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Investigating Zimbabwean mathematics teachers' dispositions on the 'O' Level calculator syllabus 4028

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The questionnaire responses of 38 secondary school mathematics teachers provided initial data for this study. About 26.3% (n=10) of this number was sampled for classroom observation and in-depth interviews in order to assess the consistency of the dispositions. Only 15.8% of the schools in the study adopted the calculator version of the 'O' Level curriculum, 4028. The teachers' dispositions showed competence to use scientific calculators during instruction but maintained teacher-centred instructional approaches in both classrooms where students possess calculators and logarithms. This finding raises fears that even when calculators are available, they may remain on the periphery of mathematics instruction when they continue to be narrowly used as computational devices. Implications of these results are explored with a goal of providing teachers with insight into how to use calculators effectively in the 'O' Level mathematics curriculum.

Background of the study

The proliferation of scientific calculators in Zimbabwe in the mid 1980s gave birth to the calculator version (4024) of the 'O' Level mathematics curriculum. The curriculum had the same content as the non-calculator version (4004). A common structured Paper I that did not allow candidates to use computational aides standardized performance of candidates in the two curricula. Candidates for the two curricula wrote equivalent Paper II in which those sitting for 4004 used logarithms and scientific calculators for candidates sitting for 4024. The questions in Paper II were of comparable difficulty to justify the issuing of a common 'O' Level certificate to candidates who sat for the two versions of the curriculum. The concurrent use of 4004 and 4024 was intended to give mathematics teachers time to train in the appropriate use of calculators to enhance the full utilization of the devices in the teaching and learning of mathematics (Demana & Waits, 1997). This was necessary because successful implementation of scientific calculators in the mathematics curriculum entails a complete change in the roles of teachers during instructional practice. The transitional period was also intended for schools to budget for the resources necessary for full implementation of the calculator curriculum reform.

Revisions of the syllabus in the mid 1990s to meet the country's new goals of mathematics education maintained the *status quo* by renaming the parallel curricula 4008 and 4028. Twenty years down the line in the new millennium, the majority (about 84.2%) of the rural and high-density suburb schools still offer the logarithms 'O' Level Mathematics curriculum, 4008. In this millennium, technology is used as a fast and efficient tool for carrying out tedious computations that continued use of obsolete logarithms alienates school mathematics from the reality of society and workplaces.

For mathematics to be relevant to pupils' needs and societal technological demands, working harder on menial tasks should be replaced by working smarter (Brumbaugh & Rock, 2001). The slow rate of adopting 4028 has been explained in terms of students' inability to afford scientific calculators because of their high prices. What makes the excuse of cost null and void is that students who proceed to study mathematics at Advanced Level purchase scientific calculators for their personal use. Belief systems of school authorities and mathematics teachers might be contributing to scientific calculators at 'O' Level becoming exotic and expensive and commonplace tools at 'A' Level.

The argument for this paper is that the continued use of 4008 is fuelled by some factors other than cost. Mathematics occupies a core status in the secondary school curriculum because it is a key to opening career opportunities for students (Brumbaugh & Rock, 2001). The utilitarian values of the subject keep enrollments high that the compulsory offering of 4028 may not be a deterrent factor for students to study the subject at 'O' Level. This study investigated possible teacher factors that inhibit the national implementation of 4028 by exploring mathematics teachers' dispositions towards the 'O' Level calculator curriculum. Dispositions are taken here to mean teachers' usual temperaments, inclinations or frame of mind towards the use of scientific calculators in 'O' Level instructional practice. Mathematics teachers' dispositions have been singled out in this study because of the central roles they play in the successful implementation of a new curriculum. The pedagogical shifts that are necessary for successful teacher implementation of 4028 are not only mediated by the mastery of skills to use scientific calculators, but also by their personal philosophies of mathematics content and mathematics teaching and learning (Goos *et al.*, 2000). Specifically, the study sought evidence that provides insight into answering the research question: What are mathematics teachers' dispositions towards the 'O' Level calculator version, 4028?

Conceptual framework

Ruthven (1996) concluded that ten years after calculator introduction in the mathematics curriculum in the United Kingdom many important issues surrounding their use during instruction remained poorly conceptualized by some teachers. Goos *et al.* (2000) reported of a similar conclusion in Australia saying that even when calculators are freely available in the mathematics curriculum, teachers may utilize them in a conservative way. Ruthven and Goos and others seem to concur that the mere presence of calculators in the mathematics classroom does not guarantee their effective use during instruction. Without appropriate teacher orientations, calculators may remain confined to the margins of mathematics classroom life when they are casually, instrumentally and uncritically used for computations only. The conclusion made by Ruthven and Goos and others reinforces the important role that teachers' dispositions on mathematics teaching and learning play in the implementation of a new curriculum. Teachers' dispositions towards scientific calculators and contextual factors at schools have strong impact on learning environments, the integration and the place of calculators during instruction; otherwise calculators may not influence learning environments in significant ways.

Teachers' beliefs on mathematics instruction influence their choice of pedagogy, which in turn influences how students use scientific calculators in their learning (Burril *et al.*, 2002). Teachers who believe that calculators replace students' need to learn basic facts, computational procedures and algebraic manipulative skills put them on the periphery of the mathematics classroom as computational gadgets. Teachers who believe that learning mathematics goes beyond computational efficiency to include critical thinking in applying mathematical knowledge in problem solving or modelling integrate calculators well in their teaching. The development of classroom explorations and learning through discovery is motivated by the belief that inquiry is superior to expository learning when calculators are used during instruction.

Successful integration of calculators in the mathematics classroom requires correct teacher orientations. Without orientation in the proper use of calculators during instruction, teachers may continue to teach mathematics in the ways they traditionally taught the subject. The correct use of calculators during instruction entails pedagogical shifts from rote learning to modeling and finding solutions of real world problems that exist in students' every day lives. Problem solving entails the use of true figures as they appear in real life situations, rather than hypothetical ones that lead to 'neat answers'. Effective implementation of calculators in instruction necessitates that mathematics content and assessment methods change so that the calculators are used for their intended purposes (Hudson & Horba, 1999; Demana & Waits, 1997; Rosenstein, 2002).

Methodology

Ordinary Level mathematics teachers from selected schools offering 4008 and 4028 in three provinces of Mashonaland Central, Harare, and Mashonaland East provided data for this study. The data were collected between September and November 2003. Teachers from schools offering 4008 and 4028 were consulted in order to make a balanced assessment of their dispositions on using calculators during instruction. The secondary schools in the sample were 15 urban schools and 14 rural schools. The urban schools included nine high density, two private and four schools for middle class children (former group A schools). The rural schools comprised 11 rural day secondary schools and three mission boarding schools. The spectrum of schools was large enough to provide a wide range of views of teachers from a diverse socio-economic background and school contexts. In all 38 mathematics teachers (N = 38) were involved in this study. At some schools more than one teacher taught mathematics at 'O' Level.

Instruments

The nature of the data that answer the research question necessitated the use of both qualitative and quantitative approaches (Vacc & Bright, 1999; Lubisi, 1997; Lederman & Zeidler, 1987). A qualitative approach was necessary to interview mathematics teachers so that they could elaborate their dispositions. A quantitative approach was used to design and analyse questionnaires on a Likert scale, strongly agree (SA) to strongly disagree (SD). Lesson observations were conducted on 10 of the teachers (four from rural and six from urban schools) who were interviewed to assess how they were using scientific calculators during instruction and whether their espoused dispositions matched their classroom practices. The lessons observed were video taped whilst interviews were audio taped and transcribed so that the assistance of colleagues in the Faculty could be sought to classify emerging themes. A cross method triangulation of questionnaires, lesson observations and interviews was used to examine whether mathematics teachers' responses were consistent.

The questionnaire that was used in this study was adapted from Goos *et al.* (2000). The questions were modified to meet the context and demands of the present study. For instance, calculators are used in lessons to facilitate time-consuming computations (item 7) or calculators are used as checking devices for accuracy in calculations (item 20). Such questions were included to determine teachers' dispositions on the purposes of calculators during instruction. The instruments were pilot tested on in-service mathematics teachers receiving upgrading pedagogical and content courses at Bindura University of Science Education for feedback on the wording and interpretation of items.

The mathematics teachers' dispositions were categorized into three major themes of pedagogical (Table 1), assessment (Table 2) and student learning (Table 3). Pedagogical dispositions depict the mathematics teachers' purposes for using scientific calculators during instruction. For instance, students using calculators persevere on exploring mathematical tasks and ideas (items 10 and 16). Such dispositions confirm or dispel teachers' use of student-centred pedagogies when calculators are available. Assessment dispositions involve the beliefs that teachers hold on students' competencies to learn mathematics with the aid of scientific calculators. For instance, questions in present textbooks are not suitable for calculator use (item 18). This leads to the same performance of students using calculators and those using logarithms in 'O' level summative examinations (item 17). Learning dispositions are beliefs expressed by the mathematics teachers on how students learn mathematics. Examples of such dispositions include 'the use of tables discourages students to learn mathematics' (item 14) because they spend a lot of time learning how to use the calculators instead of mathematical content (item 22). Items 1 and 9 were included for the purposes of determining the availability of calculators in schools.

The 10 teachers who were observed teaching were interviewed in order to give them opportunities to elaborate their dispositions. The hierarchical focusing interview technique (Tomlison, 1989) was employed. It comprised questions that sought to gain in-depth accounts of the dispositions expressed by teachers. The interviews started with relatively general questions (*How do students in your class learn mathematics?*). This was followed by a gradual coverage of the focal questions of the study (Hobson, 2003). For instance, *your students used calculators to compute simple calculations that could be done mentally; do you think it was necessary for them to do that?* The teachers were also asked to provide concrete evidence of responses they gave. This strategy gives interviewees an orientation that enables them to get confidence and familiarity with the conversation in ways that allow the provision of well thought out and elaborate responses on questions of the interview.

Results

Data analysis involved finding the frequencies of responses falling in each of the 5-point Likert scale, strongly agree to strongly disagree (Hobson, 2003; Frid 2000). The conclusions made in this study are based on the majority of teachers' responses in the strongly agree (SA) and agree (A) or disagree (D) and strongly disagree (SD) category. The conclusions made from questionnaires are substantiated by responses from the interviews to make them clear.

About 63% of the mathematics teachers expressed views that disagreed and strongly disagreed that each student possesses a personal calculator (item 9). Fifty percent (50%) of the teachers strongly agreed and agreed that students had access to a calculator during mathematics lessons (item 1). This was true of the 15.8% of the schools in the sample that offered 4028. Affluent schools such as mission boarding schools and private schools used calculators continuously during the two-year 'O' Level course. High density urban schools and rural schools that offer 4028 sometimes used calculators during instruction to the best mathematics class in the final year of 'O' Level. A teacher who used calculators in the final year of 'O' Level argued, *the method of solving a problem is more important than the answer. It is necessary for students to learn mathematics without calculators up to end of Form Three* (Interview, October 2003).

The dispositions of mathematics teachers in the three categories of pedagogical, assessment and learning are shown in Tables 1, 2 and 3. The abbreviations are explained as SA –

Strongly agree, A – Agree, N – Neutral, D – Disagree and SD – Strongly disagree. Where the total number of responses is less the 38, it means that some teachers did not indicate their dispositions on the question.

Pedagogical dispositions

Table 1 shows that the majority of the mathematics teachers in the survey disagreed and strongly disagreed that they used calculators to introduce a concept (71.05% – item 4), develop a concept (50% – item 8) and compute time consuming calculations (47.4% – item 7). Nearly equal proportions agreed to strongly agreed (42.1%) and disagreed to strongly disagreed (39.5%) that calculators are used to facilitate explorations of mathematical concepts (item 10) and that they were used as checking devices (39. 5% and 42.1%, respectively – item 20). The responses of the five items (4, 7, 8, 10, and 20) do not indicate the dispositions of teachers in the survey as categorically knowing the pedagogical purposes of calculators although they were confident to use calculators during instruction (item 25) and that they knew that the use of calculators influence the roles of teachers (item 23). The espoused teachers' pedagogical dispositions influenced their dispositions on assessment.

Table 1 Dispositions related to pedagogy (N = 38)

	SA	A	N	D	SD
4. Calculators are used to introduce a concept	1	0	9	15	12
7. Calculators are used to compute time-consuming calculations	6	9	5	13	5
8. Calculators are used to develop a concept	0	9	8	12	7
10. Calculators are used to facilitate explorations of mathematics ideas	1	15	6	10	5
16. Students using calculators persevere on mathematical tasks	4	15	12	6	1
20. Calculators are used mainly as checking devices	6	9	10	12	4
23. Calculators make a difference to the way teachers teach	5	15	10	8	0
24. Use of calculators for instruction changes the role of the teacher	0	8	13	16	1
25. I am confident to use calculators during instruction	8	15	10	3	0

Assessment dispositions

Table 2 Dispositions related to assessment (N = 38)

	SA	A	N	D	SD
5. Assessment of students' work when using calculators is difficult	2	7	8	12	7
13. Students have the skills to use calculators	1	13	8	14	1
17. 4028 is an expense to schools because there is no difference in students' performance when using calculators or tables	4	11	12	5	5
18. Questions in present testbooks are not suitable for calculator use	5	18	7	5	1

Fifty percent of the teachers in the survey portrayed dispositions that indicated that assessment of the work of styudents using calculators is easy (Table 2). Closely contesting dispositions on students' skills to use calculators (strongly agree to agree – 36.8% and disagree to strongly disagree – 39.5%) led teachers to hold beliefs in the strongly agree to agree category (39.5%) that there was no difference in the performance of students using calculators from those using tables. This disposition was influenced by an awareness that the mathematics textbooks in use are not suitable (60.5%) strongly agree and agree) for calculator use (item 18). Teachers' assessment dispositions greatly influenced their belief systems on how students using calculators and logarithms respectively learn mathematics.

Learning dispositions

As shown in Table 3, 65.8% of the teachers strongly agreed and agreed that students had the freedom to use logarithms to make some computations even though they had calculators (item 2). This disposition was held despite strongly agreeing and agreeing that students with calculators learn mathematics better than those with logarithms (63.2%), calculators have advantages in the learning of mathematics over logarithm tables (65.8%) and students should use calculators to learn 'O' Level mathematics (50%).

Table 3 Dispositions related to learning (N = 38)

		SA	A	N	D	SD
2.	Students are free to use tables to perform calculations	14	11	7	4	2
3.	Use of calculators confuses students	1	1	10	15	11
6.	Students using tables are more confident to learn mathematics than those using calculators	3	7	11	13	4
11.	Students with calculators learn mathematics better than those using tables	5	19	7	6	1
12.	All students should use calculators when learning O Level mathematics	9	10	8	6	1
14.	Use of tables discourages students to learn mathematics	5	8	7	11	7
15.	Students using calculators ask a lot of questions	2	6	17	10	1
19.	Calculators have advantages over tables when learning mathematics	7	18	5	5	0
21	Use of calculators benefits good students only	5	7	9	11	5
22.	Students spend time learning how to use calculators instead of content	2	9	9	12	6

Discussion

The results of this study showed that a small percentage of schools in the sample (15.8%) adopted the calculator version of the 'O' Level mathematics syllabus, 4028. Students attending private and boarding schools used the calculators continuously during the two-year 'O' Level course. Prolonged individual use of calculators during mathematics lessons gave rise to high student success and confidence to use the calculators in summative examinations (mean 'O' Level pass of these schools was 62.1%). The degree to which calculators were used in rural day and high density suburb schools varied by ability of students and year of the course. Owing to the shortage of calculators some schools offered 4028 to the best streams in the school (students also used the calculators in physics lessons) or to students in the final 'O' level year. The teachers justified use of calculators in the final 'O' Level year citing the need to prepare students for Paper I (paper does not require the use of calculators for all candidates) and Paper II (paper requires the use of calculators) proportionately. This conclusion was succinct in a teacher's elaboration during the interview:

> *It is necessary to make students do mathematics without calculators up to end of Form Three. The calculators can then be introduced in Form Four. I believe this will enable students to score well in Paper I where the use of calculators is prohibited* (Interview, November 2003)

Introducing calculators in the final 'O' Level year did not give students enough exposure and familiarity to use the devices. Insufficient practice in using calculators coupled with sharing of the devices during instruction in some high density and rural secondary schools limited students' practice on how to use the calculators. Insufficient time for practice led to some students being "impatient to learn the operations of a calculator that some of them resorted to use logarithms even when they had calculators". This greatly compromised the acquisition of the skills to use calculators under examination conditions.

The teachers in the survey stated that they were competent to use calculators for instructional purposes. That espoused competence did not seem to influence their perceptions of changes in their instructional roles when logarithms or calculators were available during instruction. The teachers tended to teach mathematics using calculators in ways they taught the subject using logarithms because the uses of the two devices were restricted to computations only. Teachers' traditional habits and prejudices may explain the slow transition to the national adoption of calculators in the 'O' Level syllabus. The expressed idiosyncrasies of the teachers that there were no differences in performance of students using calculators and logarithms in the summative 'O' Level examinations further reinforces their justifications for the continued use of logarithms. This illustrates that it is difficult for teachers to give up their old habits and prejudices or that curriculum change breeds teachers' resistance to change (Brumbaugh & Rock, 2001; Montessori, 1967).

The teachers in the study seemed to perceive calculators as performing the same computational roles as logarithms during instruction. Dispositions that did not depict instructional differences when using calculators or logarithms might be interpreted to mean that some teachers were not aware of the roles of calculators during instruction. An effective use of calculators during mathematics instruction shifts from primary emphasis on computations to full use of the device for explorations and modeling real world problems and finding their solutions. When used effectively calculators facilitate the development of deep conceptual understanding of mathematical content. Calculator use also presents opportunities for students to explore mathematical relationships and develop valuable critical thinking and problem solving skills (Demana & Waits, 2000). Effective calculator use accelerates the pace at which students learn mathematics and decrease the amount of time spent on computations. This makes some mathematical topics become obsolete and others introduced.

An understanding of the roles of teachers using calculators for instructional purposes influences classroom environments (Burrill, 2002). The classroom atmosphere changes from teacher-centred to a community of learners who persevere on mathematical problems through negotiations of viable methods of solving problems. Open-ended investigations that provide multiple representations of mathematical generalizations and justifications of conjectures are the norms of such classrooms. Students' competencies in such classroom environments change from production of correct answers to an understanding of the processes that lead to the construction of conjectures and proving them for their validity.

The questions and topics that suit the correct implementation of calculators change to include real world calculator sensitive problems. Calculator sensitive questions discriminate the performance of students using logarithms from those using calculators as mediums of computational aides. In calculator sensitive problems the calculator acts as a catalyst that determines the partnership between students and calculators in the learning process in which calculators do not diminish students' mathematical skills (Harvey, 1991; Ralston, 1999; Teachers Teaching with Technology, 1999). A partnership characterized by a complementary division of labour between students and calculators is ideal. In an ideal partnership students have sufficient knowledge and understanding of the mathematical processes that bring out desired outcomes but pass over the responsibility to calculators at appropriate stages to perform the tedious computations.

Conclusions

Though elsewhere in the world hand-held technologies such as graphic calculators are affordable and classroom normality rather than an oddity, Zimbabwean mathematics classrooms still have a long way to go before scientific calculators become classroom tools. The prohibitive factor of high cost that makes calculators beyond the reach of most schools and students is the immediate hurdle to overcome. A result of this survey which indicated that mathematics teachers' dispositions showed that calculator use was mainly for computational purposes in the same manner as logarithms indicates that practising teachers need to be in-serviced on the proper use of calculators for instruction. This finding also challenges teacher education programmes to equip mathematics teachers under training to acquire the right attitudes and skills to implement technology successfully in their instruction. Knowledge of calculator use during instruction alone is not enough without an awareness of supporting classroom environments that promote co-operative student construction of multiple methods of solving problems and explorations of mathematical conjectures. Programmes to update teachers' implementation of calculators in the mathematics classrooms should not focus on making them gain confidence in the use of the devices during instruction but provide them with opportunities to revise their dispositions on the national implementation of 4028.

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