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Investigating Mathematics Learning Trajectories: A Comparative Analysis of Grades at Two Major Turning Points

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ABSTRACT

The number of students completing mathematics education at higher levels are in decreasing numbers, despite good grades at primary level. This research study sought to explore the mathematics learning trajectory by collecting Mathematics grades obtained by 1652 students at the end of primary and secondary schooling. Data analysis showed a moderate association between these grades. But those who performed well at the primary level did not necessarily study the subject at the same learning performance at higher levels. This research study unveiled that girls, in general, tend to maintain their learning performance better than boys at higher levels. It also revealed that some students experienced a positive turning point in their learning, and the overarching conclusions from students' interviews included perceived usefulness of Mathematics education, intrinsic and extrinsic motivation to boost the learning process and the need to overcome past hurdles. Finally, a model was developed to monitor learning progress achievement.

Keywords: mathematics education, prior learning performance, learning trajectory, Mauritius

THE MAURITIAN CONTEXT

Mathematical skills are unavoidable prerequisites for every person to succeed in life (National Numeracy, 2017). These skills inculcate the development of the logical thinking, allowing individuals to manage complex situations and take better decisions. 'Futurologists' predict that the ten best paying jobs of the future will be mathematics dependent. In Mauritius, students spend six years in primary schools, at the end of which they sit for the Certificate of Primary Education (CPE) exams. Depending on their CPE aggregate in four of the main subjects, including Mathematics, English, French and Science, they are offered a seat in a secondary school. Learning performance, in other words, grades at the end of their first major turning point (CPE) is crucial as it lays the foundation for secondary schooling. After five years of secondary education, students sit for the School Certificate (SC) examinations, the second major turning point in their learning journey. Here, grades are assigned on two possible scales, the letter grades ranging from A to E or the number grade ranging from 1 to 8. There is a general outcry from educators who constantly draw attention to the low level of mathematics skills which many students demonstrate when joining secondary schools. In a recent study, Appavoo et al. (2013) report that on average, 76 % of students are successful in mathematics at the Certificate of Primary Education (CPE) examinations. Among these students, on average, only 42% managed to get a grade A, B or C at the School Certificate examinations.

The authors analyzed the reports of the Mauritius Examinations Syndicate (MES) and constructed a theoretical pattern that described how students who completed their CPE in 2005, eventually performed at SC in 2010. This pattern, as depicted in **Figure 1**, showed that the great majority of students regressed in their mathematics learning performance. In 2005, 5494 students obtained a grade A in Mathematics at CPE. In 2010, these students sat for the SC examinations and MES data showed only 1894 getting a grade A at this level, representing only one third of them. The other two thirds definitely got a lower grade: 3036 of them obtained a grade B and 564 a grade C. A similar trend was observed for those who obtained a grade B, C, D and E at CPE; indicating that the majority of

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Contribution of this paper to the literature

- This study confirmed that prior performance is a powerful predictor of later mathematics performance as revealed by Kyttälä and Björn (2010).
- It further revealed that most students with a good grade at the beginning of secondary schooling failed to maintain their learning performance at that level. However, girls were found to maintain their prior learning performance at the secondary better than boys.
- These findings led to the formulation of the Grade Progress Framework which can assist schools monitor students' learning progress in a more scientific manner.

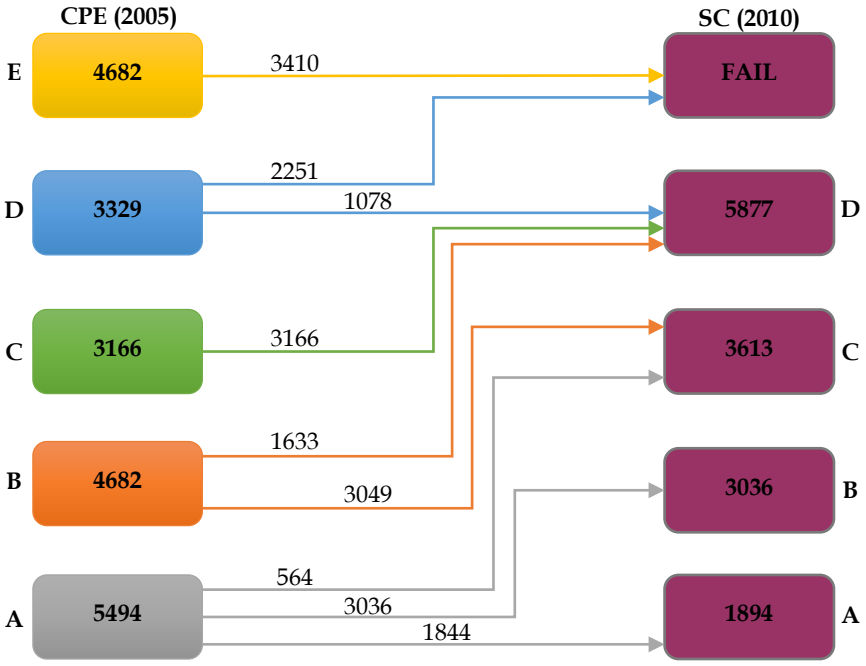

Figure 1. Comparative relationship between grades at CPE and SC

students were regressing in their mathematics learning performance. This theoretical pattern depicts that none of the students who obtained a grade B at CPE could get a similar grade at SC. In fact, most of them (3049) got a grade C and the rest (1633) a grade D. This regressive pattern put at risk a considerable number of students who eventually failed to acquire basic mathematics skills at secondary level and thus constrained their options for further studies and professional development.

While this pattern speaks a lot of truth of the learning trajectory of students, the authors decided to dig deeper and collect primary data that would give a truer picture of the situation. For example, it is well known that grade B students not only can get a grade B at SC, but even a grade A.

LITERATURE REVIEW

People learn mathematics from early childhood to late adulthood, going through a learning trajectory that can be viewed as the pathway along which prior understandings of key mathematical and cognitive components of a concept are refined over time. According to the Royal Society (2014), being educated to a high standard in Mathematics and science is likely to maximize young people's chances of success, both personally and professionally, in an increasingly competitive society. What we have learnt and how we have learnt in the past can pave the way for the acquisition of new knowledge. In a study carried out by the National Audit office (2008), it was found that pupils who mastered mathematics in their early school years were in a good position to study the subject at further level, and could also take other subjects which require a good grasp of mathematics. So, prior learning determines the way students perform at later stages (Barton et al., 2002; Beskeni et al., 2011; Roschelle, 1997; Osman & Hannafin, 1994; Voderman et al., 2011; Wetzels et al., 2011) and hence significantly influences their achievement (Hailikari et al., 2008), as confirmed by educational psychologists (Taber, 2001). Research in UK shows that children's entire subsequent mathematical education, and therefore their prospects as adults, is largely

determined by the age of eleven (Thompson & Zamboanga, 2003). According to Clements (2013), early knowledge of mathematics strongly predicts achievement into high school. So, when it comes to laying the foundation for solid mathematical skills, we had better get it right at an early stage, starting at the primary school level.

This research study therefore runs on the theoretical framework that prior learning has a serious bearing on future performance. Following a review of 183 articles, books, papers and research reports, Dochy and Segers (1998) reported that prior knowledge has direct and positive effects on study results. Those who can activate prior knowledge and integrate it with new information stand good chances of constructing new understandings. There is a scant of research, more so in the Mauritian context that has investigated correlation between grades at two different levels. The finding of this study would therefore be of great significance and add great discourse to the body of knowledge in learning trajectory. It would be misleading to say that prior learning performance is the only determinant of future learning achievement. There are certainly many other factors, including socio-economic status of parents and learners, motivation of both teachers and learners, the school learning environment, the curriculum, and assessment modes which play key roles in the overall educational development of students.

This research paper investigated how mathematics learning performance for the same students evolved from one major turning point (CPE) to the next one (SC). Is a good grade (A or B) at CPE, an asset to do equally well at SC? If not, what is the trend? In general, does performance over the years, tend to improve, stagnate or deteriorate? There is often a perception that there is a gender bias in the study of Mathematics, with boys tending to outperform girls (Bessoondoyal, 2005). This study sought to confirm if gender disparity existed.

School performance at secondary level in Mauritius is often evaluated by the quality of grades obtained by students. At the end of primary schooling the present national selection system is such that certain secondary schools benefit from a favorable intake of the most performing students at CPE. It is expected that these schools will be considered high performers given their initial head start of best intake. This paper set to propose a model, the Grade Progress Framework, which can provide a fairer approach to assess the performance of schools as opposed to the traditional approach of using percentages of passes.

RESEARCH AIM AND OBJECTIVES

Aim

Mathematics education is an ongoing process that runs across a lifetime. There are, however, two major learning periods, namely primary and secondary schooling. The aim of this paper is to investigate if learning skills at the end of primary schooling, sanctioned by grades, have determining influence on learning abilities, and hence performance, at the end of the first phase of secondary schooling namely SC.

Objectives

1. Compare mathematics grades at CPE and SC to identify any possible correlation between them.
2. Investigate trends of uncommon behavior, whereby students embrace a positive turn and change their unsuccessful mathematics experience into a successful one.
3. Analyze if there is any gender bias in Mathematics learning trajectory at secondary level.
4. Develop a tool to monitor the learning trajectory of students and thus assess school's ability to positively shape the learning experience of students.

METHODOLOGY

For the purpose of this study, the research design is longitudinal, which allows data to be collected on a sample on at least two occasions (Bryman, 2012, p.712). Data were captured through survey forms, which provided the mathematics results of students who sat for CPE in 2005 and SC in 2010. Students from 67 schools participated in the survey. Quota sampling was adopted to ensure that we have a representative sample of both female and male students coming from rural and urban areas and attending both state and private schools. The greatest challenge of this sampling process was to ensure that students of all learning performances were included in that sample. CPE results were recorded with grades A, B, C, D and E, while SC results with grades 1, 2, 3, 4, 5, 6, 7, 8 and 9. Students who join secondary schools have to pass in mathematics and that is why there is no category for 'fail' at CPE. However, at SC 'fail' results are recorded as 9. This collection of data was meant to analyze how students with different grades at CPE eventually performed at later stages, and to determine what percentage of them maintained their performance grades at SC or what percentage regressed with time.

Table 1. Categories of grades at CPE & SC

Category	Very Good	Good	Satisfactory	Poor	
CPE	A	B	C	D, E	
SC	{1,2} → A	{3,4} → B	{5,6} → C	{7, 8} → D	9 → F

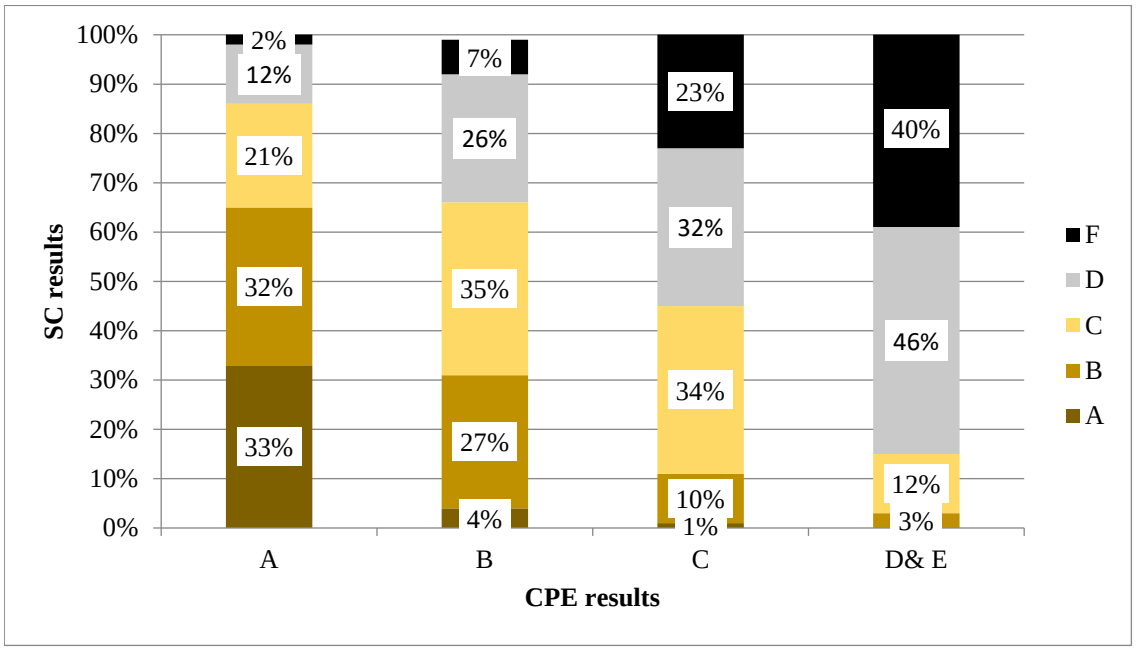

Figure 2. Distribution of grades at SC for each of the grades at CPE

To get an insight of what caused students to regress or progress over time, students including both boys and girls from different schools were interviewed. This combination of interviews and survey ensured that beyond the quantitative description of the situation, we also gathered qualitative insights into the causes of the prevailing trends.

DATA ANALYSIS

One thousand, six hundred and fifty-two students successfully completed the survey forms. The first step was to regroup and categorize the grades at CPE and SC to facilitate the comparative analysis. **Table 1** shows this categorization. For reporting purposes "CPE grade X" students mean students who obtained a grade X at CPE.

Responses from the survey forms were compiled and analyzed using Excel 2010 to produce the summarized version represented in **Figure 2** which shows the relationship between Mathematics grades at CPE (in 2005) and SC (in 2010). Only thirty- three percent of students who obtained a grade A at CPE got a similar grade (A) at SC. The remaining students got B (32%), C (21%), D (12%) and 2% even failed.

Finding 1: To get a grade A at SC, it is nearly a pre-requisite to have obtained a grade A at CPE. In fact, 87% of those who got a grade A at SC had a grade A at CPE too. But a grade A at CPE does not automatically lead to a grade A at SC, such that, only around one third of those who scored a grade A at CPE could manage to get a similar grade at SC. This is very close to the theoretical pattern developed by Appavoo et al. (2013) (**Table 1**) where it depicted that only around one third (1894/5494) of those who got a grade A at CPE, obtained a similar grade at SC.

Finding 2: Sixty seven percent of CPE grade 'A' students obtained a lower grade at SC, with around 12% performing poorly. This shows that many students with a good head start at the beginning of secondary schooling eventually regressed with time in mathematics learning performance.

Finding 3: A similar trend was observed for students who obtained B or C, whereby most of them got a lower grade at SC. For example, **Figure 2** shows that 68 % of CPE grade B students got a worse grade at SC.

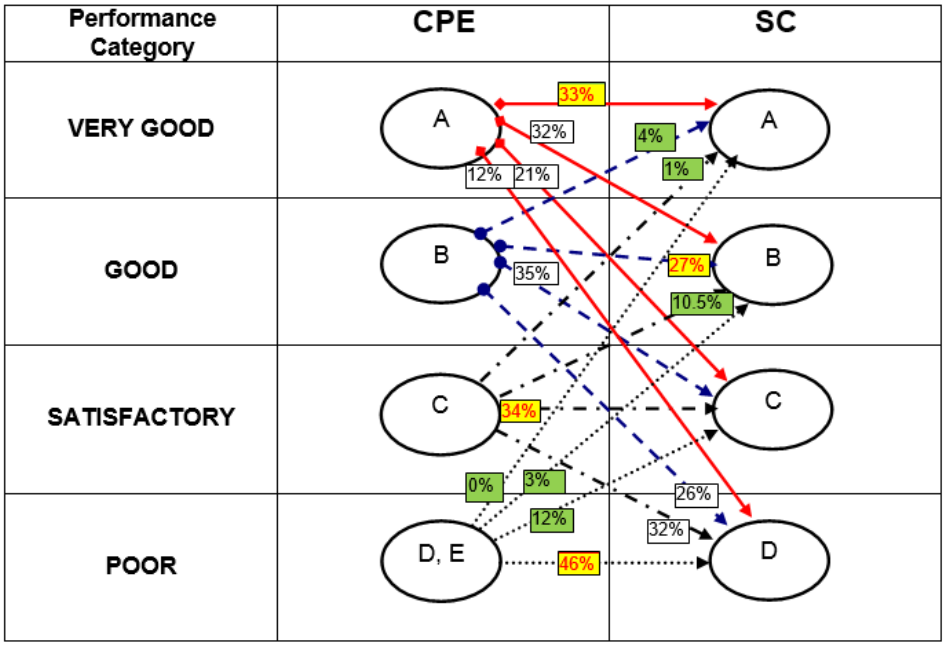

Figure 3. Grade Progress Framework

Finding 4: Figure 2 also depicts that with time some students outperformed those who initially had better CPE results. For example, 27% of CPE 'grade B' students obtained a similar grade (i.e. B grade) as 32% of 'CPE grade A' students and outperformed 35% of CPE grade 'A' students. This means that starting with a grade B at CPE, some students did as well or even better than CPE grade A students. Similarly, we observed that some CPE grade 'C' students outperforming some CPE grade A & B students.

Finding 5: Figure 2 shows that some students with a slow start at the beginning of secondary schooling made remarkable progress and did as well or even outperformed some of their peers who had better results at CPE. For example, 11% of CPE grade 'C' students got a grade B or A at SC.

Finding 6: A Chi square test was carried out and it showed a significant association between mathematics grades at primary and secondary levels (χ^2 (16, N = 1652) = 813, $p<0.001$), that is the performance of students at later stages depended on their grades at the primary level. This means what grades students scored at SC were related to their grades at CPE, and the Cramer's V value of 0.351 indicates a moderate relationship as per Cohen's set of descriptors (Cohen, 1988).

The Grade Progress Framework

One of the key performance indicators of schools is the percentage of successful students and the quality of grades at SC examinations. Secondary schools whose intake comprises high performing students eventually, year in year out, produce high percentages of success at SC compared to schools whose intake are among the average or low performing students. The model that is proposed below adopts a different approach and assesses rather the progress made by students over the five years of secondary schooling.

The Grade Progress framework, in Figure 3, shows that independent of their grades at CPE, students basically could score any grade at SC. For example, for students with a grade C at CPE, 1% obtained a grade 'A', 10.5 % a grade 'B' 34% a grade 'C' and 32% a grade 'D'. The percentages have been classified into three main groups, progressive (shaded boxes), regressive (unshaded boxes) and the status quo (yellow boxes). The progressive groups indicate desirable learning trajectories for students. Unfortunately, data from this study shows that the progressive percentages were mostly very low (4, 1, 10, 5, 12 and 3), whereas the regressive ones were relatively higher (32, 21, 35, 26 and 32), thus showing that there was a greater tendency for students to regress in their mathematics learning performance. The status quo percentages averaged the 35%. Any school can adopt this model to assess the progress achieved by students over the five years. Key performance indicators in this case would target the progressive and status quo percentages which desirably should be on the high side. Schools whose intake comprise mostly average or low performing students should be given credit when progressive percentages take an increasing trend. Every year, once the SC results are available, every school can compute the percentages and thus reveal the learning trajectory achieved by that cohort of students.

Table 2. Grade Progress Percentage for Girls

	GIRLS			
	A	**B**	**C**	**D& E**
(1-2)	40	4	1	1
(3-4)	38	31	11	3
(5-6)	15	35	35	16
(7-8)	7	25	35	50
9	00	6	17	31

Grade maintenance line

Table 3. Grade Progress Percentage for Boys

	BOYS			
	A	**B**	**C**	**D& E**
(1-2)	28	5	1	0
(3-4)	26	25	11	2
(5-6)	26	34	35	9
(7-8)	17	27	30	43
9	3	8	23	44

Grade maintenance line

Comparing Boys' and Girls' Performance

This study also analyzed if gender had an impact on the performance trend. From **Tables 2** & **3**, we observe that the values across the Grade Maintenance lines for girls were higher than that for boys, showing that girls were more successful than boys in maintaining their prior grade level at secondary level. The Cramer's V value of association was higher for girls (0.375) compared to boys (0.326). For example, 40% of girls maintained their grade 'A' at SC compared to 28 % for boys. Furthermore, 38% of these 'grade A' girls got a B at SC compared to only 26% for boys.

Finding 7: Girls demonstrated a better learning trajectory than boys and surpassed them in their mathematics learning performance.

Analysis of Special Cases

This study revealed some worth investigating cases, which could bring insights into addressing Mathematics Learning Disabilities (MDL). These cases were categorized into two groups, namely, those who experienced a positive turning point in their learning and improved their mathematical skills and those who experienced a negative turning point, and failed to maintain prior learning abilities.

Figure 2 shows that a number of students departed from the general trend in their learning trajectory. Some students, who were initially good performers at the primary level, eventually regressed with time, while a few others, quite poor performers at the beginning, climbed up the performance ladder over the years. We observe that around one third of "CPE grade A" students performed very badly at SC, scoring grades "C", "D" and even failing. A similar observation holds true for "CPE grade B" students. There were however some "CPE grade B and C" students who got a grade A at SC. This research study sought to gather a brief insight of these cases and for that purpose seven students, including both boys and girls, from two different colleges were individually interviewed. The semi structured questions were geared towards explaining how grades, hence performance changed with time and investigating into the contributing factors and the ways of empowering and encouraging poor performers to bridge their mathematics learning gap. Some of these questions included:

1. *"While results in other subjects were good, why did you obtain a B in Mathematics at CPE?"*
2. *"What helped you to take your unsuccessful learning experience into a successful one at secondary school"?*
3. *"What advice and suggestions would you give to those who want to boost their mathematics learning experience"?*
4. *"Why were you not able to do as well at SC as you did at CPE?"*
5. *"What went wrong while studying mathematics at secondary level?"*

The CPE and SC results of these students have been compiled in **Table 4**.

The overall SC aggregate sums the grades for the six best subjects at SC and the smaller the aggregate, the more performing are the students.

Table 4. Mathematics Grades at CPE & SC for Extreme Cases

	Maths (CPE)	CPE results (other subjects)	Maths (SC)	Overall SC aggregate
Regress	A	A, A, B, B	D	20
	A	A, A, A, A	D	22
	A^+	A, A, A, A	D	32
	B	A, A, A, A	D	34
Progress	B	A, A, B, B	A	14
	B	A^+, A^+, A	A	12
	B	A^+, A, A, A	A	22

Students who experienced a positive turning point in their learning trajectory

Three students, who scored a "B" at CPE, got a grade A at SC. Considering that even two thirds of CPE grade 'A' could not score a similar grade at SC, these three cases were worth our consideration. It is worth noting that grades at CPE in other subjects were mostly "A". The reasons for the grade "B" in mathematics at CPE were:

a) *"I was not matured enough"*

b) *"The teacher was not good at teaching the subject"*

c) *"I was not interested in the subject"*

Progress was achieved based on the fact that

a) *"With time, I gained confidence and hence maturity"*

b) *"The new school environment was conducive for learning"*

c) *"I developed an increased liking for my studies and wanted to do well."*

d) *"I got the appropriate support from my parents and educators and particularly the private tuition teacher."*

e) *"With time, I started to realize the importance of mathematics, especially for studies at further level."*

Table 4 shows that the SC aggregate for these students were good (14, 12, and 22). These students showed appreciation when reference to real-life applications was made to enhance interest and liking of the subject. Howard and Whitaker (2011) mentioned that mathematics learning can be enhanced when students understand the importance of mathematics and change their attitudes and beliefs about their ability to do mathematics.

When asked about what could be done to help other students upgrade their mathematical skills, the interviewees mentioned that students have to become more mature, probably through moral classes, and be more responsible towards their learning. The role of teachers was considered to be crucial in this motivating and empowerment process. When prompted about the possibility of integrating ICT in the teaching and learning process, one student wished that educators were adequately trained to embed ICT tools in their teaching.

Finding 8: Perceived usefulness of Mathematics education, intrinsic and extrinsic motivation to boost the learning process and the need to overcome past hurdles were the overarching conclusions of the discussion with students who experienced a positive turning point in their Mathematics learning trajectory.

Students who experienced a negative turning point in their learning trajectory

Unfortunately, the above scenario is not so common: the number of students who improved their mathematics grades over time were far fewer than those whose results did not improve. Four students who joined secondary school with a grade A and B finally ended with a grade D at SC (**Table 4**). Howard and Whitaker (2011) purport that some students experience a negative turning point in their mathematics learning. The interviews conducted with these students to unveil the factors causing this negative turning point provided the following most compelling comments:

a) *"I found mathematics difficult to study at secondary level"*

b) *"Friends often had a negative influence on me"*

c) *"Educators were not always motivating and did not give the adequate and individual support to those experiencing learning difficulties."*

d) *"I did not realize the importance of mathematics as an entry requirement for a great majority of fields of study at tertiary level."*

e) *"Difficult family situation had an impact on my learning performance."*

f) *"I lacked seriousness and responsibility for my studies."*

Table 4 shows that these students had good grades in other subjects at CPE, mostly "A". However, their SC aggregate were not as good with high values (20-34), showing that on the whole, their performance in other subjects too were poor. Some of the comments made by this group were contradictory to those made by the other group, like the lack of motivation from teachers and dislike for this subject.

Finding 9: Lack of motivation, negative influence from peers, perceived difficulty to study the subject, and lack of personal commitment were the main reasons expressed by learners who experienced a negative learning curve at secondary level.

CONCLUSIONS

The findings of this study point to one major conclusion which is that prior performance is a powerful predictor of later mathematics performance as revealed by Kyttälä and Björn (2010). In a previous study (Appavoo et al., 2013) it was found that although good grades at primary level were not a guarantee of good grades at secondary level, yet the majority of students who did well at the latter level were those who obtained good grades at the primary level. In a nutshell, this study reveals that:

1. Only around one third students could maintain their learning performance at the secondary level, the other two thirds got a worse grade as compared to their CPE one. Hence good grades at primary level did not necessarily lead to good grades at secondary level. Around half of good performers (those with grades A & B) at CPE did not perform as well at secondary level. Why did these students regress and even fail with time? This can probably be explained by Strangman et al. (2004) who drew our attention to the fact that students who hold inaccurate preconceptions may not be helped by prior knowledge activation strategies. So, holding prior knowledge is one thing, but activating it for further learning can be a challenge. This leads us to question if grades A and B at CPE are sufficient prerequisites for students to master further mathematical concepts at secondary level.
2. There were also exceptional cases of a reverse trend for a number of students who performed well at SC despite low grades at CPE. These students experienced a positive turning point in their math proficiency and learned to turn their unsuccessful experiences in mathematics into successful ones.
3. Students who joined secondary school with a CPE grade "C", "D" or "E" in mathematics were already at great risk and heading straight for a very poor learning experience.
4. At secondary level, girls demonstrated a better learning progression than boys by either maintaining or improving on their prior learning performance.
5. This research finally proposes a Grade Progress framework based on progress measures and which schools can use as key performance indicators rather than the traditional crude percentages of passes at SC.

RECOMMENDATIONS AND FUTURE RESEARCH WORK

Given the large number of students and schools involved in this study and the pertinent findings derived from analysis of the data, it is opportune to make the following recommendations for consideration by the major stakeholders.

A. A first avenue of intervention is to implement learning strategies that will enable more students with a good head start at CPE to maintain their learning skills at secondary level. The importance of mathematics for developing strong life skills, developing a liking for the subject and supporting learners through motivational approaches should become key areas of intervention. This will also help those who want to take a positive turn in their mathematics education.

B. Heads of schools and teachers should work towards eradicating those negative factors that caused many good students to eventually underperform. These inhibitive factors of performance should be researched more extensively and corrective measures extended to students who either lived unfortunate learning conditions during primary schooling or simply happened to be late performers.

C. In order to gather deeper insights of how the learning trajectory takes shape during these five years, it is recommended to carry out a similar longitudinal study, three years after students join secondary schools, that is, at the end of Form III, which is the final stage of lower secondary schooling.

D. Finally, there is a need to review the learning objectives and assessment mode at CPE to ensure that grades obtained are indicative of students' ability to take their Math Education to the next level. There is probably too much of teaching to test, drills and practice that automatizes the answering skills to the detriment of developing mathematical skills.

The findings of this research make a strong advocacy to review the study of mathematics in Mauritius that can emphasize mathematical thinking and reasoning right from early years of schooling. As mentioned by Clements (2013), many children will be trapped in a trajectory of failure if high-quality mathematics education does not start at an early age.

It is immensely vital to provide a new learning paradigm, where innovative learning methods will address the emerging learning styles of students, who are digital natives, surfing in a highly technological-based world of change. Stakeholders must create a seamless trajectory for math learning right from the early years of schooling. There is certainly hope but also means to enthuse a greater number of students to perform at higher levels. And to do that, good teaching is important; hence the need to train teachers to teach mathematics innovatively using technological tools (Clarke et al., 2005) where appropriate to make learning a desirable pedagogical experience. The findings of this research study lay some foundational truths that can eventually inform practice and fuel additional research that can guarantee our students a successful learning trajectory.

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