High School Learners' Mathematical Dispositions and The Influences of Mathematics Clubs

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Mathematics clubs support development of learners' dispositions through engagement with challenging problems and supporting students to communicate ideas with others in fun ways. This paper reports on the mathematics dispositions of high school learners who participated in a mathematics club in primary school. Data are drawn on their narrative stories that they wrote in high school to reflect their mathematics journeys. Data were analysed qualitatively. Learners report that the promoted learning dispositions in the clubs such as resilience, affinity for mathematics, perception of self as doers of mathematics and enjoyment in working with mathematics supported different relationships with mathematics. The paper shows that there is potential in afterschool clubs to support learners in navigating productive mathematical dispositions that extend beyond the time frames of club participation.

Introduction

South African mathematics education is widely acknowledged to be in a state of crisis (Fleisch, 2008) where mathematics achievement is abnormally low, as evidenced by sustained poor performance across international, regional, and national assessments (Department of Basic Education [DBE], 2017; Spaull & Kotze, 2015). The Eastern Cape province in South Africa, where I carried out the broader study, was the worst performing province in the National Senior Certificate [NSC] Mathematics examinations in 2020, with an average pass rate of 39.7% (DBE, 2020). The general trend of Mathematics results shows that as learners progress to higher grades their performance deteriorates, and they choose not to pursue Mathematics post-compulsory education (Mutodi & Ngirande, 2014).

To mitigate the challenges, the South African Numeracy Chair Project at Rhodes University established afterschool mathematics clubs to provide extra-curricular activities focused on developing a supportive learning community where learners' active mathematical participation, engagement, enjoyment, resilience, and sense making are the focus (Graven, 2011). The six learners in this study participated in one of the clubs for periods ranging from two to five years each while they were in primary school. The stories that are thematically analysed in this study are part of data from a larger study (Hokonya, 2021).

According to Kilpatrick et al. (2001, p. 131), "if students are to develop conceptual understanding, procedural fluency, strategic competence, and adaptive reasoning abilities, they must believe that mathematics is understandable, not arbitrary; that with diligent effort, it can be learned and used; and that they are capable of figuring it out." Developing such productive dispositions will improve the learners usual learning mood and temperament and develop habitual inclination to learning and the tendency to acquire knowledge. Interestingly, one of the salient goals of mathematics education is to help learners to develop positive dispositions toward mathematics so that they may become persistent, agentic, and confident in the subject (Kilpatrick et.al, 2001). These traits are the cornerstone of powerful and productive mathematics dispositions that help learners to handle frustrations and struggles not only in mathematics but also in all areas of learning and life in general (Bishop, 2012).

Literature Review

Scholars agree that for learners to develop a productive disposition, they require frequent opportunities to make sense of mathematics, to recognise the benefits of perseverance, and to

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experience the rewards of sense making in mathematics (Dweck, 2008; Kilpatrick et al., 2001). They need to develop conceptual understanding, procedural fluency, strategic competence, and adaptive reasoning abilities. They must believe that mathematics is understandable and not arbitrary, but that, with effort and resilience, it can be learned. Kilpatrick et al. (2001) argue that for learners to develop a productive disposition, they require frequent opportunities to make sense of mathematics, to recognise the benefits of perseverance, and to experience the rewards of sense making in mathematics. All these can be purposefully developed in the mathematical practices that they take part in, for example in the classroom or afterschool mathematics clubs. Ally (2011) notes that a high frequency of opportunities for developing productive dispositions were mostly linked to the inclusion of real world or out of class situations.

Mathematical dispositions are considered to increase learners' ownership of their learning, their opportunities to understand and value other people's ways of knowing, and their capacities to work collaboratively with colleagues in developing their mathematics practice. Black et al. (2004) further report that positive dispositions make learners connect with and appreciate mathematics, which is a tendency to think and act positively. Further, Maxwell (2001) connects learner engagement and enjoyment in mathematics directly with the activities the teacher uses in the classroom arguing that activities need to motivate the students and "make mathematics worthwhile" (p. 35).

Unfortunately, activities that motivate learners are rare in many South African classrooms as research show that many teachers foreground ritual participation (including chanting), passive listening and little sense-making, resulting in many failing to progress beyond inefficient one-to-one counting methods, even by Grade 7 (Heyd-Metzuyanim & Graven, 2016; Hoadley, 2012; Venkat & Naidoo, 2012).

However, the afterschool mathematics clubs the learners in this study attended aimed to redress this apartheid legacy of compliant, passive, and dependent learners that work counter to developing critical, creative, and active participation in mathematics problem solving as envisioned in the South African curriculum (Graven, 2015). In the clubs, learners work in smaller groups focusing on specific learner needs informed by their competence level and learning disposition (Graven, 2015). In addition, club sessions and the take-home activities, games and worksheets provided extend the time learners engage with mathematics and might promote continued mathematical learning outside of clubs and classrooms. This likely increases learners' mathematical dispositions.

In this paper I address the question: How do mathematics clubs influence learners' mathematical dispositions? I do not seek the relationship between dispositions and mathematics performance in terms of high or low marks in assessment, but to illuminate how learners' reflections show how attitude influence engagement in mathematics.

Methodology and Results

Six indicators of mathematical productive dispositions drawn from Kilpatrick et al. (2001) and Carr and Claxton (2002) were used to thematically analyse data that were gathered in the form of learners' stories written in high school about their mathematical dispositions over time. The chronological trajectory of the stories was apparent as the prompt to write the narrative story explicitly required participants to reflect on their mathematics stories from primary school to high school. The six indicators are used to thematically analyse the six stories of the learners' mathematical dispositions over time. I tabulate the six indicators of mathematical dispositions from Kilpatrick et al. (2001), and Carr and Claxton (2002) below.

My reading of the indicators of Kilpatrick et al. (2001) and Carr and Claxton (2002) revealed that there were two similar indicators (*belief that steady effort in learning maths pays off (resilience)* and *showing tendencies of resilience, persisting in difficulty respectively*). For this paper I merged them to come up with belief that steady effort in learning maths pays off (resilience) K3&CC3.

Table 1

Codes for Indicators of Mathematical Dispositions

Authors	Code	Description
Kilpatrick et al. (2001)	K1	Seeing sense in mathematics
	K2	Perceiving mathematics as useful and worthwhile
	K3	Belief that steady effort (resilience) in learning mathematics pays off
	K4	Seeing self as an effective learner and doer of mathematics
Carr and Claxton (2002)	CC1	Showing tendencies of playfulness
	CC2	Showing tendencies of reciprocity (willingness to engage or taking another point of view)
	CC3	Showing tendencies of resilience (persisting in difficulty)

To analyse the narrative stories written by learner participants, different utterances were allocated a code that was nearest to it in meaning. The utterances were designated as sentences or consecutive sentences or phrases that conveyed meaningful learners' mathematics dispositions. The six indicators were further counted to determine whether the different mathematical dispositions were attributed to primary school, high school or whether they were directly attributed to the after-school mathematics clubs. The six indicators of mathematical dispositions are expressed as either positive or negative, where the negative dispositions carry codes that have a negative sign for example, -K1. Positive indicators are utterances that show that learners' participation in mathematical activities was not coerced but done willingly and happily, for example, "Since then, I loved maths more and more, it became my favourite subject" (Unathi K4), "It's when I started maths club, in the maths club, in the maths club we had an opportunity to count using cards and we used very exciting maths activities" (Emihle K4). Negative indicators are utterances where leaners reveal anguish and discomfort in their participation in the subject for example, "I was confused when it comes to be using the column when multiplying". (Siya -K4), "In grade 7, I used to struggle because it was a little bit hard (-K1) because it was my first-time seeing x's and I couldn't understand how to solve them" (Kamva -K4).

Table 2

Indicators of Mathematical Dispositions

Level of School	Indicator of disposition	Number of participants who mention the disposition	Positive disposition	Negative disposition
Primary	K1	5	4	6
	K2	0	0	0
	K3&CC3	4	8	0
	K4	6	22	16
	CC1	3	4	0
	CC2	3	4	0
High School	K1	6	5	4
	K2	1	1	0

Level of School	Indicator of disposition	Number of participants who mention the disposition	Positive disposition	Negative disposition
	K3	4	7	0
	K4	5	10	5
	CC1	4	2	0
	CC2	5	9	1
Clubs	K1	4	5	3
	K2	1	1	0
	K3&CC3	5	7	0
	K4	6	16	5
	CC1	3	9	1
	CC2	5	8	0

Column one in the table shows the school level in which the indicator of disposition was mentioned, and the second column shows the indicators of all the dispositions. The third column shows the total number of participants who mentioned the given disposition and the last two columns show the total number of positive and negative responses (these are opposite statement made in relation to an indicator) to dispositions, respectively. This table thus summarises six learners' mathematical dispositions using their presence and frequency in the learners' stories. In the following section I unpack the table with examples from learner stories starting with those occurring the most to the least that is K4 (74), K1 (27), K3 & CC3 (24), CC2 (21), CC1 (15) and K2 (2).

Seeing Themselves as Effective Learners and Doers of Mathematics (K4)

This mathematical disposition indicator had the highest number of both positive (48) and negative (26) utterances from the learners. They described themselves as confident and effective doers of mathematics in their stories. The highest number of positive utterances was recorded in relation to their primary school (22) followed by linkages to the afterschool mathematics clubs (16). One learner explained that: "I passed it with flying colours and got a level 7 & that gave me power to love and to continue doing it till I loved it" (Sethu). Another learner (Zozo) describes herself as being "good at mathematics" in primary. From the data it seems the after-school mathematics clubs played a significant role in the development of positive mathematical dispositions in the six participants as represented in the following utterances:

> "After joining the club, I saw that my results are changing, and they are increasing" (Tando)
>
> "I loved the maths club because we had maths tricks that we used while doing on(sic) activity" (Sihle)
>
> "The maths club really helped improve my maths skills and I will be always grateful for that" (Silakhe)
>
> "Our maths club teacher was Debbie who taught us nothing but good about maths and taught us tricks about maths which we used to teach other learners in class" (Sethu)."But when I joined the maths club it made me realise that maths isn't that hard and it is not about getting the right answer, but it was about understanding it, making everything fun and coming up with great new ideas on how to solve maths problems" (Kimi)

All the learners' descriptions of the maths club as having helped in developing their perception of themselves as effective doers of mathematics cohere with Graven's (2015) argument that club activities are designed to create more engaging and confident learners. She continues that the environment in the clubs disrupt passive teacher-dependent ways of being and create an environment

where learners can increase their opportunities to re-author themselves as mathematical producers, questioners, and explorers.

Some learners, however, did not perceive themselves as effective learners of mathematics in several time frames across their schooling. They narrated negative mathematics dispositions where they considered quitting the subject. For example, Sethu writes that, "I wasn't excelling in it or understanding it. I chose to give up and quit school if they were to teach me maths." However, the time in the club helped her to develop a more positive mathematical disposition. She concluded her story with an emphatic declaration that, "I am a good maths learner and I'm very proud of myself" (Sethu).

Seeing Sense in Mathematics (K1)

According to Kilpatrick et al. (2001), opportunities to see sense in mathematics and to experience the rewards of sense making in mathematics are critical aspects in the development of positive mathematics disposition in learners. All the learners in this paper reveal that they sometimes saw sense in mathematics (14 utterances) where it was easy and fun to do and they could use it in their daily contexts, but they sometimes experienced challenges (13 utterances) where the subject was difficult, and this decreased the development of positive mathematical dispositions.

Although Kimi never saw any sense in it in the first place, he writes that "I really appreciate everything that [club facilitators] did for me, because they (sic) did not start the clubs I would be hating and failing maths." On the same spectrum of enjoyment, Sihle explains that "in grade 9 my maths was fun, it is challenging. It is very exciting because I compete with my friends and help each other with our maths problems." The learners had probably developed the sense of seeing sense and enjoyment in mathematics when they engaged in their afterschool mathematics clubs in primary school.

On the other hand, the learners came across challenging times where mathematics was difficult and not making much sense to them as represented in these excepts from Tando and Sethu: "when I started in the intermediate phase, I was struggling again because mathematics was not the same, we were working with big numbers and I was confused when it comes to be using the column when multiplying." (Tando) and "In grade 7 maths became more harder (sic) and there was a lot of work done, there came solving x variables, geometry and so on" (Sihle).

Beliefs That Steady Effort (Resilience) in Learning Pays Off (K3 & CC3)

This dispositional indicator produced 22 positive utterances from four learners, and they were evenly distributed in primary, high school and after school mathematics clubs. According to Carr and Claxton (2002) key indicators of resilience include sticking with a difficult learning task, having relatively high tolerance for frustration without getting upset and being able to recover from setback or disappointment relatively quickly. According to Sihle, mathematics "is fun, but you need to focus, that's the rule I told myself while I was going to high school and if you practise maths, then you will achieve." She stated that it is crucial to 'focus' and endure the difficult tasks that one may come across in their mathematical journey. Another learner stated high levels of tolerance and agency in mathematics practice when she explained how she approached the teacher when the subject was difficult in high school and requested that "can't the maths teacher get us some people to help us with mathematics. Then she got some learners from (Thuthuka High School) to help us." Zozo expresses her understanding that you cannot instantly be good at the subject, but it takes time and endurance and constant practice to excel.

Acknowledging that one could not do mathematics alone and asking for assistance maybe traced back to their club ethos which valued and encouraged collaboration and agency in learning the subject.

Showing Tendencies of Reciprocity (CC2)

The dispositional tendency of reciprocity is a valuable resource in learning mathematics. According to Carr and Claxton (2002), learners who lack reciprocity, that is the ability to articulate their own learning processes and problems, the ability to communicate these to others or the inclination or the courage to do so are inevitably handicapped learners. Most of the learners in this paper show their inclinations towards the disposition of reciprocity and how they used it to succeed in their mathematics practice. For example, Zozo explains that after receiving low marks and feeling bad about himself, "I asked my mom who is really good in maths to help me and s little while later, I was slowly getting there." The interaction between the learners and their parents produced positive results. The courage to articulate or share their handicaps in mathematics resulted in them getting invaluable assistance which further developed their mathematical dispositions as evidenced by their descriptions of themselves as capable and confident doers of mathematics.

Showing Tendencies of Playfulness (CC1)

Being playful includes the learners' readiness, willingness and being more creative in reacting to problems and challenges in engaging in mathematics (Carr & Claxton, 2002). In this paper, Tando showed readiness and willingness to engage with mathematics regardless of challenges when she writes that "I didn't want to go to maths club because after school I was getting hungry and, in the club, we were doing some work for an hour. I made my final decision to attend the club because I really need help." Similarly, Lise reflects that, "In grade 7, I used to struggle because it was a little bit hard because it was my first-time seeing x's and I couldn't understand how to solve them. I talked to Pam about the issue about how to solve x's, she helped me."

The learners' disposition of playfulness pushed them to endure and find creative ways without being coerced to help them to overcome some of the mathematics difficulties that they faced in their journey from primary to high school.

Perceiving Mathematics as Useful and Worthwhile (K2)

Only one learner in the paper explicitly perceived mathematics as useful and worthwhile. Sethu seemed to agree with the club coordinators on the idea that passing the subject "could get us far" in terms of life after school. This however does not mean that the other participants did not see mathematics as useful and worthwhile, they were just not explicit, but their narrative stories reveal that they saw value in the subject, hence their perseverance, resilience, and affinity regardless of the challenges and difficulties in their journeys from primary to high school.

Concluding Remarks

Positive mathematical dispositions are considered to increase learners' chances to collaborate with others and develop affinity and resilience in maths practice. All the learners in this paper illuminated how their participation in the maths club contributed towards the development of their positive mathematical dispositions in primary and high school. In South African schools, learners usually have little agency and are generally passive, and teaching is generally procedural, allowing learners little agency and requiring them to mechanically follow rules like little robots (Umugiraneza et al., 2017).

The findings from the learners' stories showed above show that learners developed positive and productive mathematical dispositions as indicated by them seeing themselves as effective learners and doers of maths and stating their resilience. The stories also reveal productive dispositional indicators that steady effort and working collaboratively and creatively help in developing their knowledge in maths. The paper shows that there is more potential in the maths clubs to support learners in navigating productive mathematical dispositions throughout their schooling.

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