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'For a moment I thought maths could be fun': the case of one student's enhanced motivation in mathematics when experiencing thinking classroom

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ABSTRACT

Different teaching approaches in mathematics classrooms can influence student engagement and motivation. This study explores the impact that the Thinking Classroom teaching approach has on students' motivation by examining the case of Zoe, a 16-year-old student who initially found mathematics boring and difficult. Traditional teaching methods were found ineffective in engaging her. When exposed to the Thinking Classroom approach, Zoe's motivation and engagement increased. The study employs self-determination theory to analyse Zoe's motivation through competence, autonomy, and relatedness. Data were collected through video recordings, field notes, and interviews with Zoe and her teacher. During the Thinking Classroom lessons, Zoe demonstrated high levels of competence, autonomy, and relatedness. The study suggests that incorporating Thinking Classroom can have a positive impact on students' attitudes towards mathematics, although Zoe's motivation returned to previous levels after the Thinking Classroom lessons ended. The findings underscore the potential benefits of alternative teaching methods in mathematics.

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Mathematics teaching; active learning; thinking classroom; motivation; self-determination theory

Introduction

> For me, maths is boring and difficult. I need help from my teacher to understand how to proceed with the tasks in the book. If I don't get help, I zoom out and do pretty much nothing. During the lessons with a different teaching approach, I found that maths can be fun.

These are the words of Zoe, a 16-year-old student studying the first mathematics course in upper secondary school. Zoe's case tells a story of a profound change in one student's motivation during mathematics lessons when using the Thinking Classroom teaching approach designed by Liljedahl (2016).

How mathematics is taught affects the students in different ways. A common teaching approach in Sweden is to present methods for the students, who thereafter work individually, mirroring the methods (The Swedish schools inspectorate, 2010, 2018). This can lead to an impression of mathematics as a series of rules and techniques to memorise (Boaler, 2000; Lithner, 2008, 2017), which makes many students perceive mathematics as difficult and boring (Boaler, 1998b, 2016).

A changed teaching approach can induce higher motivation (Koskinen & Pitkäniemi, 2022; Liljedahl, 2018) and increased learning among students (Koskinen & Pitkäniemi, 2022). It is therefore vital to incorporate various teaching approaches in mathematics and listen to the students' voices.

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In the context of a study involving four teachers who used parts of the Thinking Classroom teaching approach, one student, Zoe, caught our attention. For her, the changed teaching approach seemed to increase motivation and encourage a more positive attitude toward mathematics during the TC lessons.

The objective of this article is to use Zoe's enhanced motivation as a case to examine how Thinking Classroom can affect students' motivation for mathematics. Using a narrative approach, we present how Zoe's motivation becomes visible during a series of lessons.

Mathematics teaching approaches

The most widespread teaching approach in Swedish upper secondary schools involves, as mentioned above, a presentation of some kind by the teacher at the beginning of the lesson. Thereafter, the students work independently on tasks, often from a textbook, while the teacher circulates the classroom, providing individualised assistance to students (The Swedish Schools Inspectorate, 2010, 2018). Similar approaches have been labelled the "transmission model" (Boaler, 1998a, p. 130), "recitation" (Hiebert, 2003, p. 11) or as "teacher-centred" (Pampaka et al., 2012, p. 475). Although these are comparable to what transpires in most Swedish upper secondary schools, there are differences. Therefore, we will refer to the Swedish teaching style as the traditional approach hereafter.

The traditional approach focuses on mimicking specific methods and learning by heart, which supports the students' procedural skills (Hiebert, 2003). However, one negative impact is that the students' conceptual understanding is less developed (Hiebert, 2003) when focusing on mimicking rather than understanding. Imitation also leads the students to believe that mathematics consists of rules and methods that must be memorised (Boaler, 2000; Lithner, 2008, 2017), or as Lithner puts it, "[t]he search for algorithms *becomes* mathematics instead of being a part of it" (2008, p. 273). This entails that the students cannot use their knowledge in unfamiliar situations within the mathematics classroom or connect the mathematics learned at school to situations outside the mathematics classroom (Boaler, 2000). Another negative effect concerns word problems, where the students search for cues in the text and then combine the numbers given instead of reading and analysing the task thoroughly (Molina et al., 2018; Verschaffel et al., 2000). Overall, the traditional teaching approach leads students to consider mathematics uninteresting and boring (Boaler, 1998b, 2016).

To avoid these negative effects, several alternative teaching approaches have been studied. Koskinen and Pitkäniemi (2022) conducted a literature review focusing on learning outcomes when using an alternative teaching approach, and they found some aspects of other teaching approaches to be more beneficial. One of the aspects, namely social approaches, involves different kinds of collaborations between students with an emphasis on communication, which increases learning and motivation among students according to Koskinen and Pitkäniemi's synthesis. For example, in comparing "teacher-centred" and "learner-centred" approaches in college, Pampaka et al. (2012) found that learning outcomes were higher amongst students whose teachers used a more communicative approach. We recognise that the quality of communication is relevant in relation to learning outcomes (Sfard, 2001); however, in this study, we focus on one student's enhanced motivation, not her learning.

The ability to transfer knowledge from one situation to another is one goal of mathematics education. A study where the teaching approach focused on group work and projects that stretched over multiple lessons, Boaler (1998a, 1998b, 2000) found that these students were able to use their knowledge in new situations in a flexible way and a belief that their mathematical knowledge was useful outside of school. They could "reflect upon what they knew and adapt and change mathematical methods to fit the demands of new situations" (Boaler, 1998a, p. 139). This transference of knowledge was also visible amongst students who had been taught via what Kapur (2014) calls productive failure in comparison to direct instructions. Furthermore, students in Kapur's (2014) study showed higher conceptual understanding, while the procedural knowledge was roughly the same.

Similarly, Cai et al. (2011) found that no basic skills were lost when the skill of solving problems increased in a study focusing on the students' conceptual understanding of mathematics and problem solving. Problem solving has also been used, with the aim "to train students to 'think creatively'" (Schoenfeld, 2016, p. 4), with various outcomes.

According to the literature cited above, moving from the traditional approach towards one that engages students more seems to be beneficial in several ways. One student-centred approach that emphasises communication and personal responsibility in mathematics learning is Liljedahl's (2016) Thinking Classroom (TC). According to Liljedahl, TC offers an effective method for mathematics instruction aiming at enhancing students' engagement, which is confirmed in a study by Muir (2025). TC was developed by Liljedahl in a series of studies (e.g., Liljedahl, 2016; Liljedahl & Allan, 2013). The main purposes of the approach are to engage students in thinking mathematically more freely, increase communication between students, and enhance student engagement. The approach consists of fourteen practices that revolve around different aspects of teaching, such as how the classroom is furnished, what kind of questions the teacher answers, and how to use formative assessment. Drawing upon his research, Liljedahl (2021) recommends that teachers unfamiliar with TC start with the first three practices designed to break as many classroom norms as possible.

Practice 1 states that the lesson should start with a task that ought to be engaging and encourage the students to think. When TC is new to the students, the tasks should be unfamiliar, unlike textbook tasks, as a way of breaking one classroom norm. After the first three to five lessons, the task can be chosen from the teaching materials normally used. One vital property of a TC starting task is that every student should be able to understand how to start working with it; the task should also be challenging (Liljedahl, 2021).

Practice 2 revolves around group work. Students older than nine should work in groups of three; if the number of students is not divisible by three, pairs are recommended. To break another classroom norm, the groups must be formed randomly. Randomisation is important since students should be able to work with all their peers, and the perfect grouping does not exist; therefore, time attempting to achieve this is spent in vain. It is also vital that the randomisation is done visibly so that the students know that the process is authentic (Liljedahl, 2021).

Practice 3 says that the students must stand and work on vertical non-permanent surfaces, like a whiteboard or a window. The ease of erasing one's mistakes on a non-permanent surface contributes to students starting work on tasks faster and creates a willingness to try more ideas. Standing while working also breaks an additional classroom norm, and the energy level rises. For three students to collaborate effectively, all must be able to see what is written; thus, a vertical surface is preferred. Other advantages are that it is more visible to the teacher if a student is engaged and provides the teacher with an overview of the students' work (Liljedahl, 2021).

TC can also change how students experience mathematics, even if the learning does not increase, as shown by Liljedahl (2018), where he concluded that a student who encountered TC increased self-esteem, looked forward to the lessons in mathematics and improved her confidence. This article also focuses on one student's enhanced motivation. To explain the observed changed behaviour, mirroring motivation, self-determination theory was used.

Self-determination theory

The basis of self-determination theory (SDT) is that for humans to feel motivated, three psychological needs must be fulfilled: competence, autonomy, and relatedness (Ryan & Deci, 2017). Competence implies experiencing mastery and engaging in challenging tasks. Autonomy is explained "as the necessity of experiencing a sense of choice, willingness, and volition" (Guay, 2022, p. 80). Relatedness involves seeking belongingness with others and feelings of security. SDT distinguishes between two kinds of motivation: external and internal (Ryan & Deci, 2017). External motivation is typically described as when a student learns something to get a

good grade, impress peers, get a reward, or avoid punishment or shame. Internal motivation, on the other hand, is viewed as a driving force to understand the intended learning objective for its own sake. External and internal motivation can be seen as a continuum where the best learning outcome and higher well-being derive from internal motivation (Howard et al., 2021). The more internal the motivation is, the more autonomous the student feels. On the other side of the spectrum, the feeling of being controlled is enhanced (Guay, 2022). SDT thus provides an appropriate tool to visualise and understand students' motivation in classrooms, which we use to investigate how a different teaching approach can affect a student's motivation. As mentioned above, this article aims to use Zoe's motivation as a single case to examine how TC can affect students' motivation for mathematics.

The following research questions guide this case study.

How is one student's motivation manifested through the three basic psychological needs, namely competence, autonomy, and relatedness?

How can features of Thinking Classroom enhance one student's motivation?

Method

This section comprises a description of the research approach, the context of the study, the participant, the collected material, and the analyses.

Research approach

This study examines one case: Zoe's enhanced motivation when experiencing Thinking Classroom (TC). One case can be sufficient if it is extraordinary in terms of its uniqueness in illustrating a phenomenon (Siggelkow, 2007). Here, the phenomenon is the motivation to work with mathematics in school. The uniqueness lies in the large enhancement of motivation observed in the TC lessons. For this purpose, the case of Zoe is carefully chosen rather than random; thus, it is purposive (Bryman, 2011) since she was found to be relevant to the study at hand.

Context

This study occurred at an upper secondary school in northern Sweden. The teacher volunteered to participate in a project, making it a convenience sample (Bryman, 2011). In the project, the first three practices of TC were used in five consecutive lessons. The teacher had been a mathematics teacher at this school for over ten years and had adequate education. The class consisted of twenty students, all of whom consented to participate in the study and took their first compulsory course in mathematics. The tasks during the first three TC lessons were unfamiliar to the students, as recommended by Liljedahl (2021). For the last two TC lessons, the teacher chose tasks that revolved around probability since that was the mathematical content the class was working with.

Participant

Zoe drew the attention of the first author during the third TC lesson since she showed high motivation and persistence when working on the task. This behaviour continued during the remaining two TC lessons. The teacher informed us that this was something that she had not experienced before regarding Zoe. Thereafter, Zoe was approached and asked if she was willing to participate in an individual interview, to which she agreed. A more thorough presentation of Zoe is found in the results section.

Table 1. An overview of the data collected regarding Zoe.

Before TC	Field notes from ordinary lessons Interview with the teacher
TC lesson 1	No data
TC lesson 2	No data
TC lesson 3	Field notes
TC lesson 4	Video
TC lesson 5	Video
After TC	Three interviews: Zoe in a student group, Zoe individually, and the teacher individually

Materials

In total, two videos from TC lessons, four interviews, as well as field notes, both from ordinary lessons before TC and during the TC lessons, were collected, see Table 1.

The videos (39 and 41 min, respectively) were of Zoe when working on tasks with peers during TC lessons 4 and 5. Video recordings enable us to analyse not only utterances but also gestures and body language (Jewitt, 2012). It was not possible to video record all student groups; thus, field notes were used to complement the videos. All events perceived as interesting were noted as soon as possible and, if needed, written in more detail after the lesson. Field notes were also collected from two ordinary lessons before TC.

Two interviews with Zoe were conducted after the TC lessons, one group interview (13 min) and one individual (11 min). In the group interview, Zoe and her peers shared their views on mathematics as a subject, how they perceived ordinary lessons in mathematics, and how they felt about the TC lessons. The individual interview had the same topics as the group interview and was conducted to understand in more detail Zoe's experiences and view of mathematics. She was also invited to describe her perceived level of activity during ordinary lessons and TC lessons. In addition, one interview (3 min) with the teacher was conducted regarding her comprehension of Zoe's behaviour and motivation in mathematics lessons, both ordinary and TC. Finally, the teacher was interviewed before TC (23 min) with the focus on her teaching approach during ordinary lessons. These teacher–interviews were used to support Zoe's statements and provide context. All interviews were recorded and transcribed.

Analyses

We used SDT as a theoretical tool to interpret Zoe's motivation during TC lessons. Thus, we created an analytical tool with both positive and negative signs from the three constructs of competence, autonomy, and relatedness. The first signs were constructed from our understanding of competence, autonomy, and relatedness and initial viewing of the two videos. Thereafter, we used the tool on a smaller part of Lesson 5, which gave additional indicators. The tool was then refined during the analysis of the videos by a back-and-forth process, resulting in the following (see Table 2).

We watched the videos with these signs at hand, searching for indications of competence, autonomy, and relatedness, both positive and negative. The videos were divided into parts, ranging from 5 s up to 2 min, in which the content was one type of action. For example, Zoe walks over to another group or discusses a certain part of the task with her peers. These parts constituted units of analysis; see examples in Table 3. Since the unit of analysis comprised one type of action where multiple student behaviours, utterances and interaction is present, both positive and negative signs of competence, autonomy or relatedness can occur in the same time frame. A timeline[1] of Lesson 4 and Lesson 5 was constructed to visualise the signs of competence, autonomy, and relatedness, both positive and negative, respectively (see Figures 1 and 2 under the results section). Some parts of the videos were not possible to analyse due to the inability to hear what Zoe said or because she

[1]Inspired by Schoenfeld (2007); p. 75

Table 2. Positive and negative signs of competence, autonomy, and relatedness.

Competence	Positive	Expressing confidence ("This is easy", "I know") Success (solves a part of the task, gives suggestions on how to continue) Realisation ("Oh, then we have to", "this is wrong") Explains to others Persistence
	Negative	Insecurity ("Or?", "How should one start?") Seeks confirmation ("Is this correct?") Gives up
Autonomy	Positive	Takes initiative Independence Freedom of choice
	Negative	Passivity Dependency of others No freedom of choice
Relatedness	Positive	Facing the others Listening to others Being listened to
	Negative	Turning away from peers Getting interrupted Not listened to Interrupting others Not listening to others Doing her own thing without interaction with the others

Table 3. Examples of units of analysis using the analytical tool.

Description	Competence		Autonomy		Relatedness	
	positive	negative	positive	negative	positive	negative
Lesson 3 Completing the last task	Success Realisation Persistence		Take initiative Freedom of choice			Doing her own thing
Lesson 4 22:55-24:10 Zoe is looking at her phone				Passivity		Turning away from peers Do not listen
Lesson 5 01:00-02:10 Walks to another group, discussing the answer	Explains to others	Looking for confirmation	Take initiative		Facing the others Listening and being listened to	

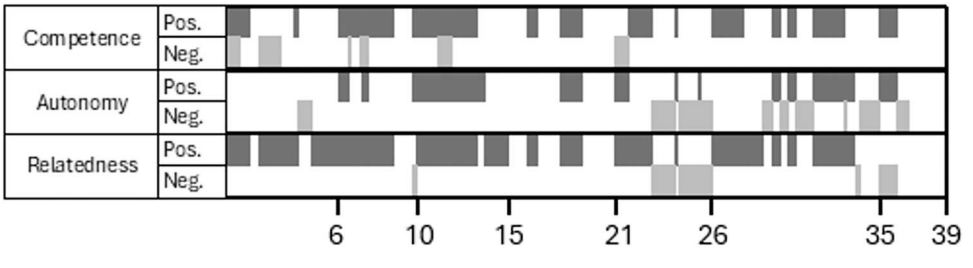

Figure 1. A timeline of Lesson 4 showing when positive and negative signs of competence, autonomy, and relatedness, were visible.

was not visible on the screen. The field notes concerning Zoe from Lesson 3 were analysed using the same tool, but no timeline was constructed due to the nature of the material.

The two interviews with Zoe were transcribed; thereafter, we conducted an inductive thematic analysis (Braun & Clarke, 2006). Each citation was assigned a code, which was later combined into

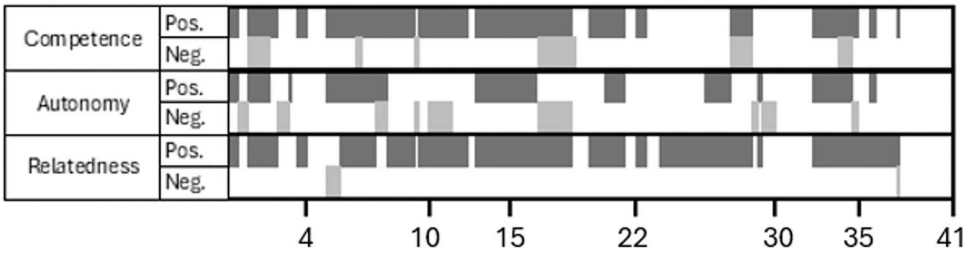

Figure 2. A timeline of Lesson 5 showing when positive and negative signs of competence, autonomy, and relatedness were visible.

Table 4. Examples from the thematic analysis.

Theme	Code	Citation
Zoe's perspective on mathematics	Feeling of maths	Boring
		Fun if you understand
		It is too hard
	Ability	I passed
		I'm not bad, but I'm not the best
Zoe's perspective on the different teaching approaches	Understanding	When I get an explanation that I understand
		I understood better
	Focus	Some difficulties concentrating
	Collaboration	We talked, worked together, listened to each other

two themes: Zoe's perspective on mathematics and the teaching approach (see examples of the thematic analysis in Table 4). These two themes describe how Zoe experiences mathematics and mathematics lessons, which can explain her higher motivation.

The two interviews with the teacher were also transcribed. The interview conducted prior to TC focused on this teacher's teaching approach during ordinary lessons and was used to provide a contextual background for the results, with the teacher's account taken at face value. The teacher's description of ordinary lessons was confirmed by the students group interview and the fieldnotes. The interview conducted after the TC lessons focused on Zoe and was used to triangulate Zoe's descriptions of her behaviour during ordinary lessons and TC lessons, also taken at face value.

Results

We have chosen to apply parts of a narrative approach in the presentation of the results, namely, as a story with a beginning (Zoe's view on mathematics and ordinary lessons before the Thinking Classroom (TC) lessons), a middle (the TC lessons), and an end (ordinary lessons after TC) where the main character is Zoe (Bryman, 2011; Lutovac & Kaasila, 2010).

The story starts with a description of Zoe's perspective on mathematics as a subject. Thereafter, ordinary mathematics lessons are presented, followed by three lessons where TC was used. Lastly, Zoe's and the teacher's descriptions of ordinary lessons after TC are given.

Zoe and mathematics

Zoe states that mathematics, as a subject, is "boring" and "awful" because it is "hard". She suggests it can be "fun" if she understands what to do, but to understand, an individual explanation from the teacher is needed. Zoe acknowledges that she can learn mathematics and that her ability to do mathematics is "quite okay", summarised as "I'm not bad, but I'm not the best either". She declares that she cannot be the best since mathematics is "too hard".

Ordinary lessons

This section starts with a description of the context, followed by an account of Zoe's activity during the ordinary lessons, and concludes with a presentation from the SDT analysis.

Most mathematics lessons start with an introduction by the teacher, according to both the teacher and Zoe. This introduction could either be a presentation of something new, a repetition, a presentation of how to solve a specific task, or a presentation of a problem to solve. According to the field notes from introductions, the teacher frequently asks the students questions; these are primarily closed and revolve around facts. The questions are often directed to the whole class, where the students mostly answer verbally. If nobody answers the question, it is given to a randomly chosen student or answered by the teacher. The teacher reports that after the introduction, the students work individually on a number of tasks from the textbook assigned by the teacher, who circulates the classroom, helping the students. She also mentioned that they work in groups a couple of times each year. The students have assigned seats in every classroom, which were decided by a teacher at the beginning of the school year and are seldom changed. The desks are arranged one by one with space between them so the teacher can walk freely; thus, the students sit by themselves.

Both the teacher and Zoe described Zoe's activity as low during the teacher's introduction, 4 out of 10, according to Zoe. The teacher is unable to discern whether Zoe is listening during the introduction since she neither answers nor poses questions: "You can't even tell if she's paying attention, if she's actually awake or not". According to Zoe, the reason for the low activity during the introduction is that she experiences "some difficulties concentrating", and her "mind wanders". Nonetheless, Zoe states that she comprehends the content during the introduction, although she often gets stuck when working independently. "Then [during the introduction] I have a rough idea of how to do it, but when the first task [in the book] comes, I still don't understand anything". During the individual work, Zoe describes that her activity depends on whether she gets help from the teacher immediately. When that happens, Zoe can work with the tasks in the book for a while, according to both Zoe and the teacher. Zoe rates her activity during the individual work as 6–7 out of 10: "It's higher if I understand; otherwise, I just kind of give up". The teacher also claims that Zoe is more active after being given help, but "she still never manages to make it through an entire lesson, but if you're there and can catch her right away, she lasts longer than she would otherwise". If it takes too long before the teacher helps Zoe, both the teacher and Zoe describe that Zoe gives up and does nothing during the rest of the lesson. The teacher states that "then she just lies down on the desk and basically falls asleep"; it is challenging to re-engage Zoe once her focus has been lost and she spends "many lessons half asleep". The teacher predicts that Zoe will pass the mathematics course, "but nothing more" even though the teacher acknowledges that Zoe "has a good sense of maths and can achieve a higher grade than just passing".

The ordinary lessons provided negative autonomy and relatedness for Zoe. What to do, what tasks to focus on, and how to solve them were decided by the teacher. The students were seated one by one, which made it hard for Zoe to collaborate with her peers. Both Zoe and the teacher stated that Zoe had mathematical competence, but that it was lowered due to a lack of persistence.

TC lessons

First, a summary of Zoe's view of the teaching approach is presented, followed by the teacher's interpretation. Then, three analysed TC lessons are presented.

Zoe rated her activity during the TC lessons as 10 out of 10. She claimed that she "understood better" even though she received no individual explanation from the teacher. Zoe suggested that this was because it was more "talking, collaborating, listening to each other, coming up with ideas, and things like that". She described that they came up with ideas and experimented together, which was much more enjoyable even though it was challenging to stand up for so long. The TC lessons, therefore, provided positive autonomy and relatedness due to the practices of TC.

The teacher declared that she was "really impressed" with Zoe's activity during the TC lessons:

> She showed so much of everything; she was really proactive and didn't give up even though it was an hour-long lesson. I thought she would go and sit somewhere and stay there for the rest of the time, but she was up on her toes most of the time, which was really exciting.

According to the teacher, Zoe seemed to be the driving force in the groups, and that was something she had not seen before. The teacher testified to visible signs of positive competence and autonomy.

Lesson 3, the pirates

The task of this lesson was an adaptation of the Josephus problem, where the goal was for the pirate captain to walk away with a diamond.[2] Starting with nine pirates and then increasing one by one, a pattern would be visible to the students.

Zoe and her two peers started the work right away and completed the task for nine, ten, eleven and twelve pirates when they spotted the pattern. Zoe showed signs of positive competence through both success, by completing the task with an increased number of pirates, and realisation when spotting the pattern. She had the freedom of choice in how to approach the problem. She was interacting with her peers, listening to them and being listened to, hence positive relatedness.

Zoe and her peers then turned to the researcher for directions on what to do next and were encouraged to figure out if their pattern had some limitations. The group discovered that when continuing their pattern with the increased number of pirates, at one point, the captain is supposed to point at himself, which contradicts the purpose of the task. Zoe showed signs of positive autonomy when taking the initiative to ask the researcher for more work, which also shows that she had the freedom of choice. Positive competence was demonstrated when Zoe and her peers successfully realised the limitation of their pattern. Zoe continued to display positive relatedness due to the interaction with her peers.

When exploring the pattern, Zoe's group found that if there are 17 pirates, the pattern starts all over again, both a success and realisation as signs of positive competence. The researcher then encouraged the group to find the next breaking point, and they established this to be 33 pirates, also a sign of positive competence. They then turned to the researcher for confirmation, a negative sign of autonomy, who asked them to check their hypothesis by drawing the pirates, which Zoe did with the help of her peers, thus positive relatedness.

Finally, the group decided that the next breaking point must be 65 pirates. Zoe drew the 65 pirates and started to verify their theory, hence positive autonomy via both independence and taking initiative. Halfway through the work, she realised that she had done something wrong (positive competence), so she erased everything and started all over again, showing signs of persistence. Even though most students and the teacher were watching Zoe's work, negative relatedness was displayed since Zoe was doing her own thing without interaction with the others.

Lesson 4, probability with dice

During this lesson, different tasks were given to the students that all revolved around probability with dice. The first task was to calculate the probability of obtaining a sum greater than three with two six-sided dice. The following tasks involved an increased number of dice and/or dice with more sides.

Zoe expressed confidence on several occasions, e.g., "Yes, then it is six times two", "This is the chance that we get more than three", and "It is going to be seven". Further, she explained to her peers, for example, "that means there are twelve sides in total" and "because the last time it was thirty-six times six and therefore it is two hundred sixteen times six now". Moreover, Zoe succeeded in solving tasks, "it is thirty-three divided by thirty-six", thus showing signs of positive competence

[2]Liljedahl, 2021, p. 229.

throughout the lesson. The negative signs of competence were shown through insecurity, for instance, shaking her head, saying "I don't know", and "ehhh, we have a problem".

At the beginning of the lesson, the negative autonomy arose from seeking confirmation like "that is over three?", "or?" or asking the teacher if their answer was correct. Between minutes 23 and 26, Zoe is mostly passive, looking around the room or at her phone, which is also the case from minute 28 approximately and forward. The positive signs of autonomy were usually when Zoe took the initiative by suggesting how they should proceed, "shall we erase those that do not exceed three?" and "now it is the next one". She also took the initiative by calculating on her phone without being asked and kept talking about the task even when her peers tried to talk about something else.

During the whole lesson, Zoe mostly interacted with her peers, listening to them and being listened to, thus showing positive relatedness. However, there were episodes of negative relatedness. By minute 10, Zoe works on the task without interaction with others, thus doing her own thing. On two occasions, she talked to the others but was not listened to. Between minutes 23 and 26, Zoe's two peers were working on the task, and Zoe was sitting a bit to the side. She once commented on their work, "it is two hundred and sixteen", but the others rejected her answer without exploring it further.

Lesson 5, probability at the cinema

The teacher presented the task at the start of the lesson.

> It is a Friday afternoon and these friends [pointing at the smartboard where she has written three names] are going to the cinema. They have booked three seats next to each other. What is the probability of Sara and Elias sitting beside each other if the tickets are randomly picked?

The task was then extended by adding one friend at a time, calculating the probability for four and then five friends.

The group started working right away, and Zoe was mainly driving the work. She quickly announced the answer for the first part of the task, namely, three friends going to the cinema. Thereafter, the work continued with four and five friends.

Zoe showed signs of positive competence during a large part of the lesson. She expressed confidence when working on the task, for example, "Then it is these times four" and "We take these times five since they are five". Success and insights were indicated through statements like "ah, we only did once", "then it is eight twenty-fourths", and "then it is fifty per cent". Zoe explained her thinking to the teacher, the researcher, and her peers such as "like, when it begins with S or E, then it can only be two [favourable outcomes] and when it begins with the other two [letters] it becomes four [favourable outcomes]". They struggled when calculating the possibility when there were four and five friends, but Zoe kept working even though her peers wandered off at times, which displayed persistence. The negative signs of competence came from insecurity voiced as "or?" and "but what is this then?"

Positive autonomy was visible when Zoe took the initiative, for instance, writing, asking for directions "what are we supposed to do now?", and driving the work forward "shall we try?" Independence was, for example, noticeable when Zoe was trying to find all possible outcomes with five friends. She started to list the outcomes by keeping one letter, symbolising one friend, constant and realised that that would take too long, "I mean, you can make like loads of them". Therefore, she erased it all and started with keeping two letters constant instead. This was also an example of freedom of choice since nobody told Zoe what to do or how to do it. The freedom of choice was lowered a couple of times. Around minute 8, the teacher stated that the answer should be expressed as a fraction, and at minute 11, the teacher guided Zoe in a certain direction (negative autonomy). The other occasions where Zoe showed negative autonomy derived from her seeking confirmation, such as asking, "is this correct?" and visiting other groups. Passivity was observable at the beginning of the lesson when Zoe was seemingly uncertain and a bit later when waiting for directions.

Throughout the lesson, Zoe interacted with her peers by looking at them, facing them, listening to them, and being listened to, indicating positive relatedness. The first appearance of negative relatedness, after five minutes, was when Zoe started to list all possible outcomes with four friends without interacting with her peers, thus doing her own thing. At the end of the lesson, Zoe suggested an answer that nobody took any notice of, and here she was not listened to.

After TC

After experiencing TC, Zoe voiced a new view of mathematics, that her opinion of mathematics had changed, and that her feelings regarding mathematics had changed. "Yeah, right after that, I got a new perspective on math, like it was a bit more fun, but then after a while, it went back to normal". The teacher reported no notable change in Zoe's behaviour or attitude during the ordinary lessons after the series of TC lessons.

Discussion

This article aimed to study how an alternative teaching approach, Thinking Classroom (TC), could affect students' motivation viewed through the lens of Zoe. The enhanced motivation was visible during the TC lessons, and through the lens of self-determination theory (SDT) (Ryan & Deci, 2017), we could frame Zoe's motivation in detail. In other words, SDT allowed us to systematically analyse what we experienced by watching Zoe's behaviour when she worked on mathematical tasks, showing high motivation.

Working in groups is one of the features of TC that we argue contributes to Zoe's enhanced motivation. Zoe showed a high amount of positive relatedness, which was visible in the videos (see Figures 1 and 2 above); the fieldnotes support this finding. Zoe also reinforces it in the individual interview, where she claims that the collaboration contributed to her higher activity in the TC lessons. Changing the norms of mathematics classrooms to let the students work in groups correlates with what Koskinen and Pitkäniemi (2022) labels as beneficial social aspects of alternative teaching approaches that increase learning. Similarly, Boaler (2016) have demonstrated that collaboration between students is one significant factor in increasing students' engagement and understanding of mathematics. In conclusion, students need to work collaboratively as this enables them to experience relatedness, which is a vital part of motivation and leads to an increased opportunity to learn. Collaborative work is not a part of the traditional approach as it is dominated by individual work (The Swedish schools inspectorate, 2010, 2018). Hence, we claim that group work needs to be included in mathematics teaching.

We also claim that the tasks used during the TC lessons contribute to Zoe's enhanced motivation. The tasks were chosen to be easy to start with and allow for more complex thinking, which gave Zoe the possibility to experience the feeling of competence visible in the TC lessons. She understood what the tasks were about and could start to discuss how to begin with a solution without any clarification or explanations from the teacher, which was stated by both Zoe and the teacher as a necessity in the ordinary lessons. Several scholars have in recent decades advocated for more problem-solving activities as a way to engage students to think by themselves (e.g., Schoenfeld, 2016). Nevertheless, it is not enough to just hand out problem-solving tasks to the students; it is also important how the task is presented (Liljedahl, 2016). According to TC, the teacher should present the task orally to further enable students to collaborate. This means that the students do not encounter the task as a word problem, and it is therefore futile to search for clue words and numbers to operate on, a common strategy as shown by Molina et al. (2018) and Verschaffel et al. (2000). Consequently, how the tasks are chosen and how they are presented in the TC lessons enable students to experience competency and relatedness, thus, higher motivation.

Standing and working on whiteboards is another feature of TC that positively influenced Zoe's motivation. The vertical surface enabled Zoe's increased autonomy since she had the possibility of

looking at other groups' work. On several occasions, Zoe looked around the classroom and said something that made us believe that she saw something that helped her to proceed. This behaviour is viewed as something positive, according to Liljedahl (2021), and should not be mistaken as mimicking since she never copies but rather gets inspired. This possibility to view others' work could also be connected to a feeling of competence. The ease of erasing on whiteboards also contributed to Zoe's higher autonomy since this property allowed Zoe to freely explore solutions, which is in line with Liljedahl's research (2016). Finally, standing and the vertical surface are also beneficial for relatedness since the students stand close to each other when working on the whiteboard. In conclusion, inviting the students to stand and work on whiteboards enables them to experience all three psychological needs. Hence, such a small change in the teaching can contribute to enhanced motivation among the students.

One can argue that Zoe's motivation would eventually drop back to the levels shown in the ordinary lessons even if TC continues to be used as a teaching approach. We acknowledge that this could happen, but we believe that the fact that Zoe kept her motivation up for five consecutive lessons indicates that her motivation would remain high if TC continued to be used. Nonetheless, TC allowed Zoe to not only feel more motivated but also experience mathematics differently, leading to a changed attitude regarding mathematics. She expressed that mathematics was fun during the TC lessons, indicating that it was not the case during the ordinary lessons.

One limitation of this study is the lack of video data from all TC lessons as well as from ordinary lessons. This constrains the possibility of a full comparison between Zoe's activity and motivation in ordinary lessons and TC lessons. However, the case of Zoe was identified during the course of the project rather than being predefined, which limited the opportunities for systematic data collection across all relevant lessons.

The researcher's participation in the lessons is another factor that inevitably shaped the classroom dynamics. This influence is understood as an inherent characteristic of the research design and, therefore, unavoidable. The researcher's participation may have affected students' and the teacher's actions, while at the same time allowing for in-depth observations of classroom activity as it unfolded.

Higher motivation has been shown to lead to increased learning (Howard et al., 2021). Furthermore, the literature establishes that learning outcomes increase with collaboration (Boaler, 2016; Cai et al., 2011; Kapur, 2014; Koskinen & Pitkäniemi, 2022). In conclusion, TC as a teaching approach promotes the three basic psychological needs, competence, autonomy, and relatedness, as shown by the case of Zoe's motivation. Thus, TC has the potential to create a more beneficial learning opportunity. To the best of our knowledge, no research has investigated this. Thus, in the future, we would like to see research regarding TC and learning outcomes.

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No potential conflict of interest was reported by the author(s).

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