Based Approaches*

In recent years, as the limitations of traditional mathematics education have become more apparent, there has been a significant shift toward student-centered learning and inquiry-based approaches. These pedagogical strategies prioritize active exploration, discovery, and problem-solving, empowering students to take ownership of their learning and fostering a deeper understanding of mathematical concepts [11].

Student-centered and inquiry-based approaches emphasize active learning, where students actively engage in the construction of their understanding through exploration, investigation, and problem-solving [12]. This contrasts with passive learning, where students mainly listen and absorb information from the teacher, which can be considered the old way of education. These new approaches prioritize the development of conceptual understanding [13], focusing on helping students grasp the underlying principles and relationships that govern mathematical concepts. This goes beyond simply mastering procedures and algorithms, enabling students to apply their knowledge flexibly and creatively in various contexts.

Student-centered learning and inquiry-based approaches are often grounded in constructivist theories of learning, which posit that knowledge is constructed by learners as they actively engage with new experiences and ideas [14]. Constructivist approaches encourage students to build on their existing knowledge, challenge their preconceptions, and make connections between different concepts. These approaches recognize the importance of collaboration and social interaction in the learning process. Students are encouraged to work together, share ideas, and engage in discussions to develop their understanding and problem-solving skills. This fosters a sense of community within the classroom and helps students develop valuable communication and collaboration skills.

Student-centered learning and inquiry-based approaches often involve the use of open-ended tasks and real-world problems that encourage students to think critically, creatively, and independently [15,16]. These tasks provide opportunities for students to explore multiple solutions, make connections between different mathematical concepts, and apply their knowledge in meaningful and relevant contexts. In contrast to traditional assessment methods, which primarily focus on evaluating students' knowledge at the end of a learning period, student-centered learning and inquiry-based approaches emphasize assessment for learning. This involves ongoing, formative assessment that provides feedback to students and teachers, allowing them to adjust their teaching and learning strategies as needed.

Research has shown that student-centered learning and inquiry-based approaches can lead to improved understanding of mathematical concepts, increased motivation and engagement, and the development of critical thinking and problem-solving skills [17]. The rapid recent development in technologies such as machine learning, AI, and robotics [18,19] has also accelerated the need for computational thinking (CT) in education [20]. The shift toward these approaches in mathematics education reflects a growing recognition of the need to better prepare students for the complex challenges of the 21st century by fostering creativity, critical thinking, and problem-solving skills.

2.3. *Creativity in Mathematics Education*

Creativity has long been recognized as an essential component of mathematical thinking and problem-solving [2]. Despite the common misconception that mathematics is a rigid and rule-based discipline, creativity plays a vital role in discovering new patterns, generating novel ideas, and developing innovative solutions to complex problems. In recent years, there has been a growing emphasis on fostering creativity in mathematics education to promote a deeper understanding of mathematical concepts, improved problem-solving abilities, and increased engagement and motivation among students [21,22].

Creativity in mathematics is manifested through various aspects, such as the ability to [23]:

- Identify and explore patterns, relationships, and connections between mathematical concepts;
- Generate multiple solutions or approaches to solve a problem;
- Think flexibly and adapt existing methods or techniques to solve novel or unfamiliar problems;

- Pose original questions or problems that stimulate mathematical inquiry and exploration.

Open-ended tasks are problems or activities that do not have a single, predetermined solution or method of solution. These tasks allow students to explore multiple pathways, make choices, and develop their own strategies for solving problems. Open-ended tasks have been shown to foster creativity, as they encourage students to think differently, take risks, and experiment with different ideas [24]. Engaging students in real-world problem-solving can promote creativity by providing meaningful and relevant contexts for mathematical exploration [25]. Real-world problems and abstract algebra often require students to integrate knowledge from various domains, consider multiple perspectives, and develop innovative solutions that meet specific constraints or requirements [26,27].

A growth mindset, as opposed to a fixed mindset, is the belief that intelligence and abilities can be developed through effort and learning. Research has shown that fostering a growth mindset can enhance students' creativity in mathematics by encouraging them to embrace challenges, persevere through difficulties, and view mistakes as opportunities for growth [28].

Teachers play a critical role in cultivating creativity in mathematics education [27]:

- Creating a supportive and safe learning environment that encourages risk-taking, experimentation, and learning from mistakes;
- Providing opportunities for students to engage in open-ended tasks, real-world problem-solving, and collaborative learning experiences;
- Encouraging students to think critically, reflect on their thinking, and develop a growth mindset;
- Modeling and valuing creativity through their own teaching practices and interactions with students.

Problem-posing in mathematics is an education theory that may involve students creating and solving their own mathematical problems, an approach that can significantly enhance creativity, understanding, and engagement [29]. This method encourages students to think beyond rote memorization, fostering the development of their critical and analytical skills. When students construct their own problems, they delve deeper into mathematical concepts and principles, broadening their understanding. Incorporating creativity into mathematics education can lead to numerous benefits, such as a deeper understanding of mathematical concepts, improved problem-solving abilities, and increased engagement and motivation among students [30]. By recognizing and nurturing creativity in mathematics, educators can help students develop the skills and dispositions necessary for success in a rapidly changing world.

2.4. Collaborative Learning and Peer Assessment

Collaborative learning and peer assessment are approaches that can foster creativity in mathematics education by providing opportunities for students to share ideas, build on each other's knowledge, and engage in critical discourse. Collaborative learning environments can also encourage students to take risks, challenge assumptions, and refine their thinking through feedback and reflection [31]. Collaborative learning and peer assessment are closely related educational strategies that emphasize the importance of social interaction and cooperation in the learning process [32,33]. Both approaches have gained attention in mathematics education research due to their potential for promoting critical thinking, problem-solving, and creativity [34]. Collaborative learning is an instructional approach that encourages students to work together in small groups or teams to solve problems, complete tasks, or explore concepts. This approach is based on the belief that learning is a social process and that students can benefit from sharing their ideas, knowledge, and experiences with their peers. Collaborative learning in mathematics education can take various forms, such as group problem-solving, joint projects, or cooperative investigations.

Research has shown that collaborative learning can lead to several positive outcomes in mathematics education, including:

- Improved conceptual understanding: By working together and discussing mathematical ideas, students can deepen their understanding of mathematical concepts and build on each other's knowledge [35,36];
- Development of critical thinking and problem-solving skills: Collaborative learning fosters critical thinking and problem-solving skills by encouraging students to analyze, evaluate, and synthesize information from multiple sources and perspectives [37];
- Increased motivation and engagement: Collaborative learning can enhance students' motivation and engagement by creating a sense of community and fostering positive social interactions [38];
- Development of communication and teamwork skills: Collaborative learning provides opportunities for students to practice and develop essential communication and teamwork skills as they work together to achieve common goals [39].

Peer assessment is an evaluation process in which students assess their peers' work based on specific criteria or guidelines. This can involve rating, ranking, or providing feedback on their peers' performance or products. In mathematics education, peer assessment can be used to evaluate students' solutions to problems, written explanations, or presentations of mathematical concepts. Research has demonstrated several benefits of incorporating peer assessment in mathematics education, such as:

- Enhanced metacognitive skills: By engaging in the process of evaluating their peers' work, students can develop their metacognitive skills, becoming more aware of their own understanding and learning strategies [40]. The stimulus of the metacognitive skills may also be a factor that promotes the student's own creativity [41];
- Improved self-regulation: Peer assessment can foster students' self-regulation by encouraging them to monitor, evaluate, and adjust their own learning and performance based on the feedback they receive from their peers [42];
- Increased motivation: Receiving feedback from peers can be more motivating for some students than feedback from teachers, as it may be perceived as less threatening and more relatable [43];
- Enhanced understanding of assessment criteria: Participating in peer assessment can help students develop a better understanding of assessment criteria and expectations, leading to improved quality of their own work [44].

2.5. Challenges and Barriers to Implementing Innovative Assessment Methods

Despite the potential benefits of innovative assessment methods, such as fostering creativity, critical thinking, and problem-solving skills, there are several challenges and barriers that educators and institutions may face when attempting to implement these approaches. Educators, administrators, and other stakeholders may be resistant to adopting innovative assessment methods due to a lack of familiarity or comfort with these approaches, or a belief in the effectiveness of traditional assessment methods. Changing deeply entrenched beliefs and practices may require significant effort and support [45].

Implementing innovative assessment methods may require additional resources, such as time for planning and development, materials, and technology [46]. Furthermore, educators may need professional development and training to effectively implement these assessment methods, particularly if they are unfamiliar with the approaches or lack confidence in their ability to use them [17]. Innovative assessment methods may not align well with existing curriculum frameworks and standards, which may prioritize content knowledge and procedural skills over creativity, critical thinking, and problem-solving. This misalignment may create challenges in terms of meeting the expectations of administrators, parents, and other stakeholders.

Implementing innovative assessment methods may be time-consuming, particularly if they involve the development of complex tasks, collaborative projects, or personalized feedback [46]. Teachers may face challenges in balancing the demands of innovative assessments with other responsibilities, such as instructional planning and classroom management. Ensuring the reliability and validity of innovative assessment methods may be

challenging, particularly when evaluating complex skills such as creativity, critical thinking, and problem-solving. Developing clear rubrics, criteria, and guidelines can help address this issue, but it may still require a significant investment of time and effort. Implementing innovative assessment methods may raise concerns about equity, particularly if they involve the use of technology or resources that are not equally accessible to all students. Additionally, alternative assessment methods may inadvertently advantage or disadvantage certain student populations, depending on factors such as cultural background, prior experiences, and language proficiency.

Despite these challenges and barriers, many educators and institutions are increasingly recognizing the need to incorporate innovative assessment methods to better prepare students for the demands of the 21st century. By addressing these challenges through targeted support, professional development, and ongoing evaluation and refinement, innovative assessment methods can become an integral part of a comprehensive and effective mathematics education.

2.6. Emerging Technologies and Digital Tools in Mathematics Education

The rapid advancement of technology has had a significant impact on education, including mathematics. Emerging technologies and digital tools offer new opportunities to enhance the teaching and learning of mathematics by providing interactive, engaging, and personalized experiences for students. Various computer-based learning environments, such as online platforms, learning management systems, and digital textbooks, enable students to access and engage with mathematical content in interactive and flexible ways. These environments can incorporate multimedia elements, such as animations, simulations, and videos, to help students visualize and explore mathematical concepts more effectively [47].

Educational games and gamification incorporate game elements [48], such as points, levels, and challenges, to engage students and motivate them to learn. In mathematics education, games can provide opportunities for students to practice skills, solve problems, and explore concepts in a fun and interactive context. Mobile learning involves the use of mobile devices, such as smartphones and tablets, to access and engage with educational content. In mathematics education, mobile learning can provide students with on-the-go access to digital resources, apps, and tools for practicing skills, exploring concepts, and collaborating with peers.

Online collaboration tools, such as digital whiteboards, video conferencing platforms, and shared document editors, can facilitate communication and collaboration among students and teachers in mathematics education. These tools can be used to support group problem-solving, peer feedback, and remote learning experiences. Learning analytics involves the collection, analysis, and use of data related to students' learning experiences to inform instructional decision-making. In mathematics education, learning analytics can help teachers monitor students' progress, identify areas of struggle, and tailor instruction and feedback to meet individual needs [43].

3. Materials and Methods

In this paper, we investigated the student-perceived impact of a new and innovative examination method aiming to promote student engagement, creativity, and problem-solving skills in a basic mathematics course in higher education. The examination involved students first inventing and solving their own mathematical tasks in four examinations over the course, presenting their solutions clearly, and finally delivering the exams to another student for anonymous peer assessment. The examination principles were introduced as a method for safe remote examination during the COVID-19 pandemic, with a start in the middle of the spring semester 2020, and the examination procedure has continued since then.

3.1. Participants

The study involved students from two Higher Education Diploma programs at Luleå University of Technology in Sweden [49,50]. A total of 153 participants were enrolled in the study over seven course occasions, between the spring semester of 2020 and the spring semester of 2023. The participants represented well-balanced gender equality, with 80 male and 73 female students. The participants were in their first year, taking a foundational mathematics course common to both programs. The students' ages ranged from 18 to 49.

3.2. Study Design

The study employed a mixed-methods, exploratory design to evaluate the student-perceived impact of the new examination method on their motivation, creativity, problem-solving skills, and self-confidence in their ability to solve mathematical tasks in their future profession. Data were collected through two primary sources: student responses in the general course evaluation and personal communication between the teacher and students. This design was chosen to obtain a more nuanced understanding of the students' experiences and their thoughts on the potential benefits or disadvantages of the examination method.

3.3. Data Collection

Course evaluations: At the end of each course, students at Luleå University of Technology complete a course evaluation survey that includes questions related to their personal experiences of the course, including the examination method, and their overall satisfaction with the course. The survey consists of both closed-ended questions using a scale between 1 and 6 and open-ended comments allowing for more in-depth responses. Four additional yes/no questions were also submitted separately to investigate the student perception of the new examination method.

Personal communication: Throughout the seven courses employing the new examination method, the teacher engaged in personal communication with students, both individually and in small groups. These conversations provided opportunities for students to discuss their experiences of the examination, ask questions, and share feedback. The teacher took detailed notes during these conversations to capture the students' perspectives.

3.4. Intervention

The intervention, which has been used on seven occasions in a basic mathematics course since its introduction in the spring of 2020, consists of four examinations throughout the 20-week course at half-time speed. The examinations involve the following topics: 1. Numerical calculations, equations and inequalities, and coordinate systems; 2. Math formulas, geometry, and trigonometry; 3. Equation systems, linear functions, and factoring; 4. Non-linear equations, exponential and logarithmic functions, and statistics.

The lectures leading up to each examination are based on more traditional approaches to lectures and problem-solving. The first task of the examination is for the students to invent and solve their own tasks based on their personal experiences and interests. Thereafter, they present the solutions clearly as a written assignment and submit their exams as online submissions. The online system delivers the exam to another student for anonymous peer correction. After conducting the necessary corrections and improvements proposed by the peer-review, the teacher performs a final review. The intervention is structured as follows:

- **Inventing tasks:** Students independently create original mathematical problems that incorporate creativity and problem-solving aspects within a specified part of the course. They are encouraged to think critically about the course material, identify interesting connections, and design problems that require a deep understanding of the concepts. Teachers provide guidance and support during the problem-creation process, ensuring that the tasks are both challenging and appropriate for the students' level. The students are instructed to create an exam with an appropriate amount of

assignments suitable to be solved during a 1.5 h lecture, and they should thereby independently estimate how many tasks are required for each exam;

- Solving tasks: Students solve their self-created problems, providing clear and detailed solutions, including explanations of their thought processes and strategies. They are expected to demonstrate their understanding of the underlying concepts and effectively communicate their reasoning through well-organized and coherent presentations;
- Peer assessment: Examinations are exchanged anonymously among students within the intervention group. Each student assesses another student's work using a provided rubric, which covers the extent of the tasks, correctness of the solutions, creativity, problem-solving, clarity, and presentation. The rubric is designed to encourage constructive feedback and promote a shared understanding of the assessment criteria among students. Teachers also review the peer assessments to ensure consistency and fairness in the evaluation process;
- Reflection and feedback: Students reflect on the peer assessment feedback and identify areas for improvement in their problem-solving skills and communication strategies. Teachers facilitate discussions and provide additional guidance to help students integrate the feedback into their learning process. Throughout the intervention, teachers monitor students' progress and adjust as needed to support their growth and development.

4. Results

The results are based on voluntary course evaluations and personal communication between lecturers and students. Five questions were selected from the standardized course evaluations at Luleå University of Technology. These questions were not specifically designed to evaluate the intervention but can, however, be used to evaluate the student's perception of the course and the new way of examination. The questions cover the students' overall experience of the mathematics course and the new examination procedures. The five questions were:

1. I am satisfied with my efforts during the course;
2. My overall impression is that this has been a good course;
3. The intended learning outcomes of the course have been clear;
4. The course planning/study guidance has given good guidance;
5. The examination was in accordance with the intended learning outcomes of the course.

The students graded their experience of each question on a scale up to a maximum score of six, where a low score implied "strongly disagree" and a high score implied "strongly agree". The combined results of four course evaluations (Fall 2020, Fall 2021, Spring 2022, and Fall 2022) are shown in Figure 1. The course evaluation was not carried out in the spring semester 2021 due to a failure in the digital system, and the evaluation for the spring semester 2023 has not yet been submitted. In total, 58 students responded to the anonymous course evaluations on four occasions.

Four additional yes/no questions were asked in a separate evaluation to investigate the student perception of the examination and peer assessment and their impact compared to traditional examinations. These questions were:

1. Do you prefer the new examination method compared to traditional exams?
2. Did the new examination method challenge my creativity and problem-solving skills more than traditional exams?
3. Did the peer assessment improve your understanding of mathematics?
4. Do you feel more prepared to face mathematical problems in your future profession now than before the course?

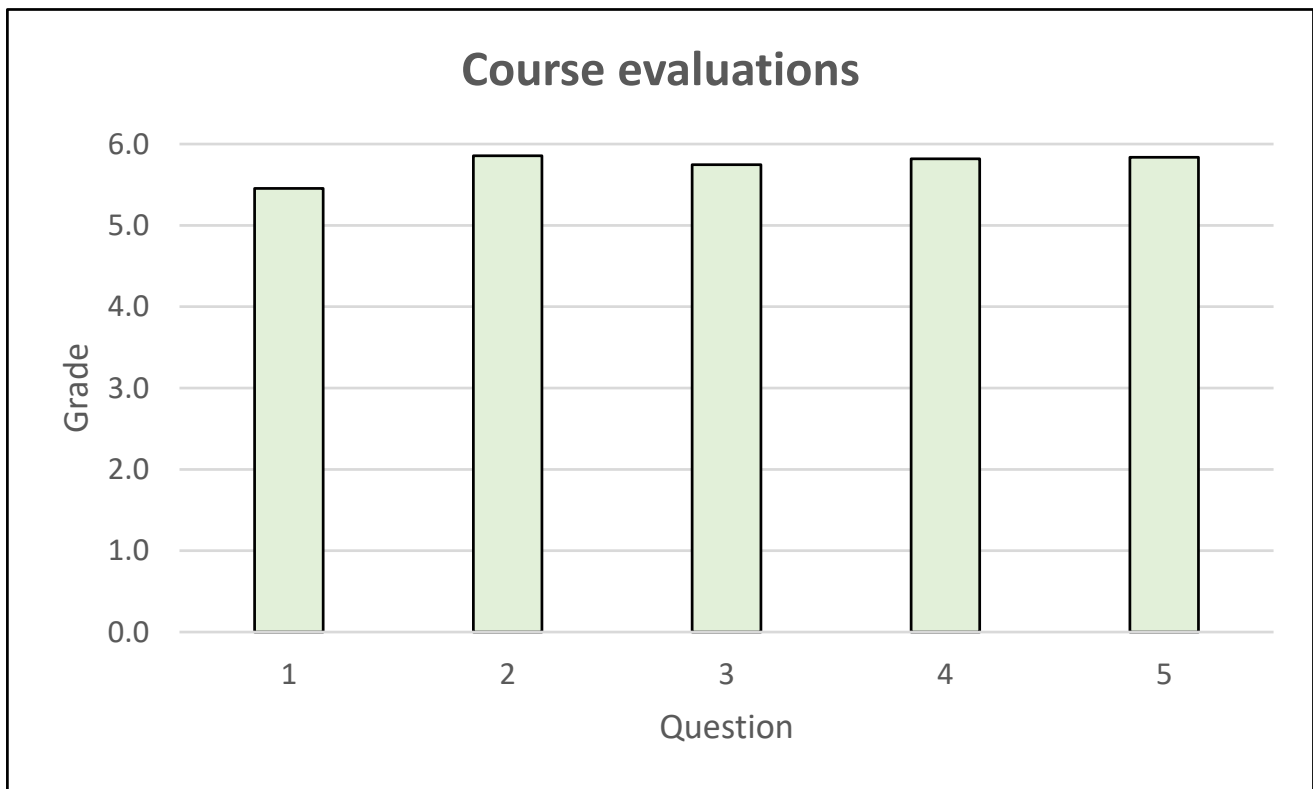


Figure 1. Combined results from four course evaluations conducted after implementing the new examination principles. The grading was between 0 and 6 and the average grades from the students were the following: (1) 5.5 on the question if they were satisfied with their own efforts during the course; (2) 5.9 on the question whether they thought it was a good course; (3) 5.7 on the question if the intended learning outcomes were clear; (4) 5.8 on the question if the course planning/study guidance provided good support; (5) 5.8 on the question whether they think that the examination was in line with the intended learning outcomes of the course.

The results of the additional questions are shown in Figure 2.

The results showed that the students have been very satisfied with the course in general, and the average score of 5.5 out of 6.0 on the question “I am satisfied with my efforts during the course” and 5.9 on the statement “My overall impression is that this has been a good course”, indicate a high level of satisfaction among students regarding their efforts throughout the course. This is a positive outcome, as it suggests that most students felt engaged and committed to their learning. The students who participated in the course evaluations have all experienced the new examination procedure for the mathematics course, which focuses more on student-centered learning approaches. This shift may have contributed to the high satisfaction score, as students who are engaged in their learning are more likely to be satisfied with their efforts [51–54]. Today’s job market demands a wide range of skills, such as critical thinking, communication, and problem-solving, which are highlighted in the new course design. The examination procedure with students inventing their own problems may contribute to emphasizing the development of these skills, leading students to put more effort into their coursework to better prepare themselves for their careers. This focus on employability could be a factor in students’ satisfaction with their efforts [55,56].

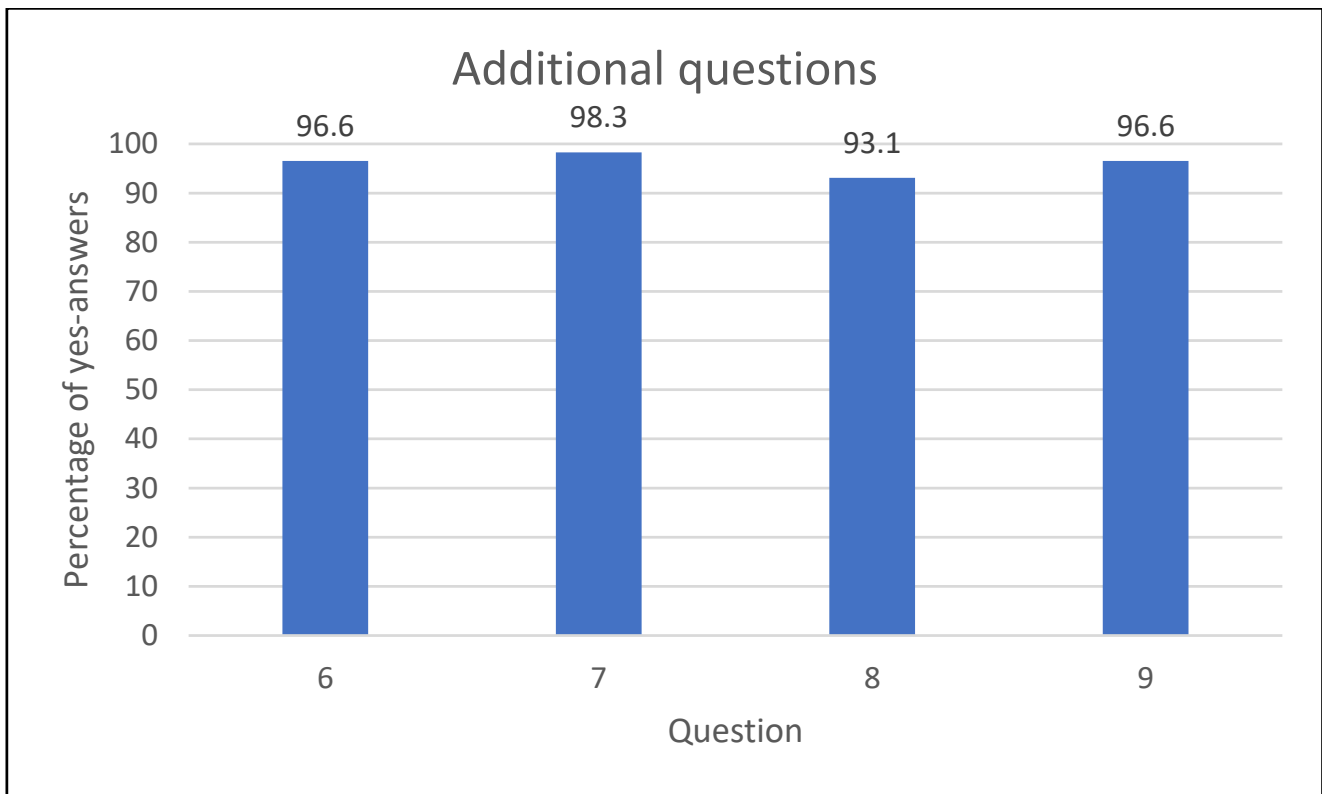


Figure 2. Results of additional questions aimed at evaluating the student perception of the new examination and assessment approaches: (6) 96.6% of the students preferred the new examination approach; (7) 98.3% of the students believe that the new examination method was better for creativity and problem-solving; (8) 93.1% of the students believe that the peer assessment improved their understanding of mathematics; (9) 96.6% of the students felt more prepared to face mathematical problems in their future profession after the course.

The course evaluation results showed average scores of 5.7 out of 6.0 on the question “The intended learning outcomes of the course have been clear” and 5.8 out of 6.0 on the question “The course planning/study guidance has given good guidance”. These results indicate that the course was well-designed and effectively communicated its learning objectives and structure to the students. The high scores on the questions regarding the clarity of intended learning outcomes and course planning/study guidance can be attributed to the effective implementation of current education theories supporting student-centered learning and inquiry-based approaches such as constructivism, scaffolding, self-regulated learning, and transparency in teaching. These theories focus on fostering a supportive and well-structured learning environment, which enables students to better understand course expectations, actively engage with the material, and ultimately achieve the desired learning outcomes [57]. Constructivism emphasizes the importance of learners actively constructing their knowledge and understanding through experiences and reflection [14]. A well-structured course with clear learning outcomes and study guidance enables students to build upon their existing knowledge, make connections, and actively engage in the learning process. The high scores show that the course adhered to constructivist principles, facilitating a more effective learning experience. Scaffolding is an instructional technique in which educators provide support and guidance to students, gradually removing that support as students become more independent and capable learners [11]. This technique was applied for the examination tasks in the mathematics course of this study, helping students navigate the learning process and gradually become more self-directed learners. Self-regulated learning involves students taking control of their own learning process by setting goals, monitoring progress, and adjusting strategies as needed. Clear learning

outcomes and well-structured course planning/study guidance can empower students to develop their self-regulated learning skills, as they know what is expected of them and can gauge their progress more effectively. The high scores on these evaluation questions imply that the students adapted well to the self-regulated learning principles involved in the process of creating and solving their own problems [58]. Transparency in teaching is an approach that emphasizes the importance of clearly communicating course expectations, learning outcomes, and assessment criteria to students. The high evaluation scores may indicate a successful attempt by the course instructor to apply transparency in teaching, which can lead to improved student engagement, motivation, and success [59,60].

The course evaluation results also showed a high average score of 5.8 out of 6.0 on the question, "The examination was in accordance with the intended learning outcomes of the course." This indicates that the students perceived the examination as well-aligned with the course's learning objectives. In this case, the examination employed an innovative method that deviated from conventional assessment practices by requiring students to invent and solve their own mathematical tasks as well as peer-correct other students' tasks. The examination method can be seen as an example of authentic assessment, which aims to evaluate students' knowledge and skills in a context that mirrors real-world situations [61]. By inventing and solving their own mathematical tasks, students are encouraged to apply their understanding of mathematical concepts to novel situations, fostering deeper learning and better preparing them for future challenges. The process of creating and solving original mathematical tasks requires students to engage in higher-order thinking skills such as analysis, synthesis, and evaluation. This aligns with Bloom's Taxonomy, which emphasizes the importance of developing students' cognitive abilities beyond mere recall of facts [62–64]. The high evaluation score may suggest that the examination method effectively promoted higher-order thinking skills in line with the intended learning outcomes. By allowing students to invent their own tasks, this examination method promotes a sense of ownership and agency in the learning process [65]. This can increase student engagement and motivation, as they are more likely to invest effort in tasks they have personally designed. The high score on the course evaluation suggests that the examination method effectively engaged students and aligned with their learning outcomes. Incorporating peer assessment into the examination process can offer several benefits. It encourages students to critically evaluate others' work, further developing their analytical skills. Additionally, by reviewing and discussing their peers' solutions, students can gain new perspectives and insights, enhancing their understanding of the subject matter. The positive evaluation score may reflect the students' appreciation of the benefits of peer assessment. Peer-correcting tasks foster a collaborative learning environment where students can learn from one another's strengths and weaknesses. Collaborative learning has been shown to improve problem-solving skills, communication, and critical thinking, which may have contributed to the positive evaluation score [66].

A selection of student responses from the personal communication are shown in the quotes below:

When the course suddenly became digital and remote, due to COVID-19, the teacher changed the form of education and examination. The changes were really good, and the remote education was on a very high level.—Spring 20

Good teacher, good lectures, good variation, and fun to invent our own math tasks.—Fall 20

It was a good course, with clear objectives and deadlines, and clearly defined and described assignments.—Fall 20

Very well-organized course, with for example detailed plans for every semester. Good assignments and examination. I thought it was very educational to invent my own tasks for examination, actually better than only having "traditional tests". It was very innovative of the teacher to invent this type of examination as an alternative during the COVID-19 pandemic.—Fall 20

I thought the course was good despite the COVID-19 pandemic and the new type of examination was implemented in a very good way.—Fall 20

What was less good was the correction of the exams, since it was peer correction it became somewhat unfair, but it still worked out in a good way.—Fall 20

The peer correcting gave me an insight to how my peers are thinking and helped me develop my own approach to problem solving.—Fall 21

I never thought that I would enjoy a mathematics course, but inventing my own tasks and peer correcting other students' exams was both fun and very educational.—Fall 21

When I joined this course I sucked at math, but now I know that I can solve most problems.—Fall 21

The course is structured in a good way, and it was a fun course!—Spring 22

The invention of my own tasks was challenging, but it gave me a much deeper understanding of mathematics.—Spring 22

Everything was good, it was the best course I have ever had.—Fall 22

Very good way to learn by inventing and solving your own tasks, and then correcting someone else's. That means you must understand how to approach the problems.—Fall 22

It has been great with self-invented examination tasks. The arrangement with home-examination was very educational, as you have fun coming up with your own tasks and calculating them yourself, and also calculating and correcting someone else's tasks. Much better than doing a big exam on everything at the end. I think this definitely provides greater and deeper learning.—Fall 22

Very clear instructions and task descriptions.—Fall 22

Good lectures that helped a lot with the home-examinations.—Fall 22

The course had clear goals and information regarding what is required for a student to succeed. Good descriptions of the different parts of the course. It was clear and easy to follow instructions.—Fall 22

The feedback from students across multiple semesters demonstrates a generally positive perception of the course, particularly in terms of organization, clarity of objectives, and the innovative examination method. The transition to remote learning due to the COVID-19 pandemic seems to have been well managed, with students appreciating the creativity and adaptability of the instructor in adjusting the course format and assessment methods. Here are the key takeaways from the student feedback:

- Smooth transition to remote learning: Students noted that the course was well organized and adapted effectively to remote learning due to the COVID-19 pandemic. The instructor's ability to adjust the course format and maintain a high level of quality during this challenging time was well-received by the students during the pandemic as well as after it. The smooth transition to remote learning that was praised by the students can be attributed to the effective use of emerging technologies and digital tools in mathematics education. The COVID-19 pandemic accelerated the adoption of such tools, which have now become indispensable in facilitating remote learning. When effectively integrated into the teaching process, these technologies can facilitate a smooth transition to remote learning, as observed in the student feedback. The teacher's success in this transition reflects their ability to leverage these tools to maintain the course's high standards, promote student engagement, and support effective learning despite the challenges posed by the pandemic. The course evaluation highlighted that mathematics is a subject that can be effectively carried out and examined online by adapting digital tools and innovative examination formats;

- **Innovative examination method:** Students appreciated the self-invented examination tasks and the opportunity to correct their peers' work. They found this approach more engaging and educational than traditional examinations and felt it contributed to deeper learning. They also emphasized that the peer correction improved their understanding of the mathematical concepts, as they had the opportunity to see the assignments and detailed solutions from other students. Several students pointed out that this procedure increased their creativity regarding the design of their own assignments and emphasized that many problems can be solved in different ways than how they would have conducted it themselves. The innovative examination method described in this paper, which involves students inventing and solving their own tasks, followed by peer assessment, can be viewed as a manifestation of student-centered learning and inquiry-based approaches to assessment. In a student-centered learning approach, students take an active role in their learning process rather than being passive recipients of information. The examination method mirrors this approach, as students are not just answering set questions but actively creating and solving their own problems. This requires a deeper engagement with the subject matter and allows for creativity and personal relevance in the tasks students develop, making the examination more personally meaningful and engaging. The peer-assessment component of the examination aligns with the collaborative and social aspects of student-centered learning. By assessing each other's work, students receive a chance to learn from their peers, see different approaches to problem-solving, and develop critical evaluation skills. This collaborative process not only enhances learning but also helps build a sense of community and shared responsibility among students. Similarly, the examination method aligns with inquiry-based approaches, which encourage curiosity, problem-solving, and the exploration of ideas. By inventing their own tasks, students are essentially formulating their own "questions" to explore and answer, mimicking the process of inquiry. This adds an element of discovery and investigation to the examination, which can make it more engaging and intellectually stimulating. Overall, the innovative examination method integrates principles of student-centered learning and inquiry-based approaches into assessment, transforming the examination from a rote exercise into a creative, collaborative, and intellectually engaging experience. This aligns with the shift towards more active, personalized, and meaningful learning experiences in modern education;
- **Clear objectives and deadlines:** Students highlighted the clarity of the course's objectives, deadlines, and task descriptions, which facilitated their understanding of the course structure and expectations. Clear objectives and deadlines are key elements of student-centered learning and inquiry-based approaches. These pedagogical strategies prioritize the active involvement of students in their learning journey, encouraging them to take ownership and responsibility for their educational progress. Student-centered learning emphasizes personalizing education to meet individual students' needs and interests. It promotes active learning, with students actively involved in the process of constructing knowledge. Clear objectives are essential in this context, as they provide students with a clear understanding of what they are expected to know or be able to do at the end of a course or lesson. This enables students to take charge of their learning, guiding their study strategies and facilitating self-assessment of their progress. Similarly, in inquiry-based approaches, students are guided to explore and investigate, forming their own questions and seeking answers through research and exploration. Here, clear deadlines are particularly important as they provide structure and manageability to the otherwise open-ended process of inquiry. Deadlines help students manage their time and efforts effectively, ensuring a fruitful and comprehensive inquiry process. The teacher's success in establishing clear objectives and deadlines, as noted in the student feedback, reflects their effective use of student-centered and inquiry-based approaches. By defining what is expected of students (the objectives) and when (the deadlines), the teacher has empowered students to take

an active role in their learning process, fostering engagement, autonomy, and self-directed learning. This aligns with modern pedagogical trends emphasizing active and personalized learning;

- **Effective lectures:** Students found the lectures helpful in supporting their learning and preparing them for the home examinations. Effective lectures, particularly in the context of student-centered learning and inquiry-based approaches, are those that go beyond mere information transmission to engage students actively in the learning process. In these pedagogical strategies, lectures serve as a springboard for exploration and inquiry, sparking students' curiosity and driving them to take charge of their learning journey. In a student-centered approach, effective lectures often involve interactive components that engage students in active learning. This could include discussion prompts, problem-solving activities, real-time quizzes, or other forms of active engagement that encourage students to apply what they're learning. The lectures are designed to be responsive to students' needs and questions, allowing for flexibility and personalization. In the context of inquiry-based learning, effective lectures often serve as a starting point for student investigation. Rather than providing all answers, they stimulate questions, challenge assumptions, and encourage students to seek their own solutions. The lectures may introduce a topic or problem and guide students on how to approach it, but the emphasis is on student discovery and problem-solving. The positive feedback from students regarding the effectiveness of the lectures suggests that the instructor was successful in implementing these approaches. By structuring lectures in a way that promoted active learning and sparked student inquiry, the instructor was able to engage students in the learning process more deeply, fostering a more dynamic and interactive learning environment. These strategies align with contemporary shifts in education towards more student-centered and inquiry-based approaches, underscoring the importance of active engagement and personal discovery in effective learning;
- **Enjoyable and engaging learning experience:** Several students mentioned that the course was enjoyable and engaging, with some even calling it the best course they had ever taken. An "enjoyable and engaging learning experience" is at the heart of student-centered learning and inquiry-based approaches. These contemporary pedagogical models prioritize active engagement, curiosity, and a sense of ownership over learning, which often result in a more enjoyable and rewarding educational experience for students. Student-centered learning, as the name implies, places the student at the center of the educational process. Instead of being passive receivers of information, students are actively involved in constructing their own knowledge and understanding. This approach recognizes that each student brings a unique set of experiences, interests, and strengths to the classroom and aims to cater to these individual differences. By allowing students to explore topics of interest, work at their own pace, and engage in hands-on, experiential learning activities, student-centered learning can make the educational process more engaging and enjoyable. Similarly, inquiry-based approaches promote enjoyment and engagement in learning by fostering curiosity and exploration. Instead of simply learning established facts or methods, students are encouraged to ask their own questions, investigate problems, and seek out their own answers. This active, discovery-based learning process can be highly engaging, as it caters to students' natural curiosity and desire to understand the world around them. The positive student feedback suggests that the instructor was successful in implementing these approaches, creating a learning environment that was not only educational but also engaging and enjoyable. By prioritizing active involvement, personal discovery, and respect for individual interests and strengths, the instructor was able to align with the shifts towards student-centered learning and inquiry-based approaches, leading to a more positive learning experience for students.

The only area of concern raised by some students was the fairness of the peer-correction process during examinations. Despite this issue, students generally felt that the course

was well-structured and provided a positive learning experience. Overall, the feedback indicated that the course successfully adapted to remote learning and leveraged innovative examination methods to maintain student engagement and promote deep learning. The instructor's efforts to provide clear objectives, deadlines, and task descriptions, as well as their effective lectures, contributed to the students' overall satisfaction with the course.

5. Discussion

This study investigated the student experiences of an innovative examination method for fostering creativity and problem-solving in a basic mathematics course in higher education. The new examination method was designed to align with contemporary ideas and approaches in higher education. The discussion will focus on how the examination method agrees with these new ideas and their potential implications for future practice. The new examination form in the mathematics course for the Higher Education Diploma programs aligns well with student-centered learning and inquiry-based approaches. These approaches emphasize the importance of students actively engaging with the content and taking responsibility for their learning process. The method supports this by encouraging students to create and solve their own mathematical problems, fostering a deeper understanding of the material, and promoting critical thinking. The self-created questions require students to actively engage with mathematical concepts by inventing their own problems, which encourages them to think deeply about the subject matter and make connections between different topics. This active engagement is a crucial element of student-centered learning and inquiry-based approaches, as it helps students internalize their understanding and develop a strong foundation for future learning [67].

By allowing students to create their own tasks, the examination method enables them to tailor their learning experience to their interests and needs. This personalization helps make the learning process more meaningful and relevant, fostering motivation and a sense of ownership over their learning. This personal-preference aspect aligns with student-centered learning, which prioritizes individual learners' needs and preferences. The examination method emphasizes problem-solving skills, as students are expected to develop and solve challenging mathematical problems. Inquiry-based approaches also focus on problem-solving, encouraging students to explore, analyze, and reflect on the concepts they are learning. This shared focus on problem-solving helps students develop critical thinking skills and a deeper understanding of mathematics. The new method also encourages students to monitor and evaluate their own learning process by reflecting on their problem creation, problem-solving strategies, and peer assessment feedback. This self-regulation and metacognitive aspect align with student-centered learning and inquiry-based approaches, which emphasize the importance of students being aware of their own thought processes and learning strategies. Developing metacognitive skills allows students to become more effective learners, adapt their strategies when necessary, and ultimately achieve better learning outcomes. The peer assessment component promotes collaboration and communication among students. In student-centered learning and inquiry-based approaches, collaboration is a vital aspect of the learning process. As students exchange feedback and discuss their work, they develop essential communication skills, learn from one another, and gain a deeper understanding of mathematical concepts. This collaborative environment fosters the sharing of ideas, problem-solving strategies, and diverse perspectives, which enhances the overall learning experience [68].

The examination's focus on inventing and solving original problems encourages students to be flexible and adaptable in their thinking, as they must consider multiple approaches and strategies to tackle a problem. This flexibility and adaptability align with student-centered learning and inquiry-based approaches, which emphasize the importance of being able to adjust and modify one's thinking in response to new information or challenges. By practicing these skills in the context of mathematics education, students are better prepared to navigate complex problems and situations in their future academic and professional endeavors. Allowing students to invent, solve, and then peer-assess each

other's tasks takes the concept of problem-posing one step further. This innovative form of assessment serves a dual purpose. Firstly, it actively involves students in the learning process, necessitating a thorough understanding of the material to create meaningful problems. Secondly, the subsequent peer-assessment phase encourages students to evaluate their peers' understanding critically, providing a different perspective and enriching their comprehension of the subject matter. The integration of problem-posing and peer assessment aligns with modern pedagogical principles, emphasizing active learning, collaboration, and critical thinking. These principles are crucial in creating dynamic, engaging learning environments where students take ownership of their learning journey, leading to a deeper and more comprehensive understanding of mathematics [69].

In summary, the innovative examination method examined in this study aligns well with contemporary ideas in mathematics education, particularly student-centered learning and inquiry-based approaches. By actively engaging students in the learning process, promoting personalization, fostering problem-solving skills, encouraging self-regulation and metacognition, facilitating collaboration and communication, and developing flexibility and adaptability, this method has the potential to significantly enhance students' creativity and problem-solving abilities in mathematics. Further research and practical implementation of this examination method can contribute to the ongoing transformation of mathematics education, better preparing students for success in a rapidly evolving world.

6. Conclusions

The study aimed to investigate the students' perceived effect of a new and innovative examination method aimed at fostering creativity and problem-solving in mathematics education. The method involved students inventing and solving their own tasks, presenting their solutions clearly, and participating in anonymous peer assessment. Based on the findings and the alignment of the examination method with contemporary ideas in mathematics education, we draw the following conclusions:

- The new examination method successfully promotes student-centered learning and inquiry-based approaches by actively engaging students in the learning process, fostering personalization, and emphasizing problem-solving skills. These aspects are crucial for effective mathematics education and the development of well-rounded learners;
- The examination enhances creativity in mathematics education by encouraging students to think critically about course material, identify interesting connections, and design problems that require a deep understanding of mathematical concepts. This focus on creativity contributes to a more engaging and meaningful learning experience;
- The incorporation of collaborative learning and peer assessment within the examination helps to develop essential skills such as communication, teamwork, and critical thinking, which are valuable for students' academic and professional success;
- The study demonstrates the potential benefits of integrating self-regulation, metacognition, and adaptability into mathematics education, which can contribute to more effective learning and better-prepared students for future challenges;
- The new method's alignment with emerging trends in higher education suggests that it could serve as a valuable addition to traditional assessment methods, potentially transforming the way students learn and engage with mathematics.

While this study has shown promising results, further research is needed to explore the long-term impact of the new examination method on the students' academic performance, retention of mathematical concepts, and attitudes towards mathematics. Additionally, it would be beneficial to investigate the scalability and generalizability of the examination method across different educational levels, mathematical topics, and diverse student populations. By continuing to explore and refine this innovative approach, educators and researchers can contribute to the ongoing transformation of mathematics education, ensuring that students are better equipped with the creativity, problem-solving skills, and adaptability necessary for success in a rapidly evolving society.

Funding: This research received no external funding.

Institutional Review Board Statement: The investigations were carried out following the rules of the Declaration of Helsinki and the Ethics Committee of Luleå University of Technology.

Informed Consent Statement: Prior to completing the course survey, the respondents were informed about the purpose of the survey and the fact that their responses were used exclusively for scientific purposes. Respondents participated in the survey on a voluntary basis. Participants were assured confidentiality of the answers provided, as the data collected were used in a summarized statistical form and quotes were not associated with specific respondents.

Data Availability Statement: The data are not publicly available due to privacy restrictions.

Acknowledgments: The author would like to acknowledge all of the students who contributed ideas and experiences for developing and improving the mathematics course in the Higher Education Diploma programs at Luleå University of Technology.

Conflicts of Interest: The author declares no conflict of interest.

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