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Collaborative Project-Based Learning of Mathematics: Student-Created Lessons Integrating Personal Interests and Real-World Contexts

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Abstract

Mathematics education in the modern era faces a dual challenge: improving student achievement while fostering engagement, interest, and creative thinking. Research indicates that many students perceive mathematics learning as a technical, abstract process disconnected from personal relevance, often leading to decreased motivation and negative attitudes toward the subject (Boaler, 2016; Schoenfeld, 2016).

This study proposes an alternative approach to designing 10th-grade mathematics lessons in Israel, emphasizing student collaboration, personalized learning, and the integration of technology. The approach is grounded in Project-Based Learning (PBL), which has been shown to enhance students' deep understanding, problem-solving skills, and the perceived relevance of mathematics to real life (Blumenfeld et al., 1991; Krajcik & Shin, 2014).

A key innovation of this research is the active involvement of students in co-designing lesson plans alongside teachers. This aligns with student-centered learning models, which emphasize autonomy and personal responsibility in the learning process (Weimer, 2013; Deci & Ryan, 2000). Moreover, the study considers both cognitive and emotional aspects of mathematics learning, demonstrating how personal engagement with content can improve students’ attitudes toward the subject (Goldin, 2000).

The learning environment further strengthens this approach by facilitating personalized learning pathways, enhancing collaboration, and improving the overall student experience (Bower, 2017). Therefore, this research aims to explore the potential of these innovative strategies to enhance students' mathematical learning experiences, increase engagement, and foster enjoyment of the subject.

Future research will focus on teacher professional development, program sustainability, and the feasibility of integrating this approach into the Israeli education system.

Keywords: Mathematics Education, Student Engagement, Project-Based Learning (PBL), Personalized Learning, Student-Centered Learning, Teacher-Student Collaboration, Attitudes Toward Mathematics, Math Anxiety.

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Introduction

Mathematics education in Israeli high schools is currently grappling with significant challenges, particularly regarding student motivation, engagement, and the perceived relevance of the subject in students' everyday lives. A considerable number of students find it difficult to relate mathematical concepts to their personal experiences, interests, or future aspirations. This disconnection is further intensified by an instructional culture that tends to prioritize rote learning, procedural fluency, and performance on high-stakes assessments, at the expense of fostering creativity, inquiry-based learning, and authentic problem-solving skills. As a result, students often view mathematics as an abstract and distant discipline, diminishing their intrinsic motivation and the potential to appreciate its real-world applications.

Despite curricular reforms in recent years aimed at modernizing instruction to align with 21st-century competencies, mathematics classrooms in Israel often remain focused on delivering predefined content and preparing students for standardized exams (Leikin & Levav-Waynberg, 2007). This narrow focus limits students' opportunities to engage in higher-order thinking, develop mathematical intuition, or explore the aesthetic and emotional dimensions of mathematics as a humanistic discipline. The pressure to complete the curriculum, especially in high-level tracks, discourages innovation and deeper inquiry, exacerbating the disconnection between mathematics and students' lived experiences.

International assessments such as the OECD's Program for International Student Assessment (PISA) highlight similar trends across various educational systems. PISA results consistently show that students' mathematical literacy is closely tied to the perceived relevance of mathematics to real-life situations and the extent to which students feel empowered in their learning (OECD, 2019a). In countries where mathematics instruction is more closely connected to real-world contexts and student interests, students tend to show higher levels of engagement and motivation, as well as better performance on assessments.

Recent literature in mathematics education underscores the transformative potential of active, student-centered pedagogies. Approaches that incorporate real-life contexts, interdisciplinary connections, and opportunities for collaborative exploration have been shown to increase students' motivation, conceptual understanding, and long-term retention (Boaler, 2016). By empowering students to take a more active role in their learning, these approaches can cultivate a sense of agency and ownership, which is critical for fostering positive attitudes toward mathematics.

However, in the Israeli context, several structural and systemic barriers hinder the widespread adoption of such pedagogies. These include high teacher workloads, rigid curricular expectations, limited time for interdisciplinary planning, and a lack of professional development focused on innovative instructional design (Barber & Mourshed, 2007). Furthermore, the traditional image of mathematics as an objective and abstract discipline often discourages the integration of personal or emotional dimensions into its instruction.

Considering these challenges, this thesis explores an alternative approach to teaching advanced mathematics, grounded in the belief that students' personal interests, experiences, and creative capacities can serve as powerful entry points into mathematical thinking. The research investigates how co-creating lesson plans with students, based on themes that are personally meaningful to them, can reshape their relationship with mathematics and improve their motivation, engagement, and emotional connection to the subject. The thesis is composed of three complementary studies:

Study 1 – Exploring Mathematics Teaching Practices in Israel: Teachers' Approaches and Strategies. This study aims to explore the methods teachers use to foster a positive attitude toward mathematics, promote students' creativity, and implement differentiated instruction based on individual knowledge, competencies, and interests. Data were collected through a questionnaire consisting primarily of open-ended questions. The responses were analyzed qualitatively using thematic analysis. Selected findings were subsequently incorporated into the development of the SMART intervention program.

Study 2 – Experimenting Collaborative Project-Based Learning in Mathematics: Student-Created Projects Integrating Personal Interests and Real-World Contexts. This exploratory study was conducted with a small group of high school students who participated in private tutoring sessions. The students, working in groups, were invited to develop projects or project ideas in the problem-based learning (PBL) model for mathematical topics taught in 10th grade based on their interests. In these projects they have integrated mathematical concepts with their personal interests, such as music, art, sports, or fashion. This collaborative process aimed to explore how involving students in the design of lesson content would influence their sense of ownership, engagement, and creativity in learning mathematics. The efficacy of the intervention program on attitude towards mathematics was measured. Also, interviews were guided with the students to get a deeper insight into the efficacy of the program and to listen to the opinion of the students about these collaborative projects. Based on the projects developed by the students and their feedback on the intervention program, but also the teachers' responses from study 1, lessons plans were developed for a classroom-based intervention.

Study 3 – Experimenting the efficacy of the intervention program based on the projects developed by the students. Building on insights from study 1 and 2, the intervention from study 2 was extended to a full classroom setting. Based on the projects developed by the students in study 2 a set of 10 lesson plans were written and quasi-experimental research with experimental and control group was set up to examine the broader applicability of the approach and assess its impact on students' attitudes toward mathematics in a formal school environment.

Together, study 2 and 3 offer a layered understanding of how personalized, interest-driven instruction can be used to reimagine mathematics teaching in ways that are emotionally resonant, intellectually engaging, and socially collaborative. The findings suggest that when students are given the opportunity to explore mathematics through the lens of their passions and everyday experiences, they develop a more positive and empowered relationship with the subject. Reported outcomes included increased enjoyment, a stronger sense of relevance, reduced mathematics anxiety, and greater willingness to persist in problem-solving tasks.

Ultimately, this thesis contributes to the ongoing discourse on innovation in mathematics education by proposing a framework for designing meaningful and motivating learning experiences. It underscores the need to view students not merely as passive recipients of mathematical knowledge, but as active co-creators of learning environments that resonate with their identities, values, and aspirations. In doing so, it advocates for a pedagogical shift ,reimagining mathematics not only as a discipline of logic and precision, but also as a language of self-expression, creative inquiry, and human connection.

Chapter 1. Attitude towards mathematics

Attitudes toward mathematics represent a multifaceted construct encompassing cognitive, affective, and behavioral dimensions that influence how students perceive, experience, and succeed in the subject (Di Martino & Zan, 2010). They reflect students' willingness to engage with mathematical content, their emotional reactions to mathematical experiences, and their confidence in overcoming challenges. A robust body of literature has highlighted key factors such as enjoyment, value, motivation, self-efficacy, and anxiety as critical dimensions that shape students' mathematical attitudes (Ma & Kishor, 1997; Zan & Di Martino, 2007). These attitudes have profound implications for academic achievement, persistence, and students' willingness to pursue advanced studies or careers in STEM-related fields (OECD, 2013; Wigfield & Eccles, 2000). While positive attitudes foster motivation and achievement, negative ones often manifest in avoidance behaviors, decreased performance, and heightened anxiety (Hannula, 2002).

1.1. Dimensions of Attitude Toward Mathematics

One of the most central dimensions is **enjoyment**, which serves as an affective driver of engagement. Students who experience pleasure, curiosity, and satisfaction from mathematical learning are more likely to persist when confronted with challenges, engaging more deeply with problem-solving tasks (Hannula, 2002; Lepper, Corpus, & Iyengar, 2005). Pedagogical practices such as project-based learning (PBL), cooperative learning, and real-world applications have been shown to increase enjoyment and deepen conceptual understanding (Boaler, 2016; Barron & Darling-Hammond, 2008).

Another key component is the **perceived value of mathematics**, which determines whether students see the subject as intrinsically stimulating, practically useful, or personally meaningful for achievement (Eccles & Wigfield, 2002; Watt, 2004). Explicit connections between mathematics and real-world contexts, especially through interdisciplinary approaches, reinforce its utility and increase long-term engagement (Schoenfeld, 2016).

Motivation also plays a central role, with intrinsic motivation driven by curiosity and personal interest emerging as a stronger predictor of deep learning than extrinsic motivation such as grades or external rewards (Deci & Ryan, 2000; Middleton & Spanias, 1999). Student-centered environments that promote autonomy and personal relevance have been found to enhance motivation significantly (Fredricks, Blumenfeld, & Paris, 2004; Dweck, 2006).

Closely related is **self-efficacy**, defined as students' beliefs in their ability to succeed in mathematics. High self-efficacy supports confidence, persistence, and adaptive strategies for problem solving, while low self-efficacy fosters avoidance and anxiety (Bandura, 1997; Pajares & Graham, 1999). Pedagogical strategies that emphasize growth mindset, constructive feedback, and opportunities for mastery are central to developing students' self-belief (Schunk & Pajares, 2002; Zimmerman & Schunk, 2011).

At the same time, **mathematics anxiety** represents a critical barrier. Research indicates that anxiety negatively impacts working memory, performance, and persistence, often creating a cycle of avoidance and failure (Ashcraft, 2002; Maloney & Beilock, 2017). Effective interventions include emotional support, PBL, growth mindset strategies, and technology-enhanced learning, which collectively mitigate anxiety and encourage resilience (Boaler, 2016; Blikstein, 2013; Dweck, 2006).

1.2. Factors Influencing Students' Attitudes Toward Mathematics

Attitudes toward mathematics are shaped by instructional methods, teacher influence, parental support, and cultural context. Student-centered pedagogies, including inquiry-based learning (IBL) and PBL, enhance attitudes by fostering curiosity and relevance (Boaler, 2016; Schoenfeld, 2016). Teachers play a pivotal role in cultivating growth mindset, supporting collaborative learning, and modeling persistence (Dweck, 2006; Slavin, 2014). Parents' beliefs about mathematics, particularly enthusiasm or anxiety, strongly shape children's self-perceptions and engagement (Gunderson et al., 2012; Maloney & Beilock, 2012). Broader cultural narratives about mathematics as a discipline reserved for the "talented" can reinforce stereotypes and discourage participation, particularly among underrepresented groups (Steele, 1997; Else-Quest, Hyde, & Linn, 2010).

1.3. Importance of Attitude in Mathematics Learning

The reciprocal relationship between attitude and achievement has been consistently emphasized: positive attitudes enhance persistence, motivation, and achievement, while negative ones reinforce avoidance and underperformance (Ma & Kishor, 1997; Hannula, 2002). Self-efficacy and anxiety remain particularly influential. High self-efficacy promotes resilience and achievement (Bandura, 1997), while math anxiety undermines cognitive functioning and self-confidence (Ashcraft, 2002; Maloney & Beilock, 2012). Therefore, pedagogical strategies that emphasize inquiry, collaboration, and real-world relevance are essential for fostering sustainable positive attitudes (Boaler, 2016).

1.4. Attitude towards mathematics among high-school students in Israel

Within Israel, mathematics occupies a prestigious and high-stakes position in education, particularly in the **5-unit track**, which acts as a gateway to advanced academic and professional opportunities (Yuliani et al., 2019; Serin, 2023). While this system motivates high-achieving students, it also generates intense pressure that often leads to anxiety, avoidance, and lower self-efficacy (Dan & Benovich, 2023; Ashcraft & Krause, 2007).

Gender disparities persist, with male students often reporting higher confidence despite similar achievement levels. Parental involvement is critical in mediating anxiety and enhancing engagement, particularly among students from lower socioeconomic backgrounds (Vukovic, Roberts, & Green Wright, 2013). Innovative approaches, such as project-based learning and technology-enhanced platforms, have shown promise in improving attitudes, but their implementation remains inconsistent (Anderson, 2020; Blikstein, 2013).

Systemic reforms that promote a **growth mindset**, encourage teacher training in student-centered pedagogies, and expand equitable access to advanced tracks are vital for transforming attitudes. By addressing academic pressure, cultural expectations, and social disparities, Israel’s education system can create a more inclusive mathematical culture that fosters resilience, confidence, and long-term engagement (Mizrahi & Gal, 2016; Boaler, 2016).

Chapter 2. The Impact of Cross-Disciplinary Skills and Teaching Strategies on the Development of the SMART Program

In the development of the SMART program, a central emphasis is placed on the integration of transversal competencies often referred to as 21st-century skills together with self-regulated learning (SRL), design thinking, active pedagogical strategies, and the use of digital technologies. These dimensions are interwoven to create a dynamic, student-centered approach to mathematics education that fosters engagement, creativity, and resilience in a rapidly changing world.

2.1. Transversal Competencies in Mathematics

Transversal skills are cross-disciplinary capacities that remain essential despite the continuous evolution of technical knowledge (Defined Learning, 2023). In mathematics, they manifest as critical thinking, collaboration, communication, creativity, adaptability, and global awareness. For example, critical thinking and problem solving encourage students not only to solve tasks but also to analyze the processes leading to solutions (Anderson & Krathwohl, 2001; Hattie & Timperley, 2007). Similarly, collaboration and communication, emphasized in international frameworks (Binkley et al., 2012), help learners articulate reasoning and co-construct understanding. Technological literacy is now equally indispensable, with the OECD (2018) underlining the importance of preparing students to use digital tools to model and visualize mathematical ideas. Creativity, once thought foreign to mathematics, is increasingly recognized as central for innovation (Binkley et al., 2012). Finally, global and cultural awareness situates mathematics in the broader challenges of climate change, economic systems, and social equity (Schleicher, 2018).

2.2. Self-Regulated Learning (SRL)

SRL is presented as a cyclical process of goal setting, monitoring, reflection, and adaptation (Zimmerman, 2001; Schunk & Zimmerman, 2012). Students who regulate their learning show greater persistence and autonomy, particularly in mathematics where sustained effort is required (Pintrich, 2000). Recent work emphasizes skills such as self-efficacy (Schunk & Zimmerman, 1994), self-monitoring (Winne & Hadwin, 1998), and adaptability (Hadwin, Järvelä, & Miller, 2011). Panadero (2017) highlights SRL as a foundation for lifelong learning, while Deci and Ryan (2000) stress the motivational aspects that drive students to pursue tasks even without external rewards. In the SMART program, SRL empowers learners to take responsibility for their progress, aligning with the broader goal of cultivating independent thinkers.

2.3. Design Thinking

Design Thing, originally developed in the fields of design and engineering, is now widely applied in education (Brown, 2009; Liedtka, 2015). It offers an iterative and user-centered framework consisting of five stages: empathize, definition, ideate, prototype, and test (Plattner et al., 2009). In educational contexts, this methodology helps students connect mathematical abstractions with authentic problems, fostering creativity and problem-solving (Razzouk & Shute, 2012). The emphasis on empathy ensures that projects remain meaningful, while iterative prototyping enables continuous refinement. Within the SMART program, design thinking is not only a method but a philosophy: it situates students as co-designers of their learning.

2.4. Teaching strategies for active learning of Mathematics

Constructivist and sociocultural theories (Piaget, 1950; Vygotsky, 1978) provide the theoretical basis for active learning in mathematics. Inquiry-Based Learning (Bruner, 1961; Artigue & Blomhøj, 2013) allows students to formulate hypotheses, while Problem-Based Learning (Lave & Wenger, 1991; Hmelo-Silver, 2004) immerses them in real-world challenges. Project-Based Learning (Dewey, 1938; Capraro & Slough, 2013) extends this to long-term investigations, cultivating collaboration and applied reasoning. Cooperative learning (Slavin, 1995; Crouch & Mazur, 2001) underscores the role of dialogue and peer teaching, whereas flipped classrooms (Bloom, 1956; Bergmann & Sams, 2012) maximize classroom time for higher-order activities using digital platforms (Redecker, 2017). Together, these strategies offer multiple pathways for active engagement and align with the ethos of the SMART program.

2.5. Project-Based Learning (PBL) in Mathematics

Research highlights PBL as a transformative pedagogy (Blumenfeld et al., 1991; Barron et al., 1998). It engages students in authentic tasks requiring mathematical reasoning and collaboration (Krajcik & Blumenfeld, 2006). Studies show that PBL fosters deeper conceptual understanding (Boaler, 1997, 2002), motivation (Hmelo-Silver, 2004), and persistence (Darling-Hammond et al., 2008). While challenges exist such as assessment practices (Shepherd, 1998) and teacher preparation (Hmelo-Silver et al., 2007) PBL remains central to equipping learners with problem-solving and critical thinking skills.

2.6. Digital tools for mathematics learning

Digital tools from computer algebra systems to AI-based adaptive platforms, have reshaped mathematics instruction (Hoyles & Lagrange, 2009; Drijvers et al., 2010). They provide immediate feedback, enable visualization of abstract concepts, and allow differentiation (Pierce & Stacey, 2010). Digital simulations bridge theory with real-world applications (Kaput & Roschelle, 2013), while learning analytics support data-driven teaching (Ruthven, Hennessy, & Deaney, 2008). Despite equity and training challenges (Noss & Hoyles, 1996), technology plays a pivotal role in advancing the SMART program's vision of adaptive and inclusive learning environments.

2.7. Contributions to the SMART Program

By weaving transversal competencies, SRL, design thinking, active learning strategies, PBL, and digital tools, this chapter demonstrates the theoretical coherence and practical innovation of the SMART program. It emphasizes the creation of student-centered environments where mathematics becomes meaningful, engaging, and socially relevant. These approaches prepare students not only for academic success but also for lifelong participation in solving complex global challenges.

Chapter 3. Study 1 - Exploring Mathematics Teaching Practices in Israel: Teachers' Approaches and Strategies

This study examined the approaches and strategies employed by mathematics teachers in Israel, with a focus on their beliefs, instructional practices, and the ways in which they foster student engagement, creativity, and positive attitudes toward mathematics.

3.1. Teachers' Beliefs and Instructional Approaches

Research highlights the importance of teachers' beliefs and their role in shaping students' experiences in mathematics (Moore, 2007). Teachers who maintain high expectations and provide encouragement help students overcome negative self-perceptions and cultivate self-efficacy (Tomlinson & Eidson, 2003; Tomlinson & Strickland, 2005). Personalized instruction emerged as a central theme, reflecting the recognition that learning goals, content, and pace should be adapted to individual students (Pane et al., 2015; Fensham et al., 2016). Teachers emphasized flexibility, reflection, and openness as essential qualities for building inclusive classrooms (Bekcer, 2016).

3.2. Methodology

The study was conducted in 2021 with a sample of 200 mathematics teachers across Israel. The research relied on a mixed-method approach, combining teacher questionnaires and semi-structured interviews. The participants included experienced high school mathematics teachers. Data was analyzed thematically, enabling the identification of recurring patterns and concepts.Data was collected using a structured questionnaire that included demographic information, Likert-scale items, and open-ended questions. The sample represented a broad range of teaching experience (2–55 years, M = 23.06) and age (22–72, M = 49.82). Most participants were women (61.5%), and nearly all had academic qualifications, with the majority holding a master's degree.

3.3.Results and Key Findings

Quantitative and qualitative analyses revealed several important insights into teachers' experiences and approaches:

3.3.1. Enjoyment in Teaching Mathematics

Most teachers reported high enjoyment in teaching mathematics (M = 4.88, SD = 0.33). Many highlighted enthusiasm and passion as central motivators for their practice, echoing findings by Frenzel et al. (2009) on the role of teacher emotions in student engagement.

3.3.2. Fostering Positive Attitudes

Teachers emphasized making mathematics relevant to students' lives through real-world applications and interdisciplinary connections, consistent with Boaler's (2016) findings. Playful learning strategies such as games, riddles, and escape rooms were frequently employed (Blumenfeld et al., 1991). Personalized attention, encouragement, and reducing fear of mathematics were also emphasized, resonating with Dweck's (2006) work on growth mindset.

3.3.3. Demonstrating the Value of Mathematics

Teachers reported strategies that linked mathematics to practical applications, future careers, and cognitive development. Examples included financial literacy, interpreting graphs, and applying mathematics to societal issues such as the COVID-19 pandemic. These strategies align with the literature emphasizing mathematical literacy as essential for civic life and decision-making (Freudenthal, 1991; Eccles & Wigfield, 2002; OECD, 2019).

3.3.4. Encouraging Creativity

Creativity was fostered through problem-solving flexibility, open inquiry, and project-based learning. Teachers encouraged multiple solution paths and divergent thinking, in line with Leikin (2009) and Liljedahl et al. (2021). Games and playful activities also emerged as a powerful tool for stimulating creative exploration (Bragg, 2007).

3.3.5. Personalization and Differentiation

Personalization was achieved through one-to-one attention, differentiated tasks, small group instruction, and the integration of digital tools. These practices reflect Tomlinson's (2014) model of differentiated instruction and Vygotsky's (1978) notion of the zone of proximal development. Teachers stressed that adaptation not only improved academic outcomes but also reduced anxiety and enhanced student confidence (Black & Wiliam, 2009; Suprayogi, Valcke, & Godwin, 2017).

One of the central quantitative findings of the study refers to teachers' enjoyment in teaching mathematics. The responses were measured using a Likert scale ranging from 1 (not at all) to 5 (very much). Results indicated that teachers reported a high level of enjoyment, with very little variance among responses.

Table 1. Enjoying teaching mathematics

Dimension	Mean (M)	Standard Deviation (SD)
Enjoyment in Teaching Mathematics	4.88	0.33

As shown in the table above, teachers demonstrated a very high level of enjoyment in teaching mathematics ($M = 4.88$, $SD = 0.33$). This suggests that enthusiasm and passion were central motivators for their teaching practice, aligning with previous research emphasizing the role of teacher emotions in fostering student engagement.

Table 2. Thematic Dimensions of Teachers' Experiences in Teaching Mathematics

Dimension	Description
Shift in Teaching Approaches	Transition toward student-centered practices emphasizing inquiry, collaboration, and creativity.
Improved Student Motivation	Greater curiosity and engagement when lessons connect to real-world contexts.
Challenges in Implementation	Barriers include time constraints and adapting existing curricula.
Contribution to Mathematical Understanding	Development of deeper conceptual comprehension and problem-solving abilities.

3.4. Discussion and Implications

This study highlights mathematics teachers in Israel as passionate and reflective practitioners who emphasize student-centered learning. Teachers reported enjoyment in teaching mathematics, which they linked to creating engaging and supportive classroom environments. A key theme was personalization through individual attention, differentiated tasks, and flexible methods aimed at improving learning outcomes and reducing math anxiety.

Teachers also stressed the importance of demonstrating the value of mathematics by connecting it to real-life contexts such as financial literacy, technology, and societal issues. Creativity was encouraged through open inquiry, problem-solving flexibility, and playful learning strategies, which supported motivation and deeper conceptual understanding.

Overall, the findings reflect teaching practices that balance academic goals with emotional and motivational support. While these practices align with best practices in educational research, a limitation is that the study did not examine how frequently teachers implemented the methods they described. These insights provided the foundation for developing the SMART program, presented in Chapter 4.

Chapter 4. Study 2 – Experimenting Collaborative Project-Based Learning in Mathematics: Student-Created Projects Integrating Personal Interests and Real-World Contexts

4.1. Introduction

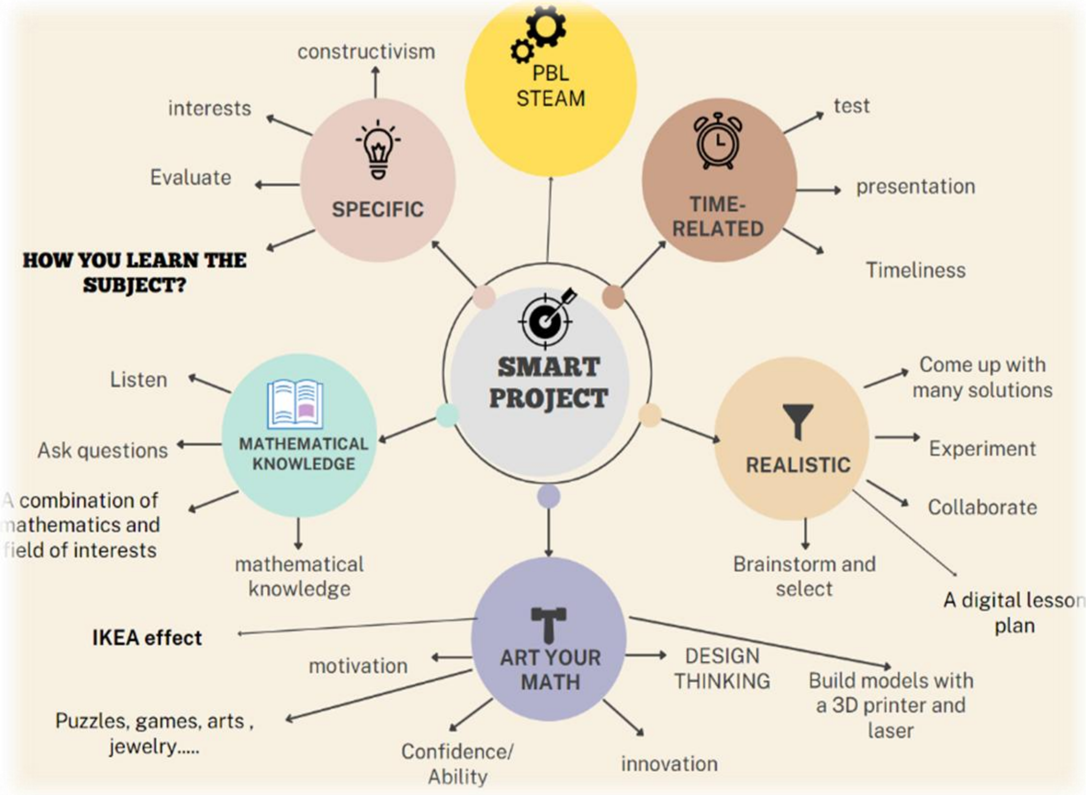
This pilot study explores the application of collaborative project-based learning in mathematics among 10th-grade students in Israel. The SMART program was designed to integrate students' personal interests with real-world contexts, aiming to foster motivation, creativity, and deeper engagement with mathematics. Grounded in project-based learning (Thomas, 2000), personalized learning (Tomlinson, 2014), and constructivist principles (Vygotsky, 1978; Lave & Wenger, 1991), the program allowed students to co-create lesson plans and projects that reflect their passions while addressing core mathematical concepts.

4.2. Development of the SMART Intervention Program

The main idea of the SMART intervention program is that students write projects or project ideas in the problem-based learning (PBL) model for mathematical topics taught in 10th grade based on their interests. The program is intended for 10th grade math, mainly for higher levels. The SMART program combines mathematics with design, science and technology. Learning in this way has been found to contribute to in-depth understanding and emphasize authentic and relevant learning derived from the student's world (Pellegrino & Hilton, 2012). During the lessons, the students are supposed to raise authentic problems, discuss possible solutions to them, additional ideas for projects combined with their interests, choose a solution, design a product that will contribute to this solution and carry out an investigation using scientific tools.

To describe the **SMART** idea, I presented in Figure 1 the theoretical structure of the Program.

Figure 1. The theoretical structure of the SMART program



Students worked collaboratively in groups, and they have freely chosen the topic of the projects based on the interests of the group members. Also, they have freely chosen the mathematical topic integrated into the projects, and in many cases also some knowledge from other disciplines were required. The researcher only provided the learning environment and the necessary tools and guided them if they required help.

Table 3 provides an overview of the diverse projects through which students applied mathematical principles to areas aligned with their personal interests. These projects served as the foundation for the development of ten innovative lesson plans, which were used in the quasi-experimental research presented in Chapter 5.

Table 3. Projects *developed* by the students

Project Title	**Mathematical Concepts**	**Student's Personal Interest**	**Real-World Application**
Math in Games: Domino Game	Differential and Integral Calculus, Geometry	Domino game instructions and mathematical theory	Game design industry, use of 3D printing or design thinking theory

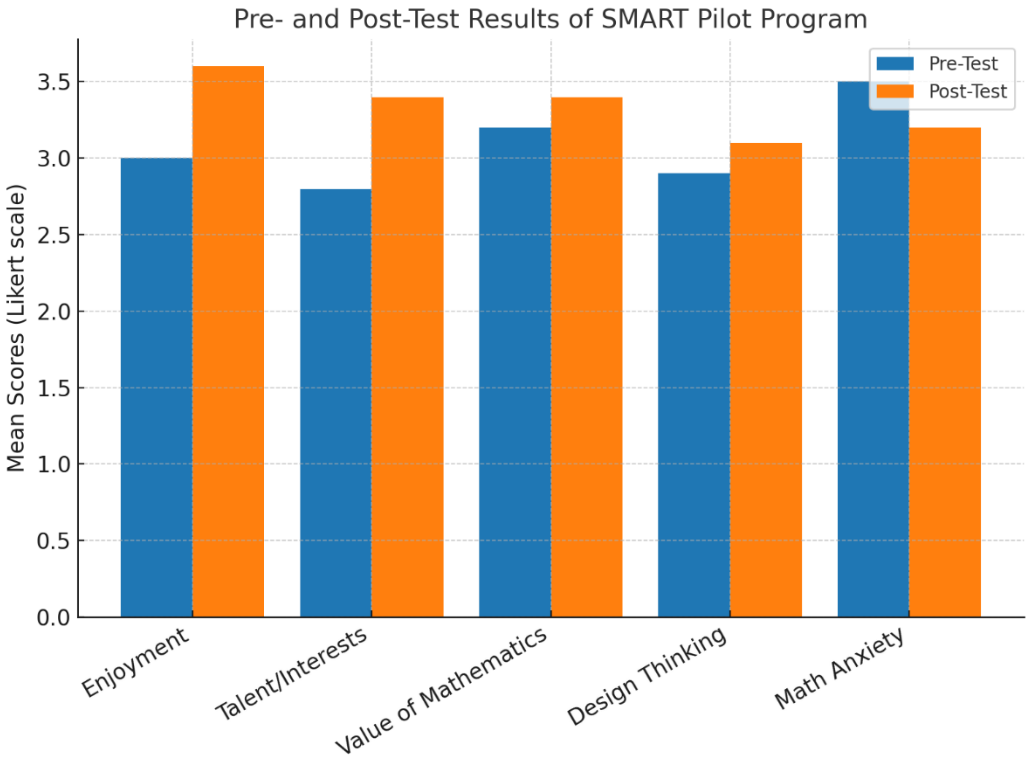
Building the Future: Cards against Math	Geometry, Algebra, Spatial Reasoning	Creative planning of short questions, review of tests, memory training and mathematical thinking that allows for quick retrieval of answers.	Developing creative and original tasks Sustainable Design
The Mystery of The Witch House- Escape room -math and probability	Probability, Statistics, Combinatorics	Video Games, Game Design	Game Development, Strategy Optimization
Sports Stats: Do you have physical fitness? Using Statistics to Analyze Athletes	Statistics, Averages, Probability	Sports, Athletic Performance	Sports Analytics, Athlete Team Management
Fashion and Geometry: Jewelry Design with Trigonometry and Geometry	Geometry, Symmetry, Trigonometry	Fashion Design	Fashion and design Original design planning
Art your math Nicole's Pythagoras	Relationships, proportions, trigonometry - mathematics combined with art.	Trigonometry and the environment, mathematics in art	Art with technology, the connection of mathematics and model building, puzzles, games
The connection between mathematics	Algorithms, Variables, Functions	Computer Science, Programming, Designing integrated	Developing software that connects the fields.

and physics, a lesson that connects mathematics and physics.		systems that combine mathematics and physics, Designing joint experiments between the fields.	
Trigonometry , Math and model building	Trigonometry, geometry, measurement, ratios,	Arts, architecture.	Architecture and Design
The Mathematics of Music and Dancing: Creating a Tik Tok song	Coordination, memory training, memorization of formulas and their use.	Visual Arts, Dance Art, Choreography	Art and Design, creativity and originality in dance
Mathematics Engineering Series: Sisa prize	Characterization of an engineering series, series, laws, general formula, general term	Investigate, discover regularities. Mathematical writing, discover general conclusions	Designing engineering series + growth and decay + finite and infinite series, algorithm for reaching a general term.

4.3. The Effect of Pilot Intervention on Students' Attitudes

The study was conducted in 2022 with 25 students from a 10th-grade 5-unit mathematics class in Haifa, Israel. A mathematics attitude questionnaire was administered before and after the intervention. The instrument included 44 items across six dimensions: enjoyment, value of mathematics, talent and interests, math anxiety, design thinking, and collaborative work. Reliability was high (Cronbach's $\alpha > 0.80$). Statistical analysis revealed significant improvements in enjoyment ($t(24) = -1.89$, $p < .05$) and talent/interests ($t(24) = -2.36$, $p < .05$). Positive but not statistically significant changes were observed in value of mathematics, design thinking, and reduced anxiety.

Figure 2. Pre- and post-test results of students' attitudes toward mathematics in the SMART pilot program.



4.4. Students' opinion about the SMART program

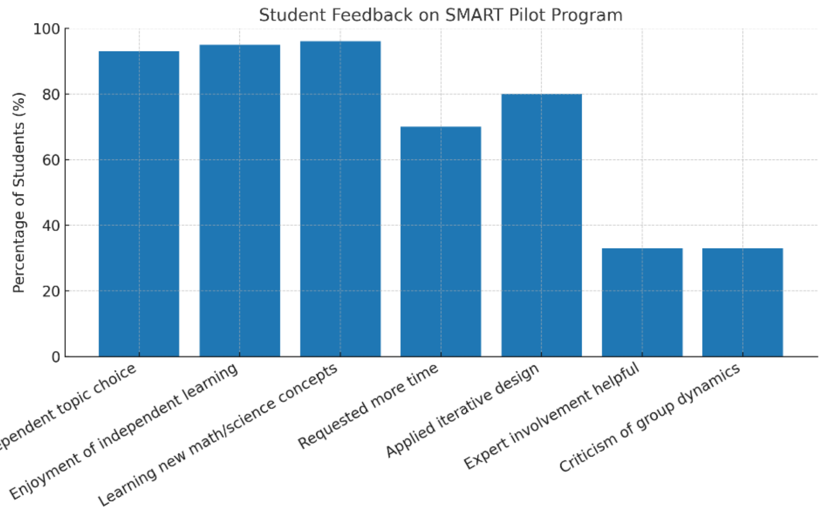
Qualitative data were collected from 15 in-depth interviews. Results showed:

- **Time constraints**: 70% requested more time to improve projects.
- **Expert involvement**: 33% found expert facilitators very helpful; others noted limited mathematical guidance.
- **Independent choice**: 93% selected their own project topics, increasing ownership and intrinsic motivation.
- **Product development**: 80% applied iterative design models, some focused on low-cost practical solutions.
- **Skills**: Students developed inquiry skills, technological proficiency (Excel, Canva, Rhino7, 3D printing), and communication abilities. 96% reported learning new mathematical/scientific concepts, and projects enhanced their discourse and critical reflection.

Students expressed high levels of enjoyment, creativity, and independent learning. While many valued teamwork, about a third criticized group dynamics (unequal contributions).

Overall, 95% appreciated independent learning opportunities, creativity, and integration of personal interests.

Figure 3. Student feedback on the SMART pilot program (percentages of responses).



This bar chart illustrates the distribution of students' responses regarding their experiences with the SMART pilot program. Most students expressed high satisfaction with independent topic choice (92%) and the enjoyment of independent learning (95%), indicating the program's success in fostering autonomy and intrinsic motivation. Similarly, 93% reported learning new mathematics and science concepts, demonstrating the program's effectiveness in integrating disciplinary content with innovative, student-driven approaches.

A significant portion of students also requested more time (70%), reflecting the demanding nature of independent, project-based work and the desire to deepen engagement. Furthermore, 80% applied iterative design strategies, highlighting the program's role in promoting creativity, problem-solving, and resilience through cycles of trial and refinement. Feedback also revealed that expert involvement was considered helpful by 33% of students, suggesting potential for expanding expert-student interactions in future implementations. However, around 32% expressed criticism of group dynamics, pointing to challenges in collaborative work and the need for scaffolding strategies to support equitable participation. Overall, the chart underscores the positive impact of the SMART program on autonomy, enjoyment, and learning, while also highlighting areas such as time allocation and group management that require further development.

Overall, the chart underscores the positive impact of the SMART program on autonomy, enjoyment, and learning, while also highlighting areas such as time allocation and group management that require further development.

4.5 Conclusions

The findings from the in-depth interviews suggest that while the SMART program was generally successful, there remain areas for improvement. Specifically, there is a need to more clearly define the project's objectives, the expected final product, and the criteria for evaluating it. Students expressed, to a large or very large extent, that they developed research-related competencies such as project planning, hypothesis formulation, information retrieval, and learning new scientific and mathematical concepts. skills closely aligned with 21st-century learning goals.

However, approximately 25% of students reported having little to no experience in constructing a physical prototype of their product. Moreover, 65% indicated that the time allotted for presenting their projects to the class was limited, which may have diminished the perceived significance of their work.

Looking forward, it is recommended to revise the program to ensure that these critical skills ,especially the practical aspects of prototyping and presentation, are fully integrated. Additionally, the findings underscore that the students valued being given the opportunity to think independently, propose creative solutions, and generate original ideas. Nearly all students (about 95%) expressed enjoyment in learning independently and appreciated being encouraged by the teacher to explore areas of personal interest.

Overall, the evidence points to a meaningful learning experience for the majority of participants, with high levels of engagement, enjoyment, and skill acquisition. These positive responses support the conclusion that the SMART program contributed significantly to students' academic and personal development, particularly by contextualizing mathematics within real-world and personally relevant domains.

Chapter 5. Study 3 – Experimenting the efficacy of the intervention program based on the projects developed by the students

5.1. Introduction

This study evaluated the SMART intervention program, a student-centered and interest-driven model for teaching mathematics, designed based on 10 projects co-created by students in the pilot research (Chapter 4). The intervention sought to test whether embedding student-developed projects into structured lesson plans could effectively foster engagement, motivation, and self-efficacy, while reducing mathematics anxiety.

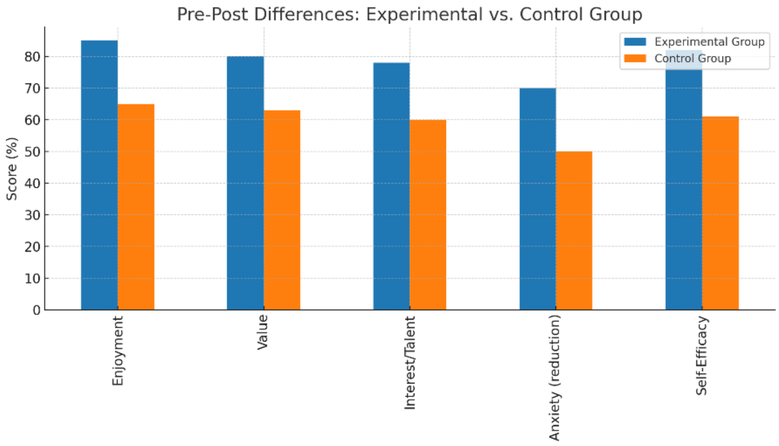
5.2. Methodology

The research was conducted in 2022 with 64 10th-grade students at Leo Baeck High School, Haifa, Israel, divided into an experimental group ($n = 30$) and a control group ($n = 27$). A refined version of the mathematics attitude scale (41 items, Cronbach's $\alpha = .857$) was administered as pretest and posttest. The scale captured enjoyment, value, interest and talent, anxiety, self-efficacy, design thinking, and collaborative work. Data analysis included descriptive statistics, t-tests, Mann–Whitney U tests, and linear mixed-effects modeling.

5.3 Key Findings

- Quantitative results revealed significant increases in students' enjoyment of mathematics and their perception of talent/interest, while math anxiety decreased.
- Qualitative interviews indicated that students valued creativity, independence, and the connection between mathematics and their personal interests.
- The SMART Program contributed to skill development in inquiry, collaboration, technological tools, and critical reflection.

Figure **4**. Change in Students' Attitudes Toward Mathematics (Pre vs. Post SMART Program)



• **Enjoyment and Value of Mathematics**: Experimental group scores rose significantly, indicating that mathematics was perceived as more meaningful, enjoyable, and relevant, while control group scores declined or remained stable.

• **Interest and Talent**: Students in the experimental group showed significant gains in connecting mathematics with personal interests, reflecting the success of integrating real-world contexts and personal passions into lesson design.

• **Math Anxiety**: Levels of anxiety decreased in the experimental group while increasing in the control group, suggesting that contextualized, interest-based approaches can foster emotional resilience in learning mathematics.

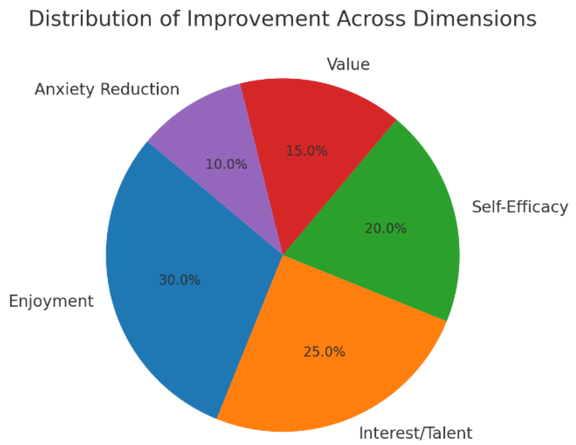
• **Self-Efficacy**: The intervention improved students' confidence in their mathematical abilities and their willingness to engage with challenging tasks.

• **Creativity and Design Thinking**: The program enhanced creativity and divergent thinking, with students reporting greater enjoyment in open-ended problem solving and exploration.

• **Collaboration**: While both groups began with high perceptions of collaboration, only the experimental group maintained and slightly improved these levels, highlighting the social benefits of project-based learning.

• **Skill Development**: Students highlighted gains in inquiry, technological proficiency, and critical reflection, reinforcing the program's role in fostering 21st-century skills.

Figure **5**. Independent Choice of Project Topics

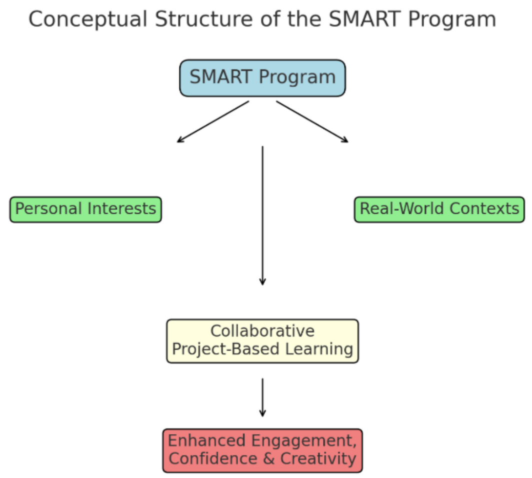


The pie chart illustrates the distribution of improvement across key dimensions following the SMART intervention program. The findings indicate that the program had the greatest impact on students' enjoyment (30%) and their ability to connect mathematics with personal interests and talents (25%). Improvements were also noted in self-efficacy (20%) and perceptions of the value of mathematics (15%). Finally, reductions in math anxiety accounted for 10% of the observed improvements. These results highlight that the program was most effective in fostering intrinsic motivation, confidence, and personal engagement with mathematics, while also alleviating stress associated with the subject.

5.4 Discussion and Contributions

This study demonstrates that student-centered, project-based, and interdisciplinary approaches can transform mathematics education from a domain associated with stress and abstraction into one marked by relevance, curiosity, and empowerment. Findings align with prior research on the efficacy of project-based learning (Cai et al., 2020), the reduction of math anxiety through tailored interventions (Dowker et al., 2016), and the benefits of STEAM and collaborative approaches (Wang et al., 2021). Beyond student outcomes, the research highlights critical pedagogical implications for teachers. Teachers require structured lesson plans and professional development to confidently integrate STEAM-based projects and interdisciplinary practices (Asli & Zsoldos-Marchis, 2021, 2023b). The SMART framework provides such a model, combining rigor with flexibility, and demonstrating scalability for broader curricular innovation**.**

Figure **6**. Conceptual Structure of the SMART Program.



The diagram illustrates the conceptual structure of the SMART Program. At its core, the SMART Program integrates students' personal interests and real-world contexts to create meaningful learning experiences. These two entry points personal interests and real-world contexts feed into collaborative, project-based learning, where students investigate, design, and solve problems together.

Through this process, students achieve enhanced engagement, confidence, and creativity. Specifically:

- Engagement: Students become active participants in their learning journey.
- Confidence: Math anxiety decreases while self-efficacy and willingness to take on challenges increase.
- Creativity: Students develop original solutions and practice divergent thinking.

In summary, the SMART Program connects personal interests and real-world contexts through collaborative project-based learning, ultimately leading to greater engagement, confidence, and creativity in mathematics education.

The SMART Program contributes to mathematics education by:

1. Demonstrating that integrating student interests increases motivation, confidence, and enjoyment.

2. Providing evidence that project-based learning in advanced mathematics can foster creativity, problem-solving, and 21st-century competencies.

3. Offering a framework for teachers to incorporate real-world contexts and student voices into curriculum design.

5.5 Conclusion

The findings of this study underscore the transformative potential of integrating students' interests into mathematics education, highlighting its capacity to enhance engagement, motivation, and problem-solving abilities. By adopting an innovative, student-centered approach that encourages the co-creation of lesson plans and fosters collaboration between students and teachers, mathematics is reimagined as a meaningful, emotionally resonant, and intellectually stimulating discipline. This participatory model empowers students to take ownership of their learning, cultivating critical thinking, creativity, and interpersonal skills.

These results are consistent with and extend prior research on student-centered pedagogies in mathematics education. For instance, Cai et al. (2020) demonstrated that project-based learning (PBL) substantially enhances student engagement and strengthens mathematical problem-solving skills ,outcomes that parallel the increased enthusiasm, creativity, and depth of understanding observed among participants in the SMART program. Similarly, Dowker et al. (2016) found that targeted pedagogical interventions can significantly reduce mathematics anxiety and promote enjoyment of the subject. These findings resonate with reports from several students in the current study, who described a transition from anxiety and avoidance to curiosity and enjoyment when engaged in personally meaningful mathematical activities.

The present study also supports Wang et al.'s (2021) conclusion that collaborative, interdisciplinary projects ,particularly in STEAM contexts ,can promote teamwork, critical thinking, and deeper engagement. The SMART environment facilitated not only student-to-student collaboration but also active student-teacher dialogue, leading to richer mathematical discourse and co-constructed knowledge.

In addition, while the primary focus of this study is on students, it also reinforces prior findings concerning teacher development. Asli and Zsoldos-Marchis (2021, 2023b) emphasized that many teachers feel unprepared to implement STEAM-based or interdisciplinary lessons due to limited training in non-mathematical disciplines. In line with their conclusions, this research highlights the importance of structured, cross-disciplinary lesson plans and professional development opportunities to build teacher confidence. These measures are essential for scaling and sustaining innovative approaches like the SMART program across diverse educational contexts.

Despite these promising findings, further research is warranted to examine the long-term implications of student-centred, interest-based approaches to mathematics. Future studies should assess the impact on student achievement, sustained engagement, and attitudes over time, as well as the feasibility of integrating such practices into teacher training and systemic curricular reforms.

Chapter 6. Conclusions

This doctoral research set out to reimagine the teaching and learning of high-level mathematics in Israeli high schools by challenging traditional paradigms and proposing an alternative, student-centered pedagogical model. At the heart of this vision lies the SMART Program, an innovative framework that positions students as co-creators of mathematical learning experiences. By integrating their personal interests, fostering collaboration, and leveraging technology, the program seeks to create emotionally resonant, meaningful, and empowering educational encounters.

The findings from the studies conducted reveal a profound shift in how students relate to mathematics when their voices, experiences, and passions are acknowledged and integrated into the learning process. Instead of viewing mathematics as rigid, external, and disconnected from their lives, students began to see it as a domain of creativity, exploration, and personal relevance. This transformation was especially evident in study 2 conducted with a small group of students in private tutoring, where students who had previously struggled with motivation became deeply engaged in designing lessons inspired by their interests—from music and art to architecture and sport. Through this process, they not only gained a stronger grasp of mathematical concepts but also developed a deeper emotional connection to the subject.

Study 3 conducted in classroom setting, confirmed these effects in a formal classroom setting. When students collaborated with their teacher to design interest-based lesson plans, the classroom dynamic shifted dramatically. Students exhibited increased autonomy, curiosity, and ownership over their learning. This co-creative process also fostered a sense of mutual respect and community between students and teachers, resonating with broader pedagogical goals such as dialogic teaching and democratic education.

6.1. Emotional and Social Dimensions of Learning

A central contribution of this research is its attention to the emotional and social dimensions of mathematical learning. The SMART Program emphasizes that emotions are not secondary to cognition but integral to it, especially in a subject like mathematics, which is often perceived as intimidating or alienating. By creating space for self-expression and shared meaning-making, the program helps dismantle emotional barriers and supports the development of positive affective dispositions such as confidence, curiosity, and joy.

Students reported feeling “seen,” “heard,” and “respected”, sentiments rarely associated with traditional mathematics instruction. These emotional experiences translated into increased engagement, perseverance in problem-solving, and a greater willingness to take intellectual risks. In this way, the classroom became not only a site for knowledge acquisition but also a place of relationship-building, identity negotiation, and belonging.

6.2. Pedagogical Implications

The implications of these findings for mathematics education in Israel are substantial. This research challenges the dominance of uniform, high-stakes instructional models that emphasize technical proficiency over conceptual depth and personal meaning. It suggests that high-level mathematics can and should be taught in ways that honor students’ identities, voices, and lived experiences.

The SMART Program offers a flexible, scalable framework for enacting this vision. Its key principles, student agency, interest-based learning, collaborative design, and reflective practice can be adapted to a wide range of educational contexts. Importantly, the program does not compromise mathematical rigor. Rather, it enhances it by embedding abstract concepts in emotionally and contextually rich environments. This supports deeper learning while aligning with global trends in STEM education that emphasize creativity, critical thinking, and interdisciplinary approaches.

Moreover, the research highlights the evolving role of the teacher, not as a sole authority or content deliverer, but as a facilitator, co-learner, and cultural mediator. Teachers who adopt the SMART approach must be open to deep listening, pedagogical experimentation, and continuous self-reflection. This paradigm shift carries significant implications for teacher education and professional development, calling for training programs that equip educators to thrive in dynamic, student-centered learning environments.

6.3. Limitations and Directions for Future Research

While this research offers compelling evidence of the SMART Program’s potential, it is not without limitations. The studies were conducted in relatively small and specific settings: a home tutoring environment and a single high school classroom, with the researcher playing a central, dual role as both facilitator and observer. While this allowed for rich insights and adaptive implementation, it may also introduce biases and limit the generalizability of the findings.

Future research should explore broader applications of the SMART model across diverse educational settings and with different facilitators. Longitudinal studies could illuminate the lasting effects of co-creative, interest-based learning environments on students' mathematical understanding, identity formation, and academic trajectories. Moreover, systemic support: curricular, institutional, and policy-level, must be examined to assess how such models might be sustainably embedded within national education systems.

An especially vital area for future inquiry is teacher professional development. Integrating the SMART framework into teacher training could cultivate a new generation of educators equipped with mindsets, tools, and confidence to foster emotionally aware, interdisciplinary, and student-centered approaches to mathematics teaching.

6.4. Final Reflections

This dissertation ultimately calls for a reconceptualization of mathematics education as a deeply human, creative, and relational pursuit. It challenges prevailing narratives of mathematical competence and success, arguing instead that when students are invited to bring their full selves into the learning process, when they are treated not merely as learners, but as co-authors, mathematics becomes a space of connection, imagination, and meaning.

The SMART Program is not a fixed solution, but a dynamic framework that centers students in the learning process. It presents a hopeful vision for the future of mathematics education: one in which every student, regardless of background, ability, or prior experience, can see themselves in the subject and discover their own path within it.

This journey began with a small group of students and a personal vision, but its implications extend far beyond. It joins a growing body of research advocating for humanistic, student-centered approaches to education, particularly in disciplines traditionally viewed as emotionally detached or rigid.

The SMART model demonstrates that mathematical rigor and student creativity are not mutually exclusive; they are mutually enriching. By grounding mathematics in relevance, emotion, and voice, we do not dilute its power, we deepen it. We help students forge lasting, personal relationships with the subject relationships based not on fear or performance, but on curiosity, meaning, and possibility.

Of course, implementing this vision requires courage, flexibility, and systemic support. It calls on educators to relinquish some control, on curricula to allow space for exploration, and on institutions to invest in professional development and cultural change. But the results are clear: when students are trusted to lead, they rise to the occasion. When their interests are honored, their motivation grows. And when they feel emotionally connected to what they learn, they carry that learning with them, far beyond the test.

This research is only the beginning. There is still much to explore: how to scale the SMART model, how to support teachers in adopting it, and how to measure its long-term impact. Yet if there is one enduring lesson from this work, it is this: mathematics can be a source of empowerment. A place where logic meets imagination, where structure meets creativity, and where every student can find not only answers, but also a reflection of themselves.

This thesis is both a reflection and an invitation: a reflection on what is possible when we let students shape their own learning, and an invitation to educators, researchers, and policymakers to reimagine what mathematics education can truly be. Let us ask not only how well students perform in mathematics, but also how deeply they connect to it, how confidently they engage with it, and how meaningfully it speaks to who they are, and who they may yet become.

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