Impact of spiral teaching on quadratics: Action research with Grade 11 students in Mauritius

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This study explores the impact of spiral teaching on students' performance on Quadratics at O-level. Eight boys from Grade 11 participated in the action research study, in which a mixed method was used. Data were collected using questionnaires, worksheet and interviews. Analysis revealed that spiral teaching has positive impact on students in terms of mathematical fluency, content retention and mastery of concepts in quadratics. Most of the students agreed that spiral teaching helped to improve their understanding of the topic. However, a major challenge is the subsequent reduction in instructional time when reviewing of previous lessons.

Introduction

With rapid development in science and technology, Mathematics is becoming increasingly important, with its wide range of application in real life. The 2009 Programme for International Student Assessment (PISA) report showed that only 50 percent of Grade 11 Mauritian students demonstrated proficiency in Mathematics. This statistic implies that only half of the Grade 11 students have acquired the basic skills which will enable them to use Mathematics in their future (Walker, 2011). Mathematics has been the bedrock of several subjects in the school curriculum. Consequently, a good understanding of Mathematics is essential as it is embedded in subjects like Economics, physics and accounting among others.

In the Mauritian schools, Mathematics is taught as a compulsory subject up to Grade 11. Students who wish to do Mathematics at A-level normally opt for Additional Mathematics. Quadratics is included in the Additional Mathematics syllabus which is introduced at grade 10. It is an important topic and extends beyond the linear function. Nevertheless, it has been found that for many secondary school students, the topic quadratics is conceptually challenging (CIE, 2011). There is agreement among researchers that students' understanding in quadratics is mostly procedural and this impacts on their work (Didis, Baş, & Erbaş, 2011; Tall, Lim & Healy, 2014; Vaiyavutjamai & Clements, 2006).

The importance of the topic of quadratics is supported by the Cambridge International Examination (CIE), since every year concepts of quadratics are assessed for the School Certificate Examination. Cambridge reports offered some insights into the difficulties faced by students in quadratics, for example: '…it was very rare to see a fully correct answer, indicating a need for more practice on this type of question…' (CIE, 2011); '...very few were able to successfully complete this final step…' (CIE, 2014); '…the correct answer was rarely seen…'(CIE, 2015). Further, the following observations were also made from the reports: students face difficulties in completing the square, in writing the correct range of values and sketching quadratic graph among others.

Students' difficulties in quadratics are often compounded to the fact that their prior knowledge affects their understanding of the topic. A review of prerequisites is essential in these circumstances. Bruner (1960) emphasised the importance of revisiting content in order to increase student mastery of concepts. He stressed that spiral teaching allows repetition to improve and deepen skills and concepts. Spiral teaching is a constructivist approach that provokes student interest by using meaningful examples that build on previous knowledge, which is in harmony with the students' cognitive skills. It provides reinforcement of recently acquired material and develops confidence through successful accomplishment of

increasingly difficult tasks (Blechman, Muller, & Naftali, 2016).

In a study in which spiral approach was used as a form of assessment, Skinner (2011) observed positive outcomes in terms of students' content retention and mastery of the concept. However, the study considered only high achievers and consequently the results could not be generalised. Ramos-Samala (2018) conducted a study involving 133 students regardless of their academic abilities and understanding. Her study revealed that students gained deep understanding of concepts through a systematic review conducted by the teacher. The researcher made use of other teaching strategies like discovery learning, cooperative learning, multimedia and laboratory activities, which helped students to better understand the concept using a spiral approach. The study recommended that review must be done only when the need arises. The key implication drawn from the study is that if teachers want to adopt the spiral teaching in class, they must be aware of other teaching strategies, which they can incorporate in their lesson plans to help motivate and aid in the success of the spiral approach. However, the use of purposive sampling limits the generalisability of the findings.

Research (Harden & Stamper, 1999; Magda, 2015) supports the use of spiral teaching in class. Magda found that the spiral technique impacted positively on students' cognitive abilities and led to an increased in students' performance (this study used a sample of girls only). Harden and Stamper (1999) observed that students regularly revisit topic is very helpful in acquiring knowledge. On the other hand, Snider (2004) pointed out that the spiral teaching is flawed since materials are presented in a spiral fashion of repeated concepts and too much repetition can reduce the instructional time devoted to the teaching of a new concept. Skinner (2011), despite an advocate of spiral teaching, observed some reluctance from teachers for the approach due to time and effort needed. Spiral teaching might cause boredom with the subject already taught in the previous class and repetition represents waste of instructional time. Furthermore, during spiral teaching, teachers tend to develop an attitude of indifference towards students as they believe that students will 'get it' again in later lessons. Review of concepts is done when the chapter is being taught and is rarely revisited (Snider, 2004).

The debate continues as to whether spiral teaching is really fruitful, owing to the fact that in some countries this approach has been discontinued (Resureccion & Adanza, 2015). Thus, evaluation of this approach is imperative. Such work focuses on the teaching of quadratics using a spiral approach proposed by Bruner (1960). It will be helpful for teachers who explore different avenues in their teaching and will also be a reference material for further research. Moreover, there appears to be a lack of in-depth research concerning the teaching of quadratics to improve students' understanding. This study aims at filling the research gap by investigating the use of spiral teaching, which is a constructivist approach to improve students' understanding in quadratics.

Methodology

Action research enables teachers to become reflective practitioners so as to improve the quality of education for himself/herself and the pupils (McNiff, 1988). Kemmis' (1988) model is used in this action research study with two cycles. In each cycle the four steps of planning, acting, observing and reflecting were conducted. The action research was conducted in two cycles, spanned over five-week from August to September 2018. During the first cycle, prerequisites of quadratics were assessed through a questionnaire. Based on the findings from the preliminary assessment, spiral teaching lessons were planned and implemented, followed by observation and reflection. The reflection stage allowed the researcher to "analyse, synthesise, interpret, explain and draw conclusions" on the lesson

and paved the way for improvement in the second cycle (Kemmis and McTaggart 1988, p. 86). Figure 1 shows the spiral model used for this study.
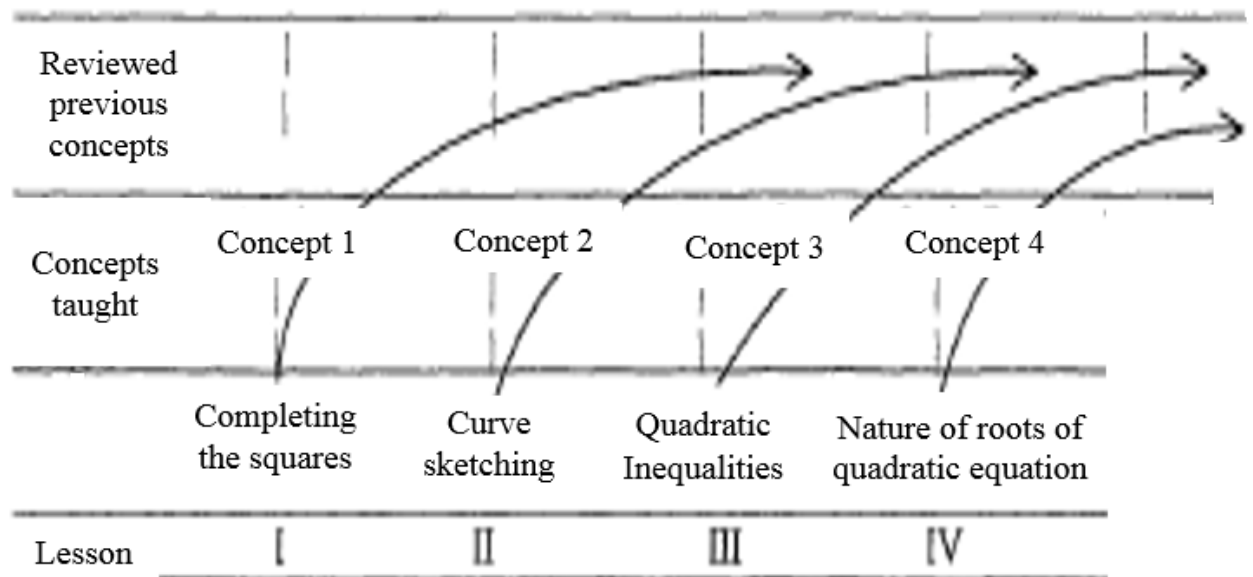

Figure 1: Spiral organisation for teaching the topic Quadratics (Adapted from Dodes, 1953).

Figure 1 shows how the different concepts were reviewed in successive lessons. For instance,
the following example illustrate a spiral activity in lesson 4. It includes concepts covered in lessons 1, 2 and 3.

It is given that f(x) = $2x^2$ - $12x$ +10.

(i)   Find the value a, b and of c for which f(x) = a(x + b)^2 + c (Lesson 1-completing the square)

(ii)   Sketch the graph of y = f(x) (Lesson 2-Curve Sketching)

(iii)   Find the range of values of x for which ($2x$–2)(x–5) < 0 (Lesson 3-Quadratic Inequalities).

Data Collection Instruments

Data were triangulated from different sources such as reports, interviews and questionnaires. Before implementing the action research cycles in class, data were gathered from the Cambridge examiners' reports to identify difficulties that students have on the topic quadratics. Informal interviews with the four Mathematics teachers were also conducted to have their views on students' difficulties and on the teaching of quadratics. Based on findings from the reports and the interviews, a worksheet was designed and administered to students to diagnose the pre-requisites for quadratics.

Questionnaires

Three questionnaires were used for this study. The first questionnaire tested the prerequisites of quadratics and was implemented at the beginning of the study. The second

one was used to gauge students' understanding of the topic at the end of the study. The third questionnaire, a 5-point Likert scale, was administered to gather students' views on the approach used and their understanding of the topic. The second questionnaire included three graded questions. Prior to its implementation, the questionnaire was piloted with two randomly selected students and two teachers who are not part of the study. The pilot study helped locate ambiguities and identified flaws in the questions which in turn led to an improvement and modification of the questionnaires.

Sampling

A convenience sample of eight Grade 10 boys, of mixed abilities, was used for the study.

Ethical considerations

Ethical clearance was sought from the different stakeholders (rectors, teachers and parents). Moreover, students were informed about the purpose of the research and were guaranteed anonymity and confidentiality.

Findings

Descriptive analysis and interpretation of the data gathered through questionnaires and interviews are next discussed.

Worksheet to evaluate prerequisite

Findings from the first questionnaire revealed that that 80% of the students have the prerequisite for the topic quadratics. For those having difficulties, it was mainly in the following essentials: factorisation, calculation and performing operations on integers. Issues with basic integer concepts impacted on the procedural fluency with algebraic terms, which is in line with other research findings in quadratics (Didis, Baş, & Erbaş, 2011; Tall, Lima & Healy, 2014; Vaiyavutjamai & Clements, 2006). Errors in calculations were mostly due to careless working out and students not revising their work once completed. Evidence of a lack of basic understanding of factorisation of quadratic expressions was prevalent in the worksheets. Students often consider only two terms while factorising rather than the three terms and end up with the wrong roots due to some false guesses, in line with other findings (Didis & Erbas, 2015; Makonye & Nhlanhla, 2014).

After completing the four lessons, using the spiral approach in Cycle 2, improvement was noted in students' understanding. At the beginning of each lesson, previous concepts were reinforced within a 5-10 minute review. New concepts were linked to previous ones. All students, irrespective of their ability, made significant progress in terms of conceptual understanding and mathematical fluency. The repetitive process of the spiral teaching increased the confidence level of students and the mastery of concepts in quadratics. The repetitive nature of spiral teaching enabled students to connect to previous knowledge and this served as a scaffold to construct new knowledge. During the later stages of the study, the initial difficulties faced by the students were no longer an issue, as they were all addressed in a repetitive manner at the beginning of every lesson.

Questionnaire Results

Responses obtained from students' questionnaire administered at the end of the study provide details about their appreciation of the spiral teaching.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	The teaching of Quadratics using the spiral approach was interesting.	0	0	4	1	3
2	Reviewing of concepts at the start of each lesson was helpful to me.	0	0	1	5	2
3	Spiral teaching has enabled me to grasp all the concepts taught in class.	0	0	3	4	1
4	Spiral teaching has increased my interest towards the topic.	0	1	1	5	1
5	Spiral teaching has helped me to better understand the concepts in Quadratics.	0	0	2	6	0
6	I would like other topics in Additional Mathematics to be taught using spiral teaching.	0	1	2	2	3
7	After experiencing spiral teaching, I can now attempt questions on Quadratics more confidently.	0	0	3	3	2
8	Spiral teaching is time consuming.	1	0	4	0	3

It is clear from the above results that half of students perceived the spiral teaching to be interesting. As observed by Cabansag (2014), it is easier to grasp concepts in spiral teaching as concepts are introduced to students from simple to complex. The result confirmed that nearly two third of the students agreed that they were able to grasp concepts by connecting their previous lessons to the new ones and the remaining one third adopted a neutral position.

Three quarters of students stateand that spiral teaching has increased their interest in the topic and agreed that spiral teaching has enhanced understanding of the concept. The result coincides with the study of Blechman, Muller & Naftali (2016) in which spiral teaching has helped students attain a comprehensive and integrative understanding of the topic taught. It was noted that two participants neither agreed nor disagreed that spiral teaching has improved their understanding and possible reason could be that spiral teaching may lead to superficial understanding of the needed skills as cautioned by Snider (2004). The data collected also showed that three students feel that the spiral approach is time consuming which supported the findings of Ramos-Samala (2018).

Interview Results

Four teachers participated in a 10-15 minute interview to provide their opinions on the difficulties students face in Quadratics.

➢ How much time do you devote to the teaching of Quadratics?
Usually, in each week, five periods of 35 minutes are allocated to the teaching of Additional Mathematics in secondary schools in Mauritius. Three out of four participants responded that they take three weeks to complete the topic of quadratics. They also highlighted that in mixed ability classes it might take four to five weeks to complete the topic.

➢ What are the difficulties that students encounter in the topic of Quadratics?

All the participants agreed that 'completing the squares' and 'quadratic inequalities' cause most difficulties to students because they involve several steps. One teacher reported that difficulties in Quadratics arise because students lack the prior knowledge related to the topic. This is in line with the findings of Kotsopoulos (2007) and Güner (2017) who found that students' difficulties in quadratic were due to a lack of prior knowledge in algebra, integers, algebraic simplification and basic multiplication.

➢ What are the teaching approaches/strategies that you used to teach the topic?

All of the respondents favoured the traditional approach. Teachers complained about the bulk of the syllabus which they have to complete within a limited time frame and thus were reluctant to use other teaching strategies like guided discovery or differentiated instruction which might be risky and time consuming. One respondent stated that "teaching approaches are not important, what really matters is that students are passing". It is evident from the interviews that teachers favoured traditional teaching. As supported by Lim (2000), traditional approaches to teaching quadratic equations are still widely used and preferred by teachers. Nonetheless, a traditional approach does not encourage interaction between prior and new knowledge nor does it promote deep understanding as supported by literature on teaching for understanding (Blythe, 1994).

In Mauritius, most of the classes are crowded (30 to 40 students) especially for lower forms, the curriculum is mostly exam oriented, and teachers are reluctant to use other teaching approaches. The findings of this study are in line with those of other scholars (Lewit & Bakel, 2000; Nyonyi, 1980) who found that teachers are constraint to use a traditional approach due to large classes which affect classroom activities and instructional techniques. It is important that teachers shift from the traditional teaching approach if they want students to grow as problem solvers and critical thinkers.

Conclusion and Recommendation

A major driving factor in spiral teaching is that concepts introduced in early lessons are revisited repeatedly with the intention to deepen student understanding. Students are therefore more aware of content area connections and complex tasks as they move to the next lessons. With spiral teaching, difficulties faced by students in previous lessons are minimised. Students are provided opportunities to catch the fundamental skills and thus developed mathematical fluency and mastery of the concepts by the end of the topic. Analysis revealed that most of the students agreed that spiral teaching has helped them improve their understanding. Additionally, around two thirds of the students conceded that they have grasped all concepts taught through spiral teaching, which conforms to the study of Magda (2015) that spiral technique impact positively on students' cognitive abilities. The qualitative data obtained support the idea that spiral teaching improves students' retention of content knowledge and has noticeably provided evidence to support the view that: the spiral teaching has promoted conceptual understanding of the topic quadratics and the study is useful for teachers. The findings suggest that spiral teaching be implemented when teaching quadratics. However, this study is limited as in the following terms: it was carried out in one boys' secondary school; no pre- and post-tests were used; only eight participants were involved; and only one topic was taught.

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