Art. # 1440, 8 pages, https://doi.org/10.15700/saje.v38n1a1440

Learning style preferences and Mathematics achievement of secondary school learners

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Mathematics is a key subject necessary to the promotion of economic development, particularly in developing countries; however, South African learners perform poorly in Mathematics when benchmarked against their counterparts in other countries. One way to address this issue is by taking cognisance of the learners' learning styles when teaching. Using the Dunn and Dunn model and the VARK model, the study on which this article is based explored the inter-relationships of Mathematics achievement and seven learning styles, as well as the learning styles of high and low achievers. To this end, the investigation employed a mainly quantitative research design involving 240 learners from one secondary school in the North-West Province. The learners completed a structured questionnaire. Among others, the results revealed that an individual learning style correlated the highest with Mathematics performance. Through follow-up interviews with 10 high achievers, the study also found that context influenced learning style preferences: in addition to individual learning at home, high performers preferred reading/writing and group learning in the classroom. The study recommends that teachers should create a positive learning environment at school, and use teaching methods that accommodate a variety of learning styles. Further research is needed to determine the impact of demographic variables on learning style preferences in Mathematics.

Keywords: Dunn and Dunn model; learning style; Mathematics achievement; Mathematics teaching; secondary school; VARK model

Introduction

Achievement in Mathematics is a fundamental indicator of the performance of a school system of any country (Reddy, 2005). Moreover, it is a key subject for countries with emerging economies, since Mathematics enables learners to enroll for careers in the fields of engineering, the natural sciences, accountancy, and many others crucial to support economic development (Makgato & Mji, 2006). It is therefore of great concern that researchers have indicated that Mathematics education in South Africa is in crisis (Hlalele, 2012; Pournara, Hodgen, Adler & Pillay, 2015; Reddy, Winnaar, Visser, Feza-Piyose, Arends, Prinsloo, Mthethwa, Juan & Rogers, 2013; Siyepu, 2013). The well-known Trends in International Mathematics and Science Study (TIMSS), conducted in 2011, found that South African learners' achievement was poor; learners from independent schools performed better than public school learners, where age-appropriate learners for a grade performed better than those who were younger or older; and girls generally outperformed boys (Reddy et al., 2013).

Among others, the above-mentioned poor performance in Mathematics seems to be caused by teachers who lack the knowledge and skills to explain concepts clearly, and a shortage of Mathematics textbooks that focus pertinently on prescribed curricula (Siyepu, 2013) by teachers who do not understand mathematical cognition in learners (Henning, 2013); as well as by the fact that most South African learners are English second language learners, who struggle to learn Mathematics through English as medium of instruction (Botes & Miji, 2010; Howie, 2003; Setati, 2008). Poor performance in Mathematics may also be related to the teaching style of the teacher, since prolonged mismatches between the teaching style in the classroom and the learning styles of most learners can contribute to poor academic achievement and negativity towards a subject (Breckler, Teoh & Role, 2011; Naik, 2013; Orhun, 2007). When the learners are taught in accordance with their learning styles, and when they consider their own styles while studying, their academic achievements seem to improve. In this regard, learning style is viewed as "the way in which individuals begin to concentrate on, process, internalize [*sic*], and retain new and difficult information" (Dunn, 1990, in Hawk & Shah, 2007:9).

The above-mentioned relationship between learning style and achievement is not simple, since learning style is influenced by demographic variables such as gender (Kiwanuka, Van Damme, Van den Noortgate, Anumendem & Namusisi, 2015; Ren, 2013); culture (Joy & Kolb, 2009; Naik, 2013; Ramburuth & McCormick, 2001); age (Hlawaty, 2008; Uganda National Examinations Board, 2013), and also, most importantly for this research, by school subject (Leung, McGregor, Sabiston & Vriliotis, 2014; Verma, 2006). Thus, a learning style that is effective for learning English or History may not be valuable for learning Mathematics.

Generally, visual learners make up the largest group in a classroom (Nel & Nel, 2013). They prefer the depiction of information by means of diagrammes, graphs and other methods to present information (Fleming, 2015). Auditory learners, who usually make up 20% or less of a class (Nel & Nel, 2013), prefer information that is spoken and heard, and they thus learn through lectures and group-discussions (Fleming, 2015; Juškevičienė & Kurilovas, 2014). Learners with a reading/writing learning style prefer information displayed as words and they learn effectively by reading and writing (Fleming, 2015; Juškevičienė & Kurilovas, 2014). These learners appreciate handouts (Prithishkumar & Michael, 2014), and make notes, which are studied (Fleming, 2015; Khanal, Shah & Koirala, 2014). Kinaesthetic learners learn best by moving and acting (Amran, Bahry, Yusop & Abdullah, 2011; Juškevičienė & Kurilovas, 2014). They often find it difficult to sit still for long periods, as they thrive on exploration (Bennett, 2013; Leopold, 2012) rather than 'chalk and talk' teaching (Şimşek, 2014).

A Mathematics teacher, who adopts a teaching style that considers visual learning may provide learners with a visual dictionary to illustrate mathematical concepts in English and in their own language. One study found that such a dictionary improved the learning of Mathematics at school (Botes & Miji, 2010). Likewise, a teacher may support the learning of visual learners through the use of appropriate Mathematics software, which provides a dynamic visualisation of concepts (Bansilal, 2015). Other learning styles also need to be considered in the classroom, due to the fact that learning style preferences differ, and some learners are multimodal. This was illustrated by a study of low and high achievers in Mathematics in Brunei, which found that the high achievers made use of an auditory learning style significantly more than did the low achievers, and used the read/write style that involved textbook reading and note-taking more effectively, in addition to memory strategies (Shahrill, Mahalle, Matzin, Hamid & Mundia, 2013). However, the preferred learning style seemed to have been moderated by age and gender, so that learners in Forms 1 to 3 relied more on the writing style than the older learners in Forms 4 to 5; and that the girls were more effective at auditory, visual and kinaesthetic learning than the boys were. This shows that learning style preferences in Mathematics may be influenced by demographic variables (investigating such influences is, however, beyond the scope of this article).

Against the above exposition as background, the study on which this article is based aimed to answer the following main research question (RQ): *What is the relationship between learning style preferences and Mathematics achievement of a group of secondary school learners?* This required the investigation of two specific research questions, namely:

- RQ1: *Is there a significant inter-relationship between academic achievement in Mathematics and learning styles of a group of secondary school learners?*
- RQ2: *Is there a significant difference between the learning styles of the top and the low achieving learners in Mathematics?*

The answers to these two questions could provide pointers for more effective Mathematics teaching. The questions were addressed in consideration of the theoretical framework of the study, which is presented in the next section.

Theoretical Framework

Constructivism has been embraced by nearly every educational reform initiative in the last two decades and includes a number of different theories which all view learners as active participants in construction of knowledge and understanding (Ertmer & Newby, 2013; Hartle, Baviskar & Smith, 2012; Slavin, 2009). Constructivist teaching is learner-centred, and the lessons build on the learners' prior knowledge by means of scaffolding. When the learners are presented with new information that their current constructs cannot account for, they need to relate the information to their own personal experiences so as to enhance understanding. However, knowledge is not only individually but also socially constructed, according to Vygotsky (1978), and the teachers can improve the learners' knowledge and insight by means of efficient support in line with group-learning.

Mathematics teachers are confronted with the formidable task of creating a constructivist learning environment, while also considering the learning style preferences of the learners in the class. The Dunn and Dunn model (Dunn, 1996) is considered to be one of the most influential learning style models that has been developed (Englander, Terregrossa & Wang, 2013; Hermond, 2014). According to Dunn (1990, in Hawk & Shah, 2007), a learning style is characterised by how a learner starts to focus on, manage, internalise, and remember new material. The interaction of these elements occurs differently in each person and may vary with gender, age and culture (Boström, 2012). The Dunn and Dunn model consists of five learning style stimuli and several elements within each stimulus. These are the following: environmental (sound, light, temperature and room design); emotional (motivation, persistence, responsibility and structure); sociological (learning alone, in a pair, with peers, with a teacher and mixed); physiological (perceptual intake while learning, chronological energy pattern and mobility needs); and psychological processing (impulsive or reflective, and global or analytic) (Dunn & Burke, 2005–2006). The teachers may have little power over some of these elements in the classroom, with the exception of sound, individual versus group learning, as well as learner mobility - which relate to the kinaesthetic, individual and group-learning styles.

Another learning style model that is particularly valuable for its practical usefulness in class is the VARK model (which refers to the visual, aural, reading and writing, and kinaesthetic modalities) (Prithishkumar & Michael, 2014). The learners may prefer one style only (V, A, R or K), or they may be bimodal, trimodal, or implement all four learning styles (Hawk & Shah, 2007; Mestre, 2010). A study reported that 41% of the population who took the instrument were unimodal, 27% were bi-modal, 9% were tri-modal, and 21% were quad-modal (Hawk & Shah, 2007).

Since the implementation of any of the above learning styles may be influenced by the subject, as mentioned, this study aimed to investigate the relationship between Mathematics achievement and learning style. To this end, the next section explains the research method, followed by the results, a discussion of the results and, finally, the conclusions (Bosman, 2015).

Method

After ethical clearance for the study had been granted by the relevant committee at the University of South Africa, an independent school located in the North-West Province was selected for participation. The school has no entrance requirements and is therefore similar in learner composition to the two neighbouring public schools (where the school's main attraction is the provision of smaller classes). Two additional reasons facilitated selection: Mathematics was the school subject in which learner achievement was the poorest; and the school was multicultural. It comprised of four main groups, namely learners from South Africa, Zimbabwe, Botswana and Malawi, which accounted for 206 participants, or 86% of the sample. Written consent for participation was attained from the principal as well as from parents/guardians and written assent from the learners.

The study was exploratory, using a quantitative approach to investigate the two research questions. This was followed by a small qualitative component to shed light on and explain the quantitative data. In this way, the study was mixed-methods. All 240 learners in Form Two (Grade Nine) through to Upper 6th (post-matric) who gave their assent to participate completed a structured questionnaire, which was designed for the study. It consisted of two main sections: the four items in the first section requested the learners' biographical details, namely age, gender, nationality, and form. In the second section the five-point Likert scale response items were used, ranging from 1 ('definitely disagree') to 5 ('definitely agree'). This section consisted of 85 items that measured seven learning styles that had practical value for the classroom teachers. The questionnaire contained 15 items on each of the auditory, kinaesthetic and visual learning styles. Reading and writing, as well as individual and group learning, were seen as opposing sides of the same coin and had seven or eight items on each style respectively - thus in total, there were 15 items on read/write and on individual/group learning. Examples of the items are:

an auditory style - 'I prefer the teacher giving me direct instructions';
a kinaesthetic style - 'I love to learn by doing things'
a visual style - 'I like the teacher using audio-visual equipment like data projectors';
a reading style - 'I like receiving handouts from my teacher';
a writing style - 'I remember best by writing things down';
an individual learning style - 'I study best when I work on my own'; and
a group learning style - 'I like working in groups in class.'

The questionnaire was pre-tested in a pilot study with 20 learners, who were randomly selected from all the grades/forms, after which certain items were simplified. For example, the item 'I enjoy handling objects' was viewed as vague, and therefore changed to 'I enjoy building things.' Mathematics achievement comprised the mean of the learners' marks at the end of the first semester and at the end of the year. Questionnaires could therefore not be completed anonymously.

Although the study was only exploratory, two experts on learning styles were consulted to evaluate the questionnaire on both content and face validity. Regarding the reliability of the questionnaire, it was calculated statistically by means of Cronbach's alpha coefficient, which is a measure of the internal consistency of questionnaire items that use Likert scale response options (Struwig & Stead, 2013). Each of the 85 items was assigned to the relevant scale corresponding to one of the seven learning styles selected for the study; thereafter, Cronbach's alpha was determined for each scale. All the correlation coefficients were 0.7 and above, except for the auditory and the kinaesthetic learning styles, which were just less than 0.7. Thus, for the purposes of this research, the questionnaire was deemed reliable (McMillan & Schumacher, 2014).

Data-analysis was done by means of the Statistical Package for the Social Sciences (SPSS). RQ1 was analysed by means of Pearson's correlation coefficient. The statistical analysis for RQ2 was by means of analysis of variance (a *t*-test). For this question, only the 56 learners who achieved 75% and above, and the 100 who achieved 50% and less for Mathematics, were included. The total average of all the items of each learning style was calculated and could be between 1 and 5 in consideration of the five point Likert scale. Since the items were formulated positively, the higher the score (and the closer to 5), the more the learners were inclined to use that particular style.

After the quantitative data analysis, a qualitative approach was used to shed further light on the results and thus gain more insight into effective teaching and learning methods in Mathematics. To this end, 10 top-achievers in Mathematics (boys and girls) were purposefully selected from Form 2 to Form 6. In interviews, the learners explained how they studied Mathematics, and which teaching methods worked or did not work well for them. The interviews were audio recorded and transcribed verbatim, before data analysis. The three main questions formed the categories of the qualitative data, while the analysis was bottom-up within each category, starting with the identification of the units of meaning (McMillan & Schumacher, 2014).

Results

RQ1: The Inter-Relationship Between Learning Style and Academic Achievement in Mathematics

An experimental hypothesis was stated indicating that a significant inter-relationship between the learners' academic achievements in Mathematics and their learning styles was expected. The results appear in Table 1.

Table 1 indicates that the learning style with the highest positive correlation with achievement in Mathematics is individual learning. The correlation between visual and auditory learning is significant, positive and medium, likewise for the correlations between kinaesthetic and visual learning, and between group-learning and kinaesthetic learning. This means that the more the learner is able to use one learning style, the more he or she is also able to implement another style. As expected, there is a significant negative and relatively high correlation between individual- and group-learning; thus, the more the learners are group learners in Mathematics, the less they are inclined to be individual learners.

RQ2: The Learning Styles of the Top and Low Achieving Learners in Mathematics

An experimental hypothesis stated that there was a significant difference between the learning styles of the top and the low achieving learners in Mathematics. The results of testing this hypothesis are presented in Table 2.

Table 1 Pearson's correlations between learning styles and achievement in Mathematics

	Visual	Kinaes.	Reading	Writing	Indivi.	Group	Maths
Auditory	.41**	.28**	.09	.22**	.01	.34**	.05
Visual		.43**	.28**	.31**	-.06	.36**	-.03
Kinaes.			.02	-.06	-.22**	.43**	-.05
Reading				.26**	.12	-.00	-.05
Writing					.16*	-.04	-.13
Indiv.						-.62**	.16*
Group							-.11

Note. $N = 240$; ** correlation significant on the 0.01 level (2-tailed); * correlation significant on the 0.05 level (2-tailed).

Table 2 The learning styles of the top and the low achieving learners in Mathematics

Learning style	Achievement	*N*	Mean	*SD*	*t*-value	Sig.(*p*)
Auditory	50%-	100	3.48	0.39	-.07	$p > 0.05$
	75%+	56	3.49	0.43		
Visual	50%-	100	3.54	0.44	-.09	$p > 0.05$
	75%+	56	3.55	0.49		
Kinaesthetic	50%-	100	3.71	0.53	.77	$p > 0.05$
	75%+	56	3.54	0.59		
Reading	50%-	100	3.38	0.52	-.27	$p > 0.05$
	75%+	56	3.40	0.71		
Writing	50%-	100	3.64	0.65	.98	$p > 0.05$
	75%+	56	3.54	0.53		
Individual	50%-	100	3.69	0.66	-2.8	$p < 0.05$
	75%+	56	4.00	0.66		
Group	50%-	100	3.45	0.90	1.91	$p > 0.05$
	75%+	56	3.20	0.70		

Considering the means presented in Table 2, the high achievers in Mathematics made use of the auditory, visual, and reading learning styles more than the low achievers ($M = 3.49$, 3.55, 3.40 versus $M = 3.48$, 3.54, 3.38), but these differences were not statistically significant ($p > 0.05$). The low achievers relied more on kinaesthetic and group-learning ($M = 3.71$, 3.45 versus $M = 3.54$, 3.20) than the stronger students, but the differences were once again not significant ($p > 0.05$). It was the preference for individual learning that significantly differentiated the low and high achievers: those learners who performed well in Mathematics were significantly more inclined to learn on their own than the poor achievers ($t = 2.8$, $p < 0.05$; $M = 4$ versus 3.69). It is also worth noting that in three instances the responses on items were relatively widely scattered around the mean, where the top achieving learners differed considerably among themselves regarding their preference for reading ($SD = 0.71$), and similarly for the learners of both groups regarding their preference for group learning ($SD = 0.7$ and 0.9).

Qualitative Findings

When the high achievers were queried regarding how they learned Mathematics, their responses indicated that context impacted on learning style preferences, in the sense that different learning styles were used when studying at home and in the classroom. At home, the learners relied heavily on individual learning, possibly related to the fact that there was no one at home to work with, as well as reading and writing. Only one reference was made to group-learning by a boy who preferred studying Mathematics with a friend. When preparing for tests and examinations the learners implemented study strategies that included reading the notes in their exercise books and textbooks, revisiting concepts which they had struggled with in class, investigating other methods on the internet for doing algebra, re-doing exercises from their notebooks, practising the examples and topics from their textbook, and completing previous test papers. They only used memorisation to recall mathematical formulae.

When the learners were asked what forms of teaching worked best for them in Mathematics classrooms, they generally referred to reading/ writing (as above), in addition to auditory and group-learning. Reading/writing in the Mathematics class included working on quizzes, and completing exercises, worksheets, and past examination papers. They also expressed the need to interact with the teachers to sort out problem areas. They appreciated teachers who gave detailed explanations and many examples, and who ensured that they understood the work. Thus, they relied heavily on their auditory learning styles as a way of understanding the work explained in class and in constructing knowledge. In this regard, a female learner stated:

> *I like Mathematics teachers who know where possible problems are and go over the weak areas.*

Apart from group learning with a teacher, reference was also made to learning from classmates, who could sometimes explain concepts better than the teacher.

When the learners were asked about the teachers' teaching methods, which did not work well for them in the Mathematics classroom, they indicated they were not in favour of teachers who created a negative learning environment by being moody, unsupportive, impatient, sarcastic, and critical, since this affected their self-esteem. Two of the learners stated,

> *The Mathematics teacher makes the learners feel dumb* (Female).
>
> *I am scared to ask questions as the teacher replies, 'I do not want to explain that again'* (Male).

The learners, especially those who relied heavily on an auditory learning style in class, were frustrated by poor explanations and by boring teachers, who discussed the work in a monotonous tone, and merely read out the learning material. Learners with reading/writing learning style were also annoyed by teachers who did not check their homework, so that there was no constructive criticism offered. Finally, some teachers lacked knowledge of the subject, and had to rely on the support from their colleagues to explain abstract concepts in class.

On being asked how the teaching of Mathematics could be improved, the learners suggested that the Mathematics teachers ought to create positive learning environments in class by building the self-esteem of the learners, by ensuring that the classes are relaxed to reduce anxiety, by explaining clearly, and by being responsive to questions, which would support auditory learning. The learners also suggested that peer tutoring be promoted, which is a form of group-learning. The learners should also be encouraged to make use of the website, examsolutions.com, which encourages both visual and individual learning.

Discussion

In contrast to a study conducted in Brunei, which found that high achievers in Mathematics relied on their auditory learning styles, in addition to their reading/writing styles to study Mathematics (Shahrill et al., 2013), Table 1 (based on RQ1) indicated that, in this study, the preference to learn individually correlated most with achievement in Mathematics. Table 2 (based on RQ2) also revealed that learners who performed well in Mathematics were significantly more inclined to learn individually than the low-achievers. The low-achievers relied on others, as well as on a kinaesthetic style, and on writing. This suggests that the learners who were not able to study Mathematics at home on their own in preparation for tests and examinations, performed poorly in the subject. What is important here is that the learners needed to have mastered the relevant Mathematical skills, including the foundational concepts and insights, to be able to study on their own. In order to empower struggling learners to reach a level of competence where they might continue to study individually at home, efficient support by their teachers and peers is invaluable to increase their 'zone of proximal development' (Vygotsky, 1978). Group-learning in class has also been recommended by the top-achievers, even though the individuals in both groups did not fully agree in respect of their preferences for group learning (see Table 2). The impact of group learning may be influenced by how the groups are formed, where one study in particular has indicated that it is better to group the high achievers together, while the poor performers ought to be clustered with the middle achievers for the effective learning of Mathematics to take place (Burke & Sass, 2011).

However, the individual- and group-learning styles are not the only important learning styles for achievement in Mathematics. Table 1 (RQ1) indicates significant positive correlations between group-learning and kinaesthetic learning, between kinaesthetic and visual learning, and between visual and auditory learning. This suggests that the learners in this study were able to be multimodal in respect of their learning styles. In addition to individual learning, the successful learners implemented reading/writing with their associated study strategies (i.e., reading on the internet for additional note-taking, completing previous examination papers, and reading their textbooks, notes and study guides) when preparing for tests and examinations. This makes sense, as writing is extensively used to practice calculations. In class, learners therefore also required the teachers to use a variety of teaching methods that accommodated a reading/writing style in order to hold their attention and encourage learning. The afore-mentioned finding is important for teachers in all developing countries who need to improve learner achievement in Mathematics so as to promote access to knowledge and skills which would facilitate economic development.

The learners require the patient, friendly and constructive support of the teachers in the Mathematics classroom. The comments and criticism of the teachers can significantly impact on the learners' self-concepts in Mathematics, thereby influencing their achievement, as found in a study which compared American and Japanese learners in this regard (Yoshino, 2012). The importance of a supportive environment has also been pointed out in a study which reported on the anxiety of rural secondary school learners in the Free State in respect of Mathematics, and which inhibited their confidence, motivation, and achievement (Hlalele, 2012). The researcher consequently recommended that the teachers create "inviting academic settings" (Hlalele, 2012:275). Mathematics teachers ought to be knowledgeable, supportive and patient, and build the self-concepts of the learners in order to strengthen their belief that they have the ability to learn individually at home. Some teachers at the relevant school may lack Mathematics content knowledge to teach effectively. When the teachers' content knowledge is improved, it significantly enhances the learners' achievement, as a study with Grade 10 learners from five schools in Johannesburg has shown (Pournara et al., 2015).

Conclusion

This study focused on Mathematics as a key subject at school in countries with emerging economies. Even though various factors may affect Mathematics achievement, this study concentrated on learning style. The study is limited by the fact that it relied heavily on a self-completion instrument. As such, it is seen as exploratory, and follow-up investigations could consider the inclusion of observation during test preparation for Mathematics tests or examination. In addition, further studies to explore the impact of demographic variables on learning style and achievement in Mathematics are recommended. However, the results of this study are valuable for determining the relationship between learning style preferences and Mathematics achievement of a group of secondary school learners, and for offering several pointers for more effective classroom teaching of Mathematics.

The first important result was that individual learning correlated the best with achievement in Mathematics. Such learning is crucial to allow self-study at home. However, group learning in class, with the support of a knowledgeable teacher and peers, is vital to enable struggling learners to acquire the necessary skills to learn individually. The top-achievers also benefitted from group-learning at school. Secondly, there were significant positive inter-correlations between visual, auditory, kinaesthetic and group-learning, implying that the learners could implement more than one learning style effectively. This was confirmed by the fact that the top-achievers in Mathematics were multi-modal, thereby highlighting the value of multimodal teaching methods.

A positive learning environment in the Mathematics class is important, with competent teachers who are helpful and empathetic. To support visual and kinaesthetic learning styles, teachers need to be creative in their use of visual media and in ways learners can handle physical objects to benefit their learning. In addition, auditory learners benefit from interaction with patient teachers who give detailed explanations, and who provide them with numerous examples to aid mathematical insight. Multi-modal teaching could contribute significantly to enable learners to study individually at home, thereby increasing their study time.

The afore-mentioned implies that Mathematics teachers require insight into the content, pedagogics, and appropriate teaching methods which consider learning styles. To this end, further training of teachers may be required. These suggestions are particularly important for the teachers in developing countries, where Mathematics can play a role to transform societies.

Notes

ii. This article is based on the doctoral thesis of Anne Bosman.

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