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Forming Positive Identities to Enhance Mathematics Learning among Adolescents

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Abstract Learners' participation in mathematics decreases during their transition from primary to high school. This is despite adolescents' cognitive growth equipping them with enhanced cognitive ability [1];[2] to learn mathematics. Hence low participation in mathematics does not result from cognitive deficiency. Rather, lack of motivation to learn mathematics may be the factor [3]. According to self-determination theory, motivation results from nurturing three human basic needs: autonomy, connectedness and competence [4]. Since identity is linked to autonomy, identities in mathematics learning impacts motivation to learn the subject. Hence, this paper reports on the action research intervention which took advantage of adolescents' preoccupation with identity formation. In line with continuous cycles of action research, the intervention is the pilot of the ongoing study that seeks to enhance mathematics learning by utilizing non-cognitive factors that resonate with the characteristics of adolescents. The paper reports on how the autonomy to form their identities in mathematics learning, impacted the adolescents' learning and attitude towards mathematics. Qualitative results show that learners lived up to their self-formed identities and this enhanced their motivation to learn mathematics. Further studies that forge positive identities in mathematics classrooms to enhance motivation to learn mathematics are recommended.

Keywords Mathematics Learning, Motivation, Adolescents, High Schools, Identity Formation, Self-determination Theory

1. Introduction

Participation in mathematics for learners in high school declines. For example, Dosey, Mullis, Lindquist and Chamber [5] found that children tend to enjoy mathematics in primary school but this level of enjoyment tends to fall dramatically when children progress into and through high school. Meece, Wigfield and Eccles [6] revealed that American surveys reported that only half of high school learners enroll for mathematics courses beyond grade 10. This is a consequence of students' reports of uneasiness, worry, and anxiety related to mathematics increases during the early adolescent years [6]. This problem has persisted in the twenty first century. For example, Byrne [7] found that there is low participation and performance in mathematics for high school learners. Also, Wang and Goldschmidt [8] found that the distribution of mathematics course taking among various subgroups not only differed in Grades 8 but also became increasingly inequitable by grade 11. Highlighting the seriousness of low performance in mathematics by teens in the US, Kronholz [9] called it an economic time bomb.

The same problem is also prevalent in South Africa; "The number of learners who participate and successfully pass mathematics and science in grade 12 is very low" [10].

Table 1 shows the trend mathematics achievement in the past five years for grade 12 students.

Despite, the low participation of learners as they enter high schools, adolescents experience dramatic cognitive growth [11]. Coleman and Hendry [12] assert that there is improvement in attention, both short and long term memory for adolescents. Harris and Butterworth [13] argue that adolescence is marked by new forms of systematic thinking which includes capacity for abstract thinking. Adding to the above cognitive abilities that come with adolescence, Lefrancois [1] and Berk [2] claim that adolescents have advanced meta cognitive skills and their cognitive self-regulation improves.

In short adolescents have the cognitive ability to learn mathematics which is by and large an abstract subject. Therefore, their decreased participation in mathematics cannot be a result of cognitive deficiency. But this may be a case of lack of motivation since achievement in mathematics has been linked to motivation and attitude [3]. Also, according to Brier [14] motivated students want to learn, they make as much effort as they can maintain that effort even in the face of frustration.

According to Deci and Ryan [4] self-determination theory (SDT) is the macro theory on motivation which is based on autonomy, connectedness and competence. SDT as a construct of motivation is intertwined with intrinsic motivation [15];[16]. The nature and nurture of these three basic needs culminates into intrinsic motivation [17]. Hence,

studies on enhancing motivation have nurtured one of the basic needs. For example, autonomous motivation has been found to promote greater conceptual understanding [18] and better grades [19].

Forming an identity involves defining who you are, what you value, and the directions you choose to pursue in life [20]. Berzonsky [21] conceptualizes identity as self-theory, a conceptual structure composed of self-representational and self-regulatory constructs. All self-theories revolve around self-definition resulting from self-beliefs. Clearly there are negative and positive self-beliefs. For example, self-efficacy is a self- belief in one's capability [22]. Self -efficacy beliefs have been shown to be the most highly related with performance in mathematics [23]. Also, Mkhize [24] argues that it is self-efficacy among other factors that enhances achievement in engineering for disadvantaged students.

According to Marcia [25], if defining who you are is done parents or teachers, then there is no identity achievement. Hence, commitment to that identity will waver. In SDT terms, autonomy has not been nurtured, consequently connectedness to that identity will be weak; leading to wavering motivation. It was this concept that underpinned the intervention discussed in this paper. Formation of positive identities in mathematics was promoted and monitored.

Finally, it is noted that adolescents are preoccupied with identity formation and this can be viewed as part of positive youth development ([26];[27];[28];[29]). Schools and families are important agents of identity formation [30]. Therefore, promoting the formation of identities augers well with adolescents as naturally, they are in the process of forming identities.

This paper reports on the intervention that assisted learners to self-define themselves positively, so as to form positive identities in mathematics learning. The objective was to enhance mathematics learning.

2. Materials and Method

2.1. Method

According to Gall, Gall & Borg [31] there are four types of knowledge that research contributes to education: (1) description, (2) prediction, (3) improvement or interventions and (4) explanation. The aim for this project is to explore, explain the impact of identities in improving mathematics learning. Hence, it contribution is mainly in improving mathematics learning through positive identity formation. The importance of identity is not only in motivation literature, but in mathematics education research as well. For example, Boaler, Dylan and Robyn [32] argue that students who develop a sense of identity which resonates with mathematics learning are more likely to continue with mathematics studies.

This project upholds the view that the research problem is the bases from which research design decisions are made ([33]; [34]; [35]). Improving mathematics learning is at the centre of this project, hence action research is the most appropriate design as "it seeks to bring together action and reflection, theory and practice, in participation with others , in pursuit of practical solution to issues of pressing concerns to people" [36]. The five steps of action research cycle by Ferrance [37] were employed. The introduction section of this paper encompasses the identification of the problem, which is the first step.

The second and third step namely, gathering data and interpret data entailed exploring the identities held by both teachers and learners in mathematics. The guiding question for this phase was: "What have you observed as problem (s) in your school that prevent grade 12 learners from passing mathematics?" The question was deliberately not explicit as it sought to extract perceived identities from the factors.

The fourth step was an intervention or action based on evidence. This started by offering learners an opportunity to form new identities in mathematics learning. Learners were divided into groups of five .The following brief was given to learners:" "Decide on who you would like to be in mathematics learning and based on that give yours group a name which must resonate with all the members of the group".

This was then followed by a series of mathematics lessons based on their curriculum for ten days. All classroom interaction deliberately propelled students to assume their identities. Classes started at 8h00 and ended at 20h30. That is why learners were given board and lodging on campus where the project was taking place There were three hours of breaks, meals and comfort breaks tea breaks and lunches in-between. This was a total of 9 hours per day of classroom interaction which is equivalent to at least one term of 11 weeks of normal classes.

Each lesson was introduced with was introduced with some history or the application of the topic. For example, the story of Carl Gauss who at the age of ten invented an arithmetic's series formula was used to introduce the arithmetic's series and sequences.

The fifth step was the evaluation and reflection of results. Learners were asked to freely and in their own words explain the impact of the intervention.

2.2. Participants

Seventeen rural high schools participated. The schools were selected on the basis of their poor performance in mathematics. For example, in 2014, 382 learners from these high schools wrote grade 12 mathematics examinations. Only 11 learners passed mathematics with at least 50%. Hence about 3% of learners passed in 2014. A total of eighty seven learners enrolled for mathematics participated. Each school was represented by high and low performing learners who are in grade 12. Each school was represented by four to six learners. All participating schools were no fee schools as their communities are impoverished. Therefore the government offers free meals to these learners.

The table below gives a brief summary of the action or intervention.

Table 1. Trend of grade 12 mathematics achievement over the past five years

Year	Total Students	No. who wrote mathematics	% who wrote mathematics	No. Achieved ≥ 40%	% Achieved ≥ 40%
2010	540 246	259 407	48	81 473	30.9
2011	496 735	221 355	44.6	61 592	30.1
2012	514 353	223 012	43.2	80 716	35.7
2013	562 467	238 370	42.4	97 790	40.5
2014	535101	223 047	41.7	78 026	34.9

Table 2. Topics for

DAY 1 : Identity formation session					
DAY 1 : Basic Algebra			DAY 2: Advanced Algebra		
Simultaneous equations Quadratic Equations			The nature of roots of a quadratic equation Exponential equations		
DAY 3: Advanced Algebra			Day 4: Sequences And Series		
Logarithms and their equations	Algebraic fractions Inequalities	Cubic Equations & remainder theorem	Arithmetic sequences and series	Quadratic sequences and series	Geometric sequences and series
DAY 5 & 6: Functions And Their Graphs: Exponential, logarithmic and quadratic					
DAY 7 & 8 Differential Calculus : Basic principles for differentiating , use of formulas					
DAY 9 : Using Calculus To Solve Problems			DAY 10 : Assessment & Evaluation		

3. Results

3.1. Factors for Failure in Mathematics

These results form part of the data after the identification of the problem. Hence, this are results from step two, that is, the step where data is gathered.

The question asked from educators' survey was: "What have you observed as a problem in your school that prevent grade 12 learners from passing mathematics?" The majority of the educators blamed the learners! Hence, clearly perceiving learners as having identities are not appropriate for effective mathematics learning. The majority of responses can be summarized as follows:

- Learners are not motivated
- Learners are lazy
- Learners lack of background
- Learners have illiterate parents who cannot assist them with their school work
- Learners do not know how to study
- Learners believe mathematics is difficult
- Learners have a negative attitude towards mathematics

The same question was given to the learners. Interestingly their responses coincided with those of their educators, but they justified themselves

Table 3. Factors for failure and their justification

FACTORS	*JUSTIFICATION*
We are lazy and demotivated	Trying to solve a problem without any success demotivates us and we end up not trying
We believe mathematics is difficult	Teachers tell us that mathematics is easy, but do not show this. All the time tests and homework are very difficult.
We have a negative attitude towards mathematics	Failing to solve mathematics problems inculcate negative attitude towards the subject.

3.2.1. Learners' New Identities in the Mathematics Learning.

These results are part of the action based on evidenced negative identities prior the intervention.

Learners were asked to sit in groups of their schools and were asked to give themselves a name that would define their aspirations, self-beliefs and their aspirations in the context of mathematics learning. The following were the names of different groups:

Table 4. Learners' new identities

Mathematics Conquerors (2 schools)	***Mathematics Mediators***	***The Hungry Birds***
Keep Mathematics Easy	*Mathematics Hunters*	*Green Pastures*
Keep Mathematics Simple	*The Hard Workers*	*The Bees*
Mathematics Experts	*Dream Team*	*Analytical Group*

3.2.2. Learners' Comments on the Impact of Intervention

The comments in this section by learners form part of the fifth step, namely, evaluation.

At the end of ten days, learners were asked to freely comment about the 10 day intervention. Their comments were grouped into five themes, namely expected increased achievement, problems solving enhanced, working in groups enhanced their understanding, improved understanding and hence attitude towards mathematics and increased motivation.

Expectation to Achieve

"The project keeps my mind mathematically"

"I can see that I can pass maths with flying colours"

"This programme will help me to pass my mathematics because I was struggling."

"I will definitely improve my marks in mathematics"

"I see that I will never get less than 40% in paper 1".

"I see that there's some improvement I can do after this project"

"I won't ever fail Maths from now onwards, and after second session I would pass with distinction".

Problems Solving Skills Enhanced:

Expected enhanced achievement is attributed to improved problem solving skills.

"I gained from the project how to attack mathematics"

"I learned more on how to deal with problems in mathematics using different methods".

"*I gained more skills of how to solve many mathematics problems"*

"The mathematics problem that I did not defeat in school, I started defeat them here"

"I never knew how to answer tricky problems, but in this project I gained the ways of solving all maths problems"

Working in Groups Increased their Mathematics Understanding:

Enhanced problem solving skills seemed to have been a function of the working in groups where learners were exposed to different methods of solving mathematics problems.

"There is more information I gained from the project on how to share with the other people because as I explain to someone, I understand more"

"*I was told about the importance of working in groups and share different opinions*"

"*I learned the importance of working as groups and share the little knowledge we have".*

Improved Understanding and Attitude of Mathematics:

With increased improved problem solving skills, invariably the attitude and understanding of mathematics changed for better

"Being here has changed my attitude towards maths"

"This project made maths easier and gave me good understanding".

"I learned that maths is not hard"

"I know maths is known as hard subject, but this has changed for me"

"I experienced greater improvement in understanding mathematics"

Increased Motivation

Teachers in general complained that learner's lack of motivation. Even though, the names for students indicated a semblance of motivation, at the end of the intervention, enhanced motivation was experienced by learners.

"After this project my mission is to conquer maths"

"This project has made a big difference and it has encouraged me to work hard".

4. Discussion

The data prior the intervention where teachers and learners gave their views on the reasons for the high failure rate in mathematics revealed negative identities from the perspectives of both learners and teachers. The "lazy learners", "learners with a negative attitude" and "learners with inappropriate beliefs about mathematics". All these labels about learners reflect the negative identities these learners have in the context of mathematics learning. In turn these are in sync with the prevalent poor performance and participation in mathematics [10]. Also, these negative identities support the argument by Boaler, William and Zevenbergen [32] about the centrality of the identity in mathematics learning.

When learners were given an opportunity and autonomy to reflect on who they would like to be in mathematics learning by redefining themselves, they shifted from "lazy" to be 'hard workers', 'mathematics hunters', 'Bees'. In particular bees are forever busy, hence the saying, as busy as a bee. They changed from the belief that mathematics is difficult to be 'mathematics conquerors', 'Keep Mathematics easy' and 'Keep Mathematics simple' , all these identities reflect beliefs contrary to the belief that 'mathematics is difficult', which was dominant.

At this point only autonomy to form their identities had been given and typical to the preoccupation of adolescents to form identities they formed positive identities.

The expressed impact of the intervention was open, that is, learners were not answering questions on understanding, working in groups, or enhanced learning. However, learners freely reported as having their mathematics learning enhanced. They specifically picked up the factors essential for effective mathematics learning, such as enhanced problem solving which is the core for enhanced mathematics learning [38]. But more importantly, learners indicated enhanced motivation to learn mathematics. In view of enhanced learning, changed attitudes, increased motivation, it was logical that students expects high achievement in mathematics. Hence, in their words learners said: *"I will definitely improve my marks in mathematics"*; *"I see that there's some improvement I can do after this project"*

"I won't ever fail Maths from now onwards, and after second session I would pass with distinction".

5. Conclusions

This action research intervention proves that there is room for improvement in mathematics learning and achievement for adolescents in high schools, if positive identities in mathematics are enhanced. Even though in general mathematics is a failed and feared subject, when learners were given an opportunity to define themselves, they define themselves in the positive light, for example, "mathematics conquers"! These self-definitions were reflections of self-beliefs and they carried them through all mathematics learning sessions as they always tried to live by their names. Hence at the end of the intervention learners' understanding of mathematics had improved and therefore problems solving skills increased which in turn enhanced their motivation in mathematics.

Adolescent learners have no cognitive deficiencies related

to mathematics learning all they need is recognition and utilization of who they are in terms of their development phase. In this case, their preoccupation with identity formation was recognized and utilized. It is the recommendation of this paper that further action research on a larger scale should be conducted as a strategy to remove the scourge of lack of motivation to learn mathematics among adolescents in high schools [5] and more importantly to dismantle the economic time bomb of low participation and performance in mathematics for teens [9].

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