



Mathematics club learners' mathematical identities: Narratives of learners and their class teacher

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(Received: 19 March 2024; accepted: 4 December 2024)

Abstract

Research into mathematics clubs has shown that learners enjoy mathematics in the clubs more than in their regular classrooms, while research on mathematical identities has shown a relationship between learners' mathematical identities and classroom practices. Bringing these two ideas together, I investigated learners' mathematical identities in a mathematics club and their regular mathematics classrooms. I used a mixed-methods design to explore the mathematical identities of learners who participated in an after-school mathematics club. The learners responded to a mathematical identity questionnaire before they started in an after-school mathematics club and after the club ended. Some learners were purposively selected to respond to two semi-structured interviews, one before and one after participating in the club activities. A teacher who was teaching the interviewed learners responded to a semi-structured interview about their mathematical identities in class after they had participated in the club activities. Two paired samples t-test analyses of the questionnaire responses show a statistically significant difference between the learners' mathematical identity scores before and after participating in the club activities. Interview findings show that the learners' mathematical identities were supported through participating in the mathematics club, which encouraged mutual engagement, meaning-making, and a sense of belonging. The teacher observed changes in the learners' participation in the class, suggesting that participation in a mathematics club that supports strong mathematical identities can influence participation in the mathematics classroom.

Keywords: mathematical identities, mathematics club, confidence, persistence, beliefs, sense of belonging

Introduction

Many learners have negative mathematical experiences and do not enjoy mathematics, and this is related largely to how the subject is presented in class (Epstein et al., 2010; Graven, 2015). For How (2022), mathematics has been perceived persistently as difficult. The thought of mathematics, especially in relation to tests, induces stress, anxiety, and fear in some learners (Shone et al., 2023; Utha et al., 2021). Other learners have described mathematics as boring (Aydeniz & Hodge, 2011) and would choose to drop mathematics if given the chance

(Bishop, 2012). Utha et al. (2021) found that many learners feel that because they do not understand mathematics they rely on memorising large volumes of information and this becomes overwhelming. For them, mathematical content is irrelevant. Other learners feel that they are not good at mathematics (Darragh, 2015) and that mathematics is reserved for bright learners (Shone et al., 2023), or that they are marginalised from mathematics (Gardee, 2019). Several researchers have turned to the idea of mathematical identity to understand these worrying experiences of learners. Their mathematical identities are based on their relationship with mathematics and can be seen in how they describe themselves and are described by others in relation to mathematics (Cribbs et al., 2015; Hall et al., 2018).

Researchers have used different approaches to try to understand why some learners enjoy mathematics and others do not. Some researchers, like Gardee (2019), have investigated learners' mathematical identities and have shown a relationship between classroom practices and these identities. Turner et al. (2011) investigated the relationship between learners' mathematical identities and mathematics clubs and found that a club that encourages collective problem-solving and that values learners' contributions can support their mathematical identities. Lampen and Brodie (2020) suggested that a club curriculum responsive to learners' strengths and weaknesses can do this. This study and that of Turner et al. (2011) pointed to the idea that learners' mathematical identities can be supported in communities in which the learners feel a sense of belonging. Studies have shown a difference between learners' experiences of mathematics in mathematics clubs and in regular mathematics classrooms (Brodie, 2022; Jacob & Jacob, 2018; Jensen & Sjaastad, 2013).

To offer learners opportunities for positive mathematical experiences and to study their developing mathematical identities and relationships with mathematics, I established an after-school mathematics club. The research questions guiding this study were:

- Can an after-school mathematics club support learners' mathematical identities?
- Can participating in an after-school mathematics club support learners' mathematical identities in the classroom?

The study contributes to understanding learners' mathematical identities by shedding light on the relationship between after-school mathematics clubs and these identities. In addition, I explored the relationship between participating in an after-school mathematics club on the one hand, and in regular mathematics classes on the other.

Previous research on mathematics clubs and learners' relationships with mathematics

Mathematics clubs encourage active participation and knowledge acquisition to support learners' interest in mathematics (Neher-Asylbekov & Wagner, 2023); learners have expressed positive experiences of mathematics in these clubs. Learners have reported increases in their confidence in, and enjoyment of, mathematics, and these were related largely to their receiving opportunities for interaction and affirmation of their mathematical

competence (Kennedy & Smolinsky, 2016). Jensen and Sjaastad (2013) showed that learners' confidence and persistence in, and beliefs about, mathematics improved when they participated in a mathematics club, and this was related to being helped to believe that with effort they could learn mathematics and with feeling comfortable in asking for help. Since club mentors were friendly, they encouraged learners to ask questions (Jensen & Sjaastad, 2013). Different ways of solving problems were encouraged in these clubs and the problems were solved collaboratively. Zhou et al. (2021) found that enjoying mathematics in a club was accompanied by an increase in confidence and a sense of belonging to the club. Learners in clubs were encouraged to be involved, by, for example, asking questions, the answers to which, along with explanations, were provided by club mentors (Zhou et al., 2021). In Brodie's (2022) club, the improvement of learners' productive dispositions was related to social interaction, collaboratively solving problems, and being helped to feel comfortable.

In some studies, class teachers observed positive shifts in learners' relationships with mathematics following their experience of such clubs. Some class teachers observed a positive shift in club learners' participation and confidence in mathematics in the class (Graven, 2015). Other class teachers said that mathematics clubs offered learners extra support and time to think and reflect on their tasks, thus increasing the chances for low achievers to succeed (Prescott & Pressick-Kilborn, 2015). Graven's (2015) and Prescott and Pressick-Kilborn's (2015) findings suggest that clubs can support learners' mathematical identities in the classroom.

Many learners enjoy mathematics in mathematics clubs but not in their regular mathematics classrooms (Brodie, 2022; Jacob & Jacob, 2018; Jensen & Sjaastad, 2013). For Jacob and Jacob (2018), learners' negative views of mathematics in their regular classrooms did not change after attending a club. These learners said that in their regular classrooms, they were often told that they were wrong but were not given any explanation and noted that there was no interaction. In the club, they had worked together with their club mentors until they solved problems so that no-one was found to be wrong, according to these learners. The club encouraged fun-filled and interactive activities aligned with the formal curriculum (Jacob & Jacob, 2018). Learners in Jensen and Sjaastad's (2013) club said that the club offered them new ways of seeing mathematics which increased their interest. According to the learners, club mentors explained in understandable ways, and the focus was on problem-solving, but in class, the focus was on calculations (Jensen & Sjaastad, 2013). Learners in Brodie's (2022) club felt that mathematics in class was an individual activity that had to be made easy by the teacher while in the club mathematics was an enjoyable, challenging, social activity to be shared.

Participating in clubs has been shown to improve learners' mathematics achievement (Brodie, 2022; Lynch et al., 2023; Schuepbach, 2015). Several studies have shown significantly better mathematics achievement outcomes among learners who participated in clubs than in control groups because the clubs allowed learners to catch up and enrich their learning (Lynch et al., 2023). Regularly attending a club in which interaction was encouraged improved learners' mathematics achievement compared to learners in a control group (Schuepbach, 2015).

Brodie (2022) showed that the mathematics results of learners who regularly attended a club increased from Grade 8 to Grade 10 while the mathematics results of non-club learners at the same school decreased. For Brodie (2022), additional time to practice doing mathematics in the club, and not having to worry about assessments may have influenced the club learners' results and attending the club prevented the decrease in the club learners' Grade 10 mathematics results that is common in South Africa.

In summary, clubs offered learners time for interaction, explanation, and for experiencing alternative strategies for solving problems. This cannot happen when class teachers are under pressure to finish the syllabus and prepare for examinations. The clubs increased learners' confidence and persistence in and beliefs about mathematics, suggesting that they can support learners' mathematical identities. Class teachers observed a positive shift in club learners' participation and confidence in mathematics in regular classrooms and noted that they enjoyed mathematics in clubs more than in their regular mathematics classrooms. Findings from the studies above suggest that clubs can support learners' mathematical identities, a suggestion that I hope to have validated in this study. Generally, studies are inconclusive about the relationship between clubs and learners' mathematical identities in class, so in this study I aimed to contribute to understanding whether clubs can support learners' mathematical identities in class.

Theorising mathematical identity

Identity is constructed in social contexts and can be participative or narrative (Darragh, 2016). The view of identity as participative holds that identity is constructed through participation and a sense of belonging to communities. Identity as narrative considers identity as constructed through stories and words, be they written or spoken (Darragh, 2016; Fellus, 2019). A person's participation and narratives are closely linked. The strength of a mathematical identity can (and often does) depend on how a person deals with persistent negative mathematical experiences. The ability to deal with these suggests a robust mathematical identity, while the inability to deal with persistent negative mathematical experiences suggests a fragile mathematical identity (McGee, 2015).

Identities are constituted by personal and social identities (Marks & O'Mahoney, 2014). Personal mathematical identities are based on personal ideas and understandings of oneself in relation to mathematics (Gardee, 2019). A personal mathematical identity takes on a stronger consideration of the self and a weaker consideration of the social. Social mathematical identities are related to how a person feels they are perceived by other mathematics community members and how others perceive them in relation to mathematics (Gardee, 2019). A social mathematical identity takes on a stronger consideration of the social.

Personal and social mathematical identities are mutually constitutive (Gardee, 2019) since how we act and describe ourselves to people in relation to mathematics can influence how people act toward us and describe us. Social mathematical identities are constitutive of personal mathematical identities since personal mathematical identities are shaped by social relationships, as seen when a person tries to be different from or similar to others (Hall et al.,

2018). Even though personal and social mathematical identities are unified in reality, they are analytically distinct (Gardee, 2019). A separate analysis of personal and social mathematical identities can show how the two components of mathematical identity relate to building mathematical identity and thus offer a deeper understanding of mathematical identities. A personal or social mathematical identity can be: robust-leaning, which means it has more robustness than fragility; mixed, which means it has relatively equal mixes of robustness and fragility; or fragile-leaning, which means it has more fragility than robustness (Gweshe & Brodie, 2024). In this study, mathematical identity, both participative and narrative, is defined as constituted by personal and social mathematical identities, each of which could be robust-leaning, mixed, or fragile-leaning.

Sfard and Prusak (2005) viewed identity as narratives that are reifying, endorsable, and significant. Cribbs et al. (2015) argued that mathematical identities are influenced by multiple internal constructs, and they offer a theoretical framework for mathematical identity that consists of three constructs: competence/performance—self-belief about understanding and performing in mathematics; interest—the desire to learn mathematics; and recognition—a person’s view of how others view them. Cribbs et al. (2015) combined competence and performance since they are strongly correlated. In this study, I drew on Cribbs and colleagues’ (2015) view of mathematical identity because mathematical identity was considered as indicated by multiple constructs seen in narratives, and not as narratives. These scholars focused on three constructs related to people’s personal characteristics: competence/performance; interest; and recognition.

For this study, I developed four indicators of mathematical identity. Confidence and persistence in mathematics and beliefs about this subject are indicators of learners’ personal mathematical identities, while a sense of belonging to mathematics communities indicates learners’ social mathematical identities. Confidence in mathematics, which encompasses Cribbs and colleagues’ (2015) notion of competence/performance, is trust in personal mathematical competence and has been used by Darragh (2013) to indicate mathematical identity. Persistence in mathematics is about not giving up despite facing setbacks such as failure or experiencing difficulties and has been used by Bishop (2012) to indicate mathematical identity. Persistent learners reported less of a decline or an increase in interest as they solved more problems than non-persistent learners (Tulis & Fulmer, 2013). Beliefs about mathematics are personal views formed by past experiences. Beliefs about mathematics as linked to mathematical identity were included, since several researchers such as Bishop (2012) have explored these. A sense of belonging to a community, which encompasses the notion of recognition listed by Cribbs et al. (2015), is a feeling of being a member of a community of practice (Wenger, 1998). A person who feels recognised in relation to mathematics is likely to feel that they belong to mathematics communities while, of course, the opposite is true. A sense of belonging has been used by Darragh (2013) to indicate mathematical identity.

A framework for mathematics clubs, classrooms, and mathematical identities

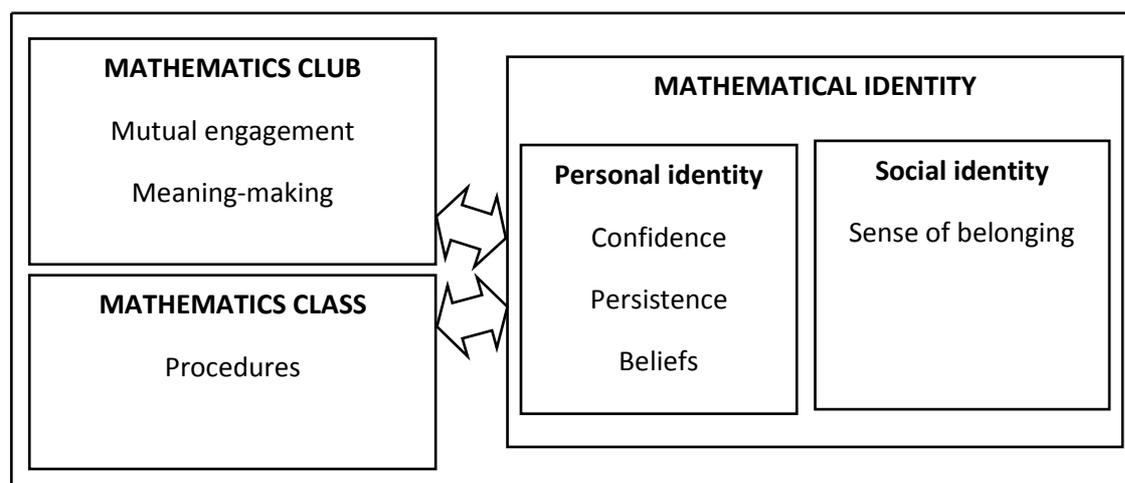
Wenger (1998) argued that learning involves four interconnected components—mutual engagement, meaning-making, a sense of belonging, and identity construction. Mutual engagement can be seen to operate when learners share repertoires such as strategies for solving problems, definitions, theorems, and laws and symbols in pursuit of a community's joint enterprise, in this case, learning mathematics. Social relationships, for example, being friendly and caring, develop through mutual engagement as learners and their club mentors or teachers work towards developing a common understanding of what mathematics is, and is about, and what it means to learn mathematics. Mutual engagement offers learners opportunities to experience many different strategies aimed at solving problems and to connect related ideas into a structured network useful for solving problems. This leads to their experiencing the world of mathematics as meaningful. In other words, mutual engagement supports meaning-making since an idea developed in a certain context used to solve problems in other contexts points to this. A learner's mutual engagement and their meaning-making signifies their past participation experiences, indicates what they have learned and are ready to learn, and is an indicator of their sense of belonging to a mathematics community. Changes in a learner's confidence and in their beliefs about mathematics as well as persistence in wanting to belong to a mathematics community indicate *identity construction*; the learner changes from seeing mathematics as boring to enjoying engaging with this subject.

A learner's mathematical experiences in the different mathematics communities like, for example, a mathematics club and a regular mathematics classroom through which the learner moves, contribute to their mathematical identity. The learner's mathematical experience in one of the communities may be more influential on their mathematical identity than their experience in the other community. This depends on the learner's choices and decisions that are often made in consideration of past and present experiences of mathematics.

Wenger's (1998) theory of interconnected components of learning lends itself to the exploration of a mathematics club, mathematics classrooms, and learners' mathematical identities since it relates practices useful for pursuing mathematics, which include but are not limited to mutual engagement and meaning making, to identity. The components of learning assist in analysing and describing the practice of mathematics in a mathematics club and a regular mathematics classroom community. Figure 1 presents a framework that shows the potential relationships among mathematics clubs, regular mathematics classrooms, and learners' mathematical identities. Clubs usually encourage mutual engagement and meaning-making while regular mathematics classrooms encourage the quick and accurate performance of mathematical procedures.

Figure 1

The relationships between and among clubs, classrooms, and identities



The mathematics club

Site, participants, and sessions

The club under discussion was an informal learning space that engaged learners in problem-solving activities to encourage mathematical reasoning and positive shifts in mathematical identities (see Lampen & Brodie, 2020). The club was established at a school located in a township area in which people of low socio-economic status reside. I was the volunteer main club mentor while a volunteer teacher joined me and assisted as a co-mentor. He attended the club sessions frequently, observed my facilitation, and also facilitated some of the club sessions. The club took place after school to offer learners time and space to work collaboratively on challenging problem-solving activities. Eighteen club sessions were conducted over eight months. Learners attended an average of 15 sessions, each of which lasted for 90 minutes.

Principles

The club adopted key principles that drew on the work of Boaler et al. (2018) and Lampen and Brodie (2020).

- Productive struggle and making mistakes are valuable opportunities to learn.
- Mathematics is about making connections between ideas.
- Assisting others and sharing ideas provide valuable opportunities to learn.
- Trying to explain your thinking to others before asking for assistance is a valuable learning opportunity.
- Mathematics is interesting.

These principles were explicitly stated regularly and explained to learners in the club.

Curriculum and activities

The club was part of a larger project involving three clubs in South Africa and I gained the experience of running a club by participating in one of the first two clubs before establishing the third one.¹ The three clubs shared a curriculum responsive to learners' ideas, strengths, and weaknesses; for more detail, see Lampen and Brodie (2020). The curriculum was premised on developing learners' mathematical reasoning and supporting their mathematical identities rather than on repetition of mathematical procedures as is often the case in many regular mathematics classrooms and extra-lesson sessions. Mathematical reasoning was seen as a mode of thinking involving taking ideas apart and putting them together and using the ideas to solve problems (Lampen & Brodie, 2020).

Learners were expected to represent their reasoning in different ways, for example, graphically, diagrammatically, in tables, equations, or expressions, or with physical objects and they had to critique their own and others' reasoning (Lampen & Brodie, 2020). Opportunities to engage in problem-solving activities not normally seen in the classroom were offered in the club. The activities had to be solved using more than one strategy and through mutual engagement and meaning-making to align them with Wenger's (1998) components of learning.

Method

I adopted a mixed-methods design in which a qualitative analysis helped explain and contextualise the results from a quantitative analysis. Using this design allowed me to incorporate the strengths of two designs while minimising their weaknesses (see McMillan & Schumacher, 2010) and this enhanced the chances of having a comprehensive understanding of learners' mathematical identities. The quantitative design was a quasi-experiment because I did not randomly select participants and did not involve a control group. The qualitative design was a narrative inquiry because I wanted to understand learners' mathematical identities through their and their class teachers' narratives.

Sample

Of 328 Grade 10 mathematics learners at a selected school, 50 volunteered to participate in the study along with one class teacher. I chose this school because I was teaching there at the time of conducting the study, so it was convenient for sampling. I decided to involve learners in Grade 10 because few studies focus on mathematics clubs attended by learners at this level in South Africa; most studies involve Grade 2 to 9 learners (e.g., Graven, 2015; Stott et al., 2019).

The university's ethics committee provided ethical clearance for the study. The provincial education department and the school principal allowed me to conduct the study at the school. The parents consented to their children taking part in this study as did the participating

¹ The other two clubs are reported on in Brodie (2022), Frenzel et al. (2019), and Lampen and Brodie (2020).

teachers. All the participants were assured of confidentiality and anonymity before the study commenced.

Instruments and data collection

The learners responded to the same mathematical identity questionnaire before they joined the club and after its activities ended. The purpose of the questionnaire was to compare the learners' mathematical identities before and after participating in the club activities. It consisted of 16 items and used a Likert scale with responses ranging from strongly agree which was scored as 5 to strongly disagree which was scored as 1. Questionnaire items were adapted from previous studies that had investigated the indicators of learners' mathematical identities under study (e.g., Boaler, 2013; Darragh, 2013). Table 1 shows the four indicators of learners' mathematical identities about which the learners were asked, the corresponding number of questions for each indicator, and an example of a question for the indicator.

Table 1
Identity indicators and the number of questions asked

Identity indicator	No. of questions	Example of a question
Confidence	4	I am good at maths
Persistence	4	Even if I fail maths this term, I will try again next term
Beliefs	5	Practising can improve my ability in maths
A sense of belonging	3	In maths, I feel important

As can be seen, thirteen questions asked learners about their personal mathematical identities (i.e., confidence, persistence, and beliefs) and three questions asked about their social mathematical identity (i.e., a sense of belonging). A learner's personal mathematical identity score was calculated by adding the scores from the four confidence questions, four persistence questions, and five beliefs questions, while their social mathematical identity score was calculated by adding the scores from the three questions based on their sense of belonging. The total possible score for each question was five, so, the total possible personal mathematical identity score was 65 and the total possible social mathematical identity score was 15. Personal mathematical identity scores were put into three groups: robust-leaning (52–65), mixed (27–51), and fragile-leaning (13–26). Social mathematical identity scores were put into three groups: robust-leaning (12–15), mixed (7–11), and fragile-leaning (3–6).

The learners' personal and social mathematical identity scores before they started in the club were also used to purposively select a smaller group of learners for two semi-structured interviews, the first before the learners participated in the club activities and the second after this. Interviewing a small group of learners meant that a small quantity of data would be collected that could lead to a deeper understanding of mathematical identity, based on the learners' narratives of how this came about, that could offer insights into the relationship between mathematics clubs and mathematical identities.

Since the study had different personal and social mathematical identity groups, this resulted in learners narrating different combinations of these. Learners with different combinations of personal and social mathematical identities were asked to participate in the interviews. In this paper, I discuss the interview responses of four learners who agreed to be interviewed: Kelly and Cindy² who narrated fragile-leaning personal and social mathematical identities before participating in the club; and Ben and Rose, who narrated robust-leaning personal and social mathematical identities before participating in the club. These four learners were more articulate than the other learners who volunteered to be interviewed and their class teacher, Mr. Kent, who was not involved in the club activities, also agreed to be interviewed. I wanted to determine what he had observed in relation to the club learners' mathematical identities in the classroom after their participation in club activities.

I conducted both learner and teacher interviews and these were audio-recorded and transcribed.³ Each interview lasted for about 40 minutes. Some of the learner interview questions were adapted from previous studies that had investigated learners' mathematical identities or constructs influencing mathematical identities (Bishop, 2012; Boaler, 2013; Darragh, 2015; Vanayan et al., 1997). Teacher interview questions and other learner interview questions were constructed with the help of researchers who have conducted studies on mathematics clubs, mathematical identities, and related constructs. Table 2 shows the three instruments and examples of questions in each of the instruments.

Table 2
Instruments and questions

Instrument	Examples of questions
Learner pre-interview	What do you think about maths? How do you see yourself as a maths learner?
Learner post-interview	What do you think about the after-school maths club? Can you compare your days before joining the club and after joining the club?
Teacher interview	Please tell me about what type of maths learner s/he was before and after joining the maths club. Do you see the learner pursuing maths in the future?

Questionnaire analysis

The null hypothesis for the quantitative analysis was formulated and tested at 0.05 level of significance, a level commonly used in education research to indicate that the observed differences are not attributed to chance.

- There is no statistically significant difference between the mean pre- and post-personal and social mathematical identity scores of Grade 10 learners who participated in the activities of an after-school mathematics club.

² All names are pseudonyms.

³ The participants' responses have not been edited.

The questionnaire was on a Likert scale, so each learner's personal and social mathematical identity scores before and after participating in the club activities were calculated, as discussed above. Therefore, there were two sets of data from one group of learners, so two paired-sample t-tests were computed, one for personal mathematical identities and the other for social mathematical identities. Rejecting the null hypothesis meant that the differences between the club learners' mean personal and social mathematical identity scores before and after participating in the club activities were statistically significant. Not rejecting the null hypothesis meant that the differences were not statistically significant.

Interview analysis

The learner interview transcripts were deductively coded to draw on theory and inductively coded to allow new themes to emerge. Deductive coding involved carefully assigning predetermined codes drawn from the literature and considered relevant to the data. Inductive coding involved creating codes, while reading the data carefully many times. Some responses were multi-coded and cycles of checking that the assigned codes fit the data were conducted.

Three categories representing learners' descriptions of their experiences of learning mathematics in a club and their classrooms were constructed from the codes: Personal identity, Social identity, and Learning. The first two categories were constructed in line with Marks and O'Mahoney's (2014) components of identity, and they supported an analysis of the learners' mathematical identities in the club and classroom. The last category was constructed in line with Wenger's (1998) theory of learning as meaning-making and it supported an analysis of how learners experienced mathematics in the club and classroom. Table 3 shows the categories, codes, code descriptors, and examples of learner statements represented by the codes.

Table 3
Learner categories and codes

Category	Code	Descriptor (bold) and example of a learner's statement
Personal identity	Confidence	The club supports learners' confidence. When I'm in the club, in one problem I get many ideas and getting all these ideas makes me feel like I'm the man.
	Persistence	The club encourages learners to persist in mathematics. When stuck on a problem I no longer just stay and say I got stuck, I now look around at how I can connect that thing with something else.
	Beliefs	The club changes learners' beliefs about mathematics. It [is] very useful because it changes people's attitudes towards maths, what makes maths hard is wiped off.
Social identity	Belonging	Participating in mathematics activities. I try to work with others so I can get some opinions from them, and I also give them mine.
	Sharing ideas	The club encourages discussions. In the club, I enjoy working in groups because different people come up with different ideas.

Category	Code	Descriptor (bold) and example of a learner's statement
Learning	Multiple strategies	The club encourages multiple ways of solving problems. Someone comes up with another method that you don't know and it's new to you.
	Mistakes	The club encourages making, noticing and correcting mistakes. I enjoy noticing our mistakes in the club; that helps me not to repeat them.
	Enjoyment	The learner enjoys learning mathematics in the club. We do different stuff that is more interesting than textbook stuff.
	Identity messages	The learner adopted ideas from identity messages. I enjoy noticing our mistakes in the club.
	Supplement	The club provides additional practice activities. I'm helped with those things that maybe I didn't understand in class.

The teacher interview transcript was coded using the same approach as the learner interview transcripts. Some codes describing learner interview data did not fit the teacher interview data and this suggested that not everything said by the learners was noticed by the teacher, and that the teacher's perception of some of the learners' relationships with mathematics was different from the learners' perceptions. Similarly to the analysis of the learner interviews, the three categories of Personal identity, Social identity, and Learning were constructed. Table 4 shows the categories, codes, code descriptors, and examples of teacher statements represented by the codes.

Table 4
Teacher categories and codes

Category	Code	Descriptor (bold) and example of a teacher's statement
Personal identity	Confidence	Learner shows supported confidence. After the maths club, I noticed that she now wants to go to the board and do something.
	Persistence	Learner shows supported persistence. These days he is coming up with extra problems and he asks me if his answers are correct.
	Beliefs	Learner shows supported beliefs. She didn't want to be wrong. . . Now she can ask if she solved it correctly.
Social identity	Belonging	Learner participates in mathematics activities. She would make noise and wouldn't cooperate. After the maths club. . . her attitude has changed.
Learning	Assists others	Learner helps others. After the club, if the person who was writing on the board asked how they did something then she'd assist them.
	Alternative strategies	Learner suggests alternative strategies for solving problems. She can even say, "Sir, let's try this question this way."

Category	Code	Descriptor (bold) and example of a teacher's statement
	Mistakes	Learner is not afraid of making mistakes. Now she is one of the learners who jumps first to say, "I want to give you the corrections on the board."

Findings

The results from the questionnaire analysis showed that the club learners' personal and social mathematical identities were supported. Analysis of the learners' interview responses also suggested that their personal and social mathematical identities were supported through experiencing meaning-making in the club. The teacher's interview response suggested a positive shift in the learners' personal and social mathematical identities in the class.

Learners' mathematical identities

Questionnaire

The paired samples t-test for personal mathematical identity showed that there was a statistically significant difference between the club learners' personal mathematical identity scores, calculated as discussed above, before participating in the club activities ($M=26.62$, $SD=8.18$) and after participating in them ($M=29.58$, $SD=9.54$); $t(49)=4.108$, $p=0.0002$. The paired samples t-test for social mathematical identity showed that there was a statistically significant difference between the club learners' social mathematical identity scores, calculated as discussed above, before participating in the club activities ($M=5.70$, $SD=2.22$) and after doing so ($M=8.86$, $SD=2.14$); $t(49)=7.99$, $p<0.0001$. The null hypothesis on mathematical identity was thus rejected. The club learners' mean personal mathematical identity score increased by 2.96 points while their mean social mathematical identity score increased by 3.16 points. This result showed a positive shift in the learners' mathematical identity scores, suggesting that their mathematical identities had shifted toward more robust-leaning identities, and, therefore, had been supported.

Learner interviews

As discussed above, three categories: Personal identity, Social identity, and Learning were constructed. I provide excerpts illustrating how the learners constructed their Personal mathematical identities, indicated by changes in their personal characteristics: confidence; persistence; and beliefs. The learners' Social mathematical identities were indicated by the social characteristic of belonging. The third category included opportunities for meaning-making: sharing ideas; multiple strategies; productive struggle; identity messages; mistakes; and supplementation.

I start by discussing Kelly and Cindy, learners who narrated fragile-leaning personal and social mathematical identities before participating in the club activities and robust-leaning personal and social mathematical identities after having done so. I then discuss Ben and Rose, learners who narrated robust-leaning personal and social mathematical identities before and

after participating in the club activities. For each learner, I draw comparisons between their comment before participating in the club activities and their comment after doing so.

For Kelly, mathematics was learned differently in the club, which she enjoyed, and this led to her personal and social mathematical identities shifting towards the more robust.

Table 5

Kelly's comments before and after participating in the club

	Learner Comment	
	Before	After
Kelly	I don't participate because I'm afraid that my answers will be wrong, and I get embarrassed. Some [peers] say I should go to maths lit [when stuck on a problem]. I feel I should leave maths.	In the club, I enjoy working in groups because different people come up with different ideas. I'm helped with those things that maybe I didn't understand in class.
	I will not be doing maths for long because it's difficult, I feel like I just can't do it.	The club is different. It's not what I'm used to doing. I didn't know that maths could be done in so many ways. I feel that maths is getting easier.

Kelly's beliefs about mathematics were supported by the club, shown by changing from believing that mathematics is difficult, before participating in the club, to viewing mathematics as getting easier, after doing so. The change in Kelly's beliefs about mathematics was related to learning through sharing ideas, getting help, and experiencing many strategies for solving problems in the club (i.e., practices that support meaning-making) and suggests a shift in her personal mathematical identity from fragile-leaning toward robust-leaning.

Kelly's comment before participating in the club suggested that she experienced fear and discouragement in her regular mathematics classroom while her comment after doing so suggested that she felt helped in the club, thus indicating a sense of belonging to the club and a sense of not belonging in her regular classroom. The support to Kelly's sense of belonging was related to a difference in the way learners interacted in the club and classroom, and it suggests a supported social mathematical identity by the club.

Cindy's comments offered insights into changes in her narrated personal and social mathematical identities, related to experiencing meaning-making in the club.

Table 6

Cindy's comments before and after participating in the club

	Learner Comment	
	Before	After
Cindy	<p>Maths is difficult, that's why I don't compromise on my time for maths.</p> <p>I participate because I'm looking forward to succeeding and making a fortune.</p>	<p>The club is messing with our minds because when the teacher corrects our mistakes, we realise it wasn't that difficult. Now I see certain things, it's funny that I didn't know these things, and I've become more capable of doing maths. In class, other learners are selfish, they don't share what they know with me but in the club, we share everything. Since I'm a club member, people consider me as very good at maths.</p>

Cindy's beliefs about mathematics were supported by the club, shown by her changing from believing that mathematics is difficult before participating in the club, to believing that mathematics is not that difficult after having done so, thus suggesting that her personal mathematical identity shifted from fragile-leaning toward robust-leaning. Cindy's comment before participating in the club indicated confidence in mathematics related to getting a well-paying job, suggested by wanting to make a fortune. Her comment after participating in the club indicated supported confidence and meaning-making related to experiencing mathematical identity messages, suggested by talking about "mistakes" as helping her to "see certain things" that she previously could not see and resulting in her becoming "more capable." The change in Cindy's confidence suggests a shift in her personal mathematical identity from fragile-leaning toward robust-leaning.

Cindy's talk about sharing ideas suggested a sense of belonging to the club and not belonging to her regular mathematics class and therefore a social mathematical identity that was supported by the club. Her comment after participating in the club suggested that she learned mathematics differently in the club through experiencing meaning-making, suggested when she talked about the club as "messing" with her mind and experiencing mathematical identity messages through learning from "mistakes." Despite Cindy's response after participating in the club being largely positive, her talk about being considered "very good at maths" suggests that she attended the club with the belief that by attending, she would be viewed as good at mathematics by others, indicating some fragility in her supported mathematical identity.

Ben's robust-leaning personal and social mathematical identities, before participating in the club, were supported in relation to experiencing meaning-making in the club.

Table 7

Ben's comments in relation to meaning-making

	Learner Comment	
	Before	After
Ben	I'm very good at maths because there is nothing that I think I'm unable to do. He [teacher] was teaching me from last year, so he understands how I do things. Everyone can learn maths, they just need to work hard and avoid laziness. They [peers] praise and encourage me and that encourages me to help more learners.	When I'm in the club, in one problem I get many ideas and getting all these ideas makes me feel like I'm the man. Someone comes up with another method that you don't know and it's new to you. I enjoy noticing our mistakes in the club; that helps me not to repeat them because as you know, we learn from our mistakes. It [is] useful because it changes people's attitudes towards maths, what makes maths hard is wiped off. When stuck on a problem I no longer just stay and say I got stuck, I now look around at how I can connect that thing with something else.

Ben's confidence in mathematics, before participating in the club, was supported by the club through his being exposed to "many ideas", thus related to sharing ideas, a learning practice that supports meaning-making. Ben's positive beliefs about mathematics before participating in the club, were supported by the club through his experiencing mathematical identity messages, suggested by talking about mistakes and their importance. Ben's talk about "attitudes towards maths" changing and mathematics as not "hard" after participating in the club suggests supported beliefs about mathematics in other club learners and possibly in himself. His persistence in mathematics and meaning-making were supported by experiencing mathematical identity messages, suggested when he talked about connecting ideas. The changes in Ben's confidence and persistence in and beliefs about mathematics suggest a strengthened robust-leaning personal mathematical identity by the club related to experiencing meaning-making.

Before participating in the club, Ben felt that he was understood by his regular class teacher and was encouraged by his peers, thus suggesting a sense of belonging to his classroom community. His feeling "like a man" in the club, suggested a supported sense of belonging to the club community and therefore a strengthened robust-leaning social mathematical identity, related to experiencing meaning-making.

Similarly to Ben, Rose's robust-leaning personal and social mathematical identities before participating in the club were supported in relation to the meaning-making encouraged by the club.

Table 8

Rose's comments before and after participating in the club

	Learner Comment	
	Before	After
Rose	As I said maths is fun. I started liking maths in Grade 8, it was difficult, but I found it interesting because sometimes when you think that you know something then something comes up. They [peers] try to help me when I'm wrong, we don't laugh at each other.	Maths hasn't been that difficult ever since I started working together with others in the club. It's interesting and you are free to ask questions. I didn't think that my mind could think this further. Sometimes I struggle a lot with some equations but then I try very hard to understand and work with others so I can get some opinions from them, and I also give them mine. We do different stuff that is more interesting than textbook stuff [in the club]. In the class, we just write, calculate and do corrections, so the club is cool because we don't just calculate but we do shapes with crayons and it's very interesting.

Before participating in the club, Rose believed that mathematics was fun, indicating a robust-leaning personal mathematical identity. Her comment after participating in the club suggested that her beliefs about mathematics were supported through sharing ideas in the club, being offered the opportunity to “think further” than she could imagine, and learning mathematics differently, all practices that support meaning-making. Rose's persistence in mathematics was supported by the club, suggested by talking about struggling leading to mutual engagement. The changes in Rose's persistence in and beliefs about mathematics suggest a robust-leaning personal mathematical identity that was strengthened by belonging to the club.

Rose felt a sense of belonging to her classroom and the club communities as indicated by feeling helped in the classroom and free in the club, suggesting that the club helped to strengthen her robust-leaning social mathematical identity.

The four learners reported that their personal and social mathematical identities shifted toward more robust identities. Talk about “working in groups”, getting “many ideas”, connecting “that thing with something else”, and getting and giving “opinions” suggest that the club encouraged meaning-making. Opportunities to experience mathematical identity messages were offered by the club.

Class teacher's views of club learners' mathematical identities

Mr. Kent's interview response corroborated Kelly's, Cindy's, and Ben's pre- and post-club interview responses. His interview response corroborated Rose's post-club interview response but not her pre-club interview response. Provided excerpts show observed improvements in the club learners' participation and relationship with mathematics in the class.

See the table below for Mr Kent's comments on Rose and Kelly.

Table 9

Teacher's comments on Rose and Kelly

Teacher	Learner	Teacher's comment
Mr. Kent	Rose	She was a little bit reserved, shy to participate and not that enthusiastic about maths but now she is one of the learners who jumps first to say "I want to give you the corrections on the board." I've noticed that if she knows what the next topic will be she tries to go and prepare herself before I start the topic.
	Kelly	Before the maths club, I just saw a quiet child. After the club, she doesn't like to stand up but what I've noticed is that if she had a group that she was working with and the person who was writing on the board asked how they did something then she'd assist them.

Mr. Kent observed a positive shift in both Rose's and Kelly's participation in the class that suggested a shift in confidence in mathematics and a sense of belonging to the classroom mathematics community and, therefore, a shift in these two learners' personal and social mathematical identities towards more robust ones. Rose's interview response before participating in the club suggested that she had confidence and persistence in, and positive beliefs about, mathematics and felt a sense of belonging to her classroom mathematics community, which was not suggested by her teacher. Rose's response after participating in the club was corroborated by her teacher's response, thus suggesting a supported mathematical identity.

According to Mr. Kent's comment, Cindy's personal and social mathematical identities shifted positively after participating in the club activities.

Table 10

Teacher's comments on Cindy

Teacher	Learner	Teacher's comment
Mr. Kent	Cindy	Before the club, sometimes when she got stuck, she got frustrated and gave up quickly. She would make noise and wouldn't cooperate. She would say, "Sir, I don't know" before she even tried the problem. She didn't want to be wrong and complained a lot. The other thing that worried me was that she thought too little of herself and used to tell me that she was practicing to pass and not to know these things. After the maths club, I noticed that she now wants to go to the board and do something. Now she can come up with extra work from somewhere and ask if she solved it correctly. Her attitude has changed. She can even say, "Sir, let's try this question this way."

According to the teacher's comment, Cindy tended to ask for help without attempting questions and she thought "too little of herself" before participating in the club, thus indicating low confidence and low persistence in mathematics in the class and therefore a fragile-leaning personal mathematical identity. Cindy's confidence and persistence in mathematics in the class shifted positively after she participated in the club, indicated by "going to the board" and doing "extra work." Cindy's beliefs about mathematics were

supported by the club, shown by her changing from being afraid of making mistakes, before participating in the club, to not being afraid of doing so after such participation, and this was related, possibly, to experiencing positive mathematical identity messages and therefore meaning-making. The change in Cindy's confidence and persistence in and beliefs about mathematics suggest a shift in her personal mathematical identity from fragile-leaning, before participating in the club, toward robust-leaning, after doing so.

There was no mention of Cindy's disruptive behaviour after participating in the club, but she suggested alternative ways of solving problems and offered to participate productively in mathematical activities, thus indicating a positive shift in her sense of belonging to the class and, therefore, her social mathematical identity.

According to Mr. Kent, Ben had a positive relationship with mathematics before and after participating in the club activities.

Table 11
Teacher's comments on Ben

Teacher	Learner	Teacher's comment
Mr. Kent	Ben	He was and is still a good learner. He helps others, yes that one I know. These days he is coming up with extra problems and he asks me if his answers are correct. One problem that he asked me was whereby you make one of the variables the subject of the formula, yeah! He came up with something interesting and I think it took me two days to figure it out.

Ben's robust-leaning mathematical identity, before participating in the club, was supported by the club and indicated by his doing challenging "extra problems" and suggesting an improved understanding of the importance of engaging in productive struggle and a positive shift in persistence in mathematics and therefore personal mathematical identity. His helping others suggested a sense of belonging to the classroom community and therefore a robust-leaning social mathematical identity before and after participating in the club.

In summary, Mr. Kent observed a positive shift in how club learners participated in the class, suggesting a shift in the learners' mathematical identities toward more robust identities. Learners like Rose, who were "reserved" before participating in the club became active after doing so.

Discussion, limitations, and conclusion

In this section, I show how the findings add to previous research about mathematics clubs and learners' mathematical identities. In response to the first research question, "Can an after-school mathematics club support learners' mathematical identities?" I suggest that the club supported the learners' personal and social mathematical identities. Their mean personal and social mathematical identity scores before they started in the club and afterwards were significantly different. The mean scores showed that the learners' personal and social mathematical identities shifted toward more robust-leaning ones. The four learners' interview

responses showed that their personal and social mathematical identities were supported by the club. These findings support the study by Turner et al. (2011) that showed that clubs can support learners' mathematical identities.

Club activities encouraged sharing ideas and helping others, contributed to seeing mathematics as "not that difficult" and gave learners a sense of belonging to a group and of feeling "capable." Problems were solved using many different methods, thus supporting the learners' meaning-making, and they were encouraged not to give up on solving problems and this supported their persistence in mathematics.

In relation to the second research question, "Can participating in an after-school mathematics club support learners' mathematical identities in the class?" Mr. Kent observed a positive shift in the club learners' participation, confidence, and persistence in and beliefs about mathematics, and their sense of belonging to their mathematics classrooms, thus indicating a shift in the learners' personal and social mathematical identities in the class. Other class teachers have observed a positive shift in club learners' participation and confidence in mathematics in the class (see Graven, 2015). This finding suggests that clubs can support other indicators of learners' mathematical identities in the class, in addition to the previously known ones. The study contributes to understanding how club experiences can be replicated in the classroom, which, according to Brodie (2022), who argued that clubs can run side-by-side with regular mathematics classrooms, might be difficult to achieve given the different constraints in clubs and classrooms.

Despite suggested mathematical identity changes in regular classrooms by their class teacher, the learners said that they did not enjoy learning mathematics in their regular classrooms. Several studies have found no change in these negative views of learning mathematics in regular classrooms after the learners participated in clubs (Jacob & Jacob, 2018; Zhou et al., 2021). This finding supports McGee's (2015) argument that mathematical identities can strengthen despite persistent negative mathematical experiences. In this study, the strengthening was achieved through participating in an after-school mathematics club, but there was no transfer to the class.

The learners' interview responses showed a comparison between the club and class ways of learning mathematics providing insights into how the club supported the learners' mathematical identities. Kelly's and Rose's responses suggested that they worked collaboratively on club activities, which was usually not the case in their regular mathematics classrooms. This finding supports studies that have shown that mathematics classes encourage individual activities while mathematics clubs encourage social activities (Brodie, 2022; Jacob & Jacob, 2018). Kelly did not feel comfortable participating in the class because of her fear of being laughed at by peers and being embarrassed but she felt comfortable participating in the club because she got help from peers, and this indicated a difference in peer-to-peer relationships in the club and classroom. Club activities were engaged in using strategies not normally used in the classroom, thus influencing Cindy to "see certain things" that she could not see previously and Rose to believe that mathematics is interesting. Several studies have explored ways of learning mathematics that are different from those normally

used in regular mathematics classrooms and have found that learners enjoy these ways, and the learners' relationships with mathematics are thus supported (Jacob & Jacob, 2018; Kennedy & Smolinsky, 2016). Cindy's interview response indicated that she attended the club with the belief that by attending she would be viewed as good at mathematics by others. Papanastasiou and Bottiger (2004) argued that such learners might eventually develop positive perceptions of mathematics because of the mathematical experiences gained in the club, which are different from regular class experiences.

This study has limitations that offer opportunities for further studies. It has a bias toward the narrative view of identity as constructed through stories and words and does not pay attention to the participative view of identity as constructed through participation, which, if investigated, may add depth to the findings. The participating school was selected because of its convenience. Conducting a similar study but with learners of a different socio-economic status and different experiences with mathematics to those in this study may offer additional insights into the relationship between mathematics clubs and learners' mathematical identities. Participating in this study was voluntary so the participants may have had some interest in mathematics. Working with a control group in the quantitative design will allow for comparisons, thus adding depth to the findings.

Based on the findings, it can be concluded that learners enjoyed experiencing mathematics differently in employing different strategies to solve problems, engaging in productive struggle, and sharing ideas in the club. So, teachers need to find ways of presenting mathematics in a way that is motivating for learners, which requires creativity on their part, and an understanding of what it is that learners describe as motivating. This is not to say that classrooms should or can be turned into clubs since they operate with different constraints (Brodie, 2022). Clubs that encourage mutual engagement, meaning-making, and a sense of belonging to mathematics communities, however, can be considered as complementary spaces to classrooms for supporting learners' mathematical identities. The club supported learners' narrations of different mathematical identities, indicating the flexible nature of the club. A relationship between learners' mathematical identities in the club and their mathematical identities in the class was suggested.

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