Thinking styles of Mathematics and Mathematical Literacy learners: Implications for subject choice

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In this article I report on research intended to characterise and compare the thinking styles of Grade 10 learners studying Mathematics and those studying Mathematical Literacy in eight schools in the Gauteng West district in South Africa, so as to develop guidelines as to what contributes to their subject choice of either Mathematics or Mathematical Literacy in Grade 10. Both a qualitative and a quantitative design were used with three data collection methods, namely document analysis, interviews and questionnaires. Sixteen teachers participated in one-to-one interviews and 1046 Grade 10 learners completed questionnaires. The findings indicated the characteristics of learners selecting Mathematics and those selecting Mathematical Literacy as a subject and identified differences between the thinking styles of these learners. Both learners and teachers should be more aware of thinking styles in order that the learners are able to make the right subject choice. This article adds to research on the transition of Mathematics learners in the General Education and Training band to Mathematics and Mathematical Literacy in the Further Education and Training band in South Africa.

Introduction and background

This article focuses on the characterisation of the thinking styles of Grade 10 Mathematics and Mathematical Literacy learners in eight schools in Gauteng West, South Africa. Since 2006, learners have had the choice to study either Mathematics or Mathematical Literacy in Grades 10–12 (Department of Education [DOE], 2003a).

A subject is defined as 'a specific body of academic knowledge' where 'knowledge integrates theory, skills and values' (DOE, 2003c, p. 6). In this article I refer to a subject as a particular area of study that schools offer, for example Accounting, English, Mathematics or Mathematical Literacy.

Learners study Mathematics from Grade 4 to Grade 9; Mathematical Literacy is a new subject which can only be studied in Grade 10 to Grade 12. Initially, parents and teachers guide learners in their subject choices, based on factors such as future career, language, socio-economic background, interests and achievements in the lower grades (Spangenberg, 2008). However, in the higher grades, learners' own thinking styles influence their preference for the different subjects (Borromeo Ferri, 2004).

Research reveals that thinking styles play an important role in teaching and learning (Borromeo Ferri, 2004; Cilliers & Sternberg, 2001; Grigorenko & Sternberg, 1997; Moutsios-Rentzos & Simpson, 2010; Sternberg, 1990; Sternberg & Wagner, 1992a; Zhang, 2006). In particular, Sternberg and Grigorenko (1993) found that certain thinking styles correlated positively to a learner's success in a variety of academic tasks, whereas other thinking styles tended to correlate negatively to success in the same tasks. Van der Walt (2008) also noted that a learner's thinking style is a factor that influences the effective learning and teaching of mathematics and could predict achievement of mathematics in school. Therefore, I argue that learners' thinking styles could affect their choice to study either Mathematics or Mathematical Literacy. By establishing which thinking style is associated with learners in each of the two subjects, one should be able to guide them, their parents and teachers in making more informed decisions with regard to the choice between Mathematics or Mathematical Literacy as a subject.

A study that characterises and compares the thinking styles of Grade 10 learners taking Mathematics and those taking Mathematical Literacy is new to South Africa, although there have been investigations into thinking styles at both teacher and learner levels (Cilliers & Sternberg, 2001, De Boer & Bothma, 2003). In addition, Moutsios-Rentzos and Simpson (2010) conducted a study in Greece on the thinking styles of university students, Zhang (2006) asked 'Does student–teacher thinking style match/mismatch matter in students' achievement?' in Hong Kong, and Borromeo Ferri (2004) conducted an empirical study on mathematical thinking styles of 15–16-year-old learners in Germany. All these researchers referred to the thinking styles inventory of Sternberg and Wagner (1992b); I too have used the precepts of Sternberg's theory in order to characterise and compare the thinking styles of learners taking Mathematics and those taking Mathematical Literacy in South Africa. This article reports on part of a broader study that I had previously conducted on the placement of Grade 10 learners to provide advice for learners, parents and teachers in terms of choosing between Mathematics and Mathematical Literacy (Spangenberg, 2008).

The question arising from the above discussion is: Which thinking styles are associated with learners taking Mathematics and those taking Mathematical Literacy? Hence, I conducted a literature inquiry with regard to the thinking styles and the nature of Mathematics and Mathematical Literacy.

Thinking styles

A style is a particular procedure or manner by which something is done or a specific way or tendency unique to a person (Soanes, 2002). In particular, Zhang and Sternberg (2000) define a thinking style as 'a source of individual differences in academic performance that are related not to abilities but how people prefer to use their abilities' (p. 469). Whereas a learning style refers to a way of approach to learning (Kolb, Boyatzis & Mainemelis, 1999), a thinking style refers to a particular act, idea, tendency or way of thinking about the execution of a task in the learning process (Sternberg, 1994). Thus, a learning style is how a learner receives information, whilst a thinking style is how a learner processes information and reflects on ideas in their mind. For Cilliers and Sternberg (2001, p. 14) a thinking style is a 'preference' for using abilities in certain ways during processing.

The theoretical basis for this study is based on Sternberg's theory of mental self-management. Sternberg and Wagner (1992b) developed a thinking style inventory consisting of 13 thinking style dimensions divided into five categories, namely functions, forms, levels, scopes and learning (Sternberg, 1990).

Functions refer to the 'basic types of thinking styles', including legislative (preference for creativity), judicial (preference for judging) and executive (preference for implementing rules and instructions) thinking styles. *Forms* are 'general ways' in which learners 'approach their environments and the problems the environment presents' including hierarchic (preference for having multiple prioritised objectives), anarchic (preference for flexibility), monarchic (preference for focusing on only one goal) and oligarchic (preference for having multiple equally important targets) thinking styles. *Levels* refer to the 'amount of engagement individuals prefer in a given activity' including local (preference for details and the concrete) and global (preference for general and the abstract) thinking styles. *Scopes* are 'stylistic variables which divide learners into two basic personality types, including internal (preference for working alone) or external (preference for working in a group) thinking styles. Finally, *learning* explains 'the methods and rules by which learners solve problems' including liberal (preference for novelty and originality) and conservative (preference for conformity) thinking styles (Richmond, Krank & Cummings, 2006, p. 59). Each of these thinking styles has its own characteristics, as represented in Table 1.

Sternberg (1990, p. 368) noted that a teacher may not appreciate a learner's ability and may view him or her as 'slow' or 'behind' because of a difference in thinking style between the learner and the teacher. Conversely, Van der Walt (2008) argued that learners' thinking styles may contribute to their inability to solve mathematical problems, even though they have the necessary knowledge. However, research conducted by Sternberg (Grigorenko & Sternberg, 1988, 1997; Sternberg, 1990, 1994, 1997) has revealed that teaching and learning can improve if teachers give more attention to thinking styles. Both learners and teachers bring their own individual characteristics and thinking styles to the learning environment (Zhu, 2011). These thinking style preferences lead to learning style preferences and in turn determine learners' dominant cognitive modes, that is, the ways in which they communicate and receive information. More specifically, 'cognitive functions are accommodated when teaching activities are constructed to comply with a learner's preferred mode of thinking' (De Boer & Bothma, 2003, p. 1).

TABLE 1: Thinking style dimensions.

Category	Style	Characteristic
Functions	Legislative	Likes to create, discover, design; does things using own method; less structure.
	Executive	Likes to follow instructions; does what is requested; structure must be given.
	Judicial	Likes to criticise and evaluate people and things.
Forms	Monarchic	Likes to do one thing at a time; spends almost all the energy and resources on it.
	Hierarchic	Likes to do many things at once; prioritises what and when to do a thing and how much time and energy to spend on it.
	Oligarchic	Likes to do many things at once, but experiences problems with prioritising.
	Anarchic	Likes to follow an extraordinary approach to problems; hates systems, guidelines and any restrictions.
Levels	Global	Likes to work with the bigger picture, generalisations and abstracts.
	Local	Likes to work with detail, specifications and concrete examples.
Scopes	Internal	Likes to work alone; focuses on the inside and is independent.
	External	Likes to work with other people; focuses on the outside and is interdependent.
Learning	Liberal	Likes to do things in a new manner and deviates from traditions.
	Conservative	Likes to do things in a proven and real manner and follows traditions.

Source: Adapted from Sternberg, R.J. (1994). Allowing for thinking styles. *Educational Leadership, 52*(3), 36–40

The nature of Mathematics and Mathematical Literacy

In South Africa, Mathematics and Mathematical Literacy relate to each other, but differ in terms of their nature and aims. In particular, Mathematics 'enables creative and logical reasoning about problems in Mathematics itself', which 'leads to theories of abstract relations' (DOE, 2003c, p. 9). On the other hand, Mathematical Literacy equips and sensitises learners with an understanding of the relevance of mathematics in real-life situations (DOE, 2003b, p. 9). Its purpose is to apply mathematics to make sense of the world. Mathematical Literacy was specifically introduced as an intervention to improve numeracy skills of South African citizens in response to poor performance in mathematics in the past (Bansilal, Mkhwanazi & Mahlabela, 2012).

Learners who can think in terms of 'symbolic representation or abstract conceptualization – thinking about, analyzing, or systematically planning' and in terms of the concrete reality, including mathematical modelling and more applied mathematics, should achieve in Mathematics, whereas learners who can only think 'through experiencing the concrete, tangible, felt qualities of the world, relying on our senses and immersing ourselves in concrete reality', and not in terms of abstraction, should achieve in Mathematical Literacy (Kolb, Boyatzis & Mainemelis, 1999, p. 3). Moreover, the Grade 10–12 Mathematics syllabus, as set out in the National Curriculum Statement (DOE, 2003c) is a purely academic subject which focuses more on content that the learners have to deal with, memorise and reflect on, as opposed to Mathematical Literacy which is a practical subject where learners learn practical skills that will enable them to find concrete solutions to numeric, spatial and statistical problems associated with the everyday challenges of life. In Mathematics attention has to be paid to specific details and, as Bohlmann and Pretorius (2008, p. 43) claim, 'the conceptual complexity and problem-solving nature of Mathematics make extensive demands on the reasoning, interpretive and strategic skills of learners.' Mathematics is an abstract, deductive discipline that is required in the scientific, technological and engineering world. According to Venkat (2007):

> Emphasis is laid on abstract rather than concrete concepts, on intra-mathematical connections rather than mathematics-real-world connections, on rigour and logic rather than interpretation and critique, and on knowledge itself, as well as applications of knowledge. (p. 77)

In comparison to Mathematics, which is more abstract in nature, most definitions of Mathematical Literacy focus on the concrete dimension of mathematics with the context determining the content to be learned. Learners use real-life situations to gain new knowledge; thus, a learner who tends to process information in a concrete way should achieve in Mathematical Literacy. Gal (2009) pointed out that Mathematical Literacy focuses on the relevance of learned knowledge to everyday life and linked it to diverse real-world contexts, whilst Frith and Prince (2006) stated that people are mathematically literate if they have the ability to express quantitative information in a verbal and visual form. Mathematical Literacy creates a consciousness about the role of mathematics in the modern world and is therefore driven by practical applications. The subject develops the ability and confidence of learners to think numerically in order to interpret daily situations (DOE, 2003b).

According to Zhang (2002, p. 179) 'students who reasoned at a higher cognitive developmental level tended to use a wider range of thinking styles than students who reasoned at a lower cognitive developmental level'. Therefore, learners taking Mathematics, which focuses on 'creative and logical reasoning' (DOE, 2003c, p. 9), likely utilise different styles of thinking when reasoning than learners taking Mathematical Literacy. Ideally, Mathematical Literacy learners should be able to reason by communicating, either verbally or in written form, because Mathematical Literacy uses everyday language for 'practical relevance and applications', which may be easier for learners to understand, whereas Mathematics uses highly technical mathematical language for 'further math learning' (Graven & Venkat, 2007, p. 69). In particular, Venkat, Graven, Lampen, Nalube and Chitera (2009) noted that Mathematical Literacy promotes 'thinking as communication' which 'consists of acts such as asking questions, hypothesizing, finding counter-arguments and drawing conditional conclusions within a situation' (p. 48). In contrast, Mathematics learners should use higher levels of visual-spatial reasoning and abstract thinking. Hence, to achieve in Mathematics, the 'use of symbols and notations' and 'mental processes that enhance logical and critical thinking, accuracy and problem solving' and 'mathematical problem solving' (Department of Basic Education [DBE], 2011b, p. 8) should be emphasised as the content is in an abstract and generalisable form.

Mathematics deals with concepts as ideas or abstractions which learners have to bring together to solve a mathematical problem to enable them 'to understand the world' (DBE, 2011b, p. 8). In contrast, Mathematical Literacy deals with 'making sense of real-life contexts and scenarios' and 'mathematical content should not be taught in the absence of context' (DBE, 2011a, p. 8). Table 2 presents the differences between Grade 10 Mathematics and Grade 10 Mathematical Literacy with regard to the content as prescribed by the National Curriculum Statement (DOE, 2003b, 2003c).

Due to the differences in the natures of Mathematics and Mathematical Literacy, it is expected that learners require different thinking styles to achieve in these subjects. The identification of the different thinking styles will contribute towards informing teachers, parents and learners, in an objective manner, about the choice of either Mathematics or Mathematical Literacy as a subject.

Research design

The research question is intended to characterise and to compare the thinking styles of learners taking Mathematics and of learners taking Mathematical Literacy. As noted

TABLE 2: Differences in content between Grade 10 Mathematics and Mathematical Literacy.

Grade 10 Mathematics	Grade 10 Mathematical Literacy
Number and number relationships: • convert between terminating or recurring decimals • fluctuating foreign exchange rates.	Number and operations in context: • percentage • ratio • direct and inverse proportion • scientific notation.
Functions and algebra: • graphs to make and test conjectures and to generalise the effects of the parameters a and q on the graphs • algebraic fractions with monomial denominators • linear inequalities in one variable • linear equations in two variables simultaneously.	Functional relationships: • numerical data and formula in a variety of real-life situations, in order to establish relationships between variables by finding the dependent variable and the independent variable.
Space, shape and measurement: • volume and surface area of cylinders • co-ordinate geometry • the trigonometric functions sin ϑ, cos ϑ and tan ϑ; and solve problems in two dimensions by using the trigonometric functions in right-angled triangles.	Space, shape and measurement: • international time zones • circles • draw and interpret scale drawings of plans to represent and identify views.
Data handling and probability: • measures of dispersion (range, percentiles, quartiles, interquartile and semi-interquartile range) • frequency polygons • Venn diagrams.	Data handling: • investigate situations in own life by formulating questions on issues such as those related to social, environmental and political factors, people's opinions, human rights and inclusivity • collect or find data by appropriate methods (e.g. interviews, questionnaires, the use of databases) suited to the purpose of drawing conclusions to the questions • representative samples from populations.

above, learners' thinking styles can influence their subject choices. The lack of guidelines from the DOE with regard to the placement of Grade 10 learners in either Mathematics or Mathematical Literacy convinced me to research for a practical solution to guide learners, parents and teachers to make informed subject choices and, thus, to adopt a pragmatic philosophy that is concerned with 'what works' and 'what provides solutions' in an authentic situation (Creswell, 2003, p. 11). I utilised both quantitative and qualitative techniques in the study because a combination of the two techniques provides a more in-depth knowledge of the theory and practice (Creswell, 2003).

Purpose of the study

The purpose of this article is to establish which thinking styles are associated with learners studying either Mathematics or Mathematical Literacy, so as to develop guidelines that will contribute to the subject choice of either Mathematics or Mathematical Literacy by Grade 10 learners, and eventually to better performance in the two subjects. I established teachers' perceptions regarding the differences in thinking styles between learners selecting Mathematics and those selecting Mathematical Literacy as a subject through a qualitative technique whilst I compared the thinking styles of learners quantitatively.

The following research questions were addressed in the qualitative approach:

- Which thinking styles of learners are you using to advise learners on their choice between Mathematics and Mathematical Literacy?
- Which characteristics would you attribute to learners who have chosen Mathematics?
- Which characteristics would you attribute to learners who have chosen Mathematical Literacy?

In order to compare the thinking styles of Grade 10 learners taking Mathematics and those taking Mathematical Literacy, the following hypothesis was interrogated in the quantitative approach:

- There are significant differences between a learner's thinking style dimensions and the subject they choose, either Mathematics or Mathematical Literacy.

Research methods and procedures

Sample

A convenience stratified sampling technique (Creswell, 2003) was used to select teachers and learners from secondary schools in a single district in South Africa, namely Gauteng West. The area was chosen because I worked in the area and had easy access to schools. Before sampling, the population of 32 secondary schools in the district was divided into types: there were nine Afrikaans-medium suburban schools, three English-medium suburban schools, three rural schools and 17 township schools, all of which were heterogeneous in respect of learners studying Mathematics and Mathematical Literacy. Thereafter, the population was sampled within each stratum; I chose eight schools: two Afrikaans-medium suburban schools, one English-medium suburban school, one rural school and four township schools. These schools were selected to ensure that all types of school in the district were represented proportionally and because I had good working relations with them. The sample also included eight Mathematics teachers and eight Mathematical Literacy teachers, one teacher from each subject (Mathematics and Mathematical Literacy) from each participating school. The teachers were selected on a voluntary basis and they granted me the right to interview them. All the Grade 10 Mathematics and Mathematical Literacy learners from each selected school were included in the sample, a total of 1046 Grade 10 learners. Moreover, I could only utilise a naturally formed group, namely learners in a classroom setup, for this research, which justifies a convenience sample (Creswell, 2003, p. 162).

The 16 teachers who were interviewed were selected on the basis that they had at least one year's teaching experience in Grade 10 Mathematics and/or Mathematical Literacy, thus ensuring that they had the necessary knowledge and experience to teach these subjects. The teachers differed in age and both men and women were included in the sample. The teachers participated on a voluntary basis.

In terms of the quantitative phase of the study, 1046 learners completed the questionnaire on thinking style dimensions, indicating their choice of either Mathematics or Mathematical Literacy. Of these, 56.2% (588) selected Mathematics.

Data collection: Document analysis, interviews and questionnaires

Both a qualitative and a quantitative design were used to collect the data through document analysis, interviews and questionnaires (Creswell, 2003). Document analysis of the content for Grade 10 Mathematics in comparison with the content for Grade 10 Mathematical Literacy, as prescribed by the National Curriculum Statements of South Africa, was conducted to establish whether different thinking styles would be demanded in Mathematics and Mathematical Literacy. This document analysis was used to supplement the data obtained from the other methods (Bell, 1995). Unfortunately, access to learners' written work and assessment documents was denied due to the integrated quality management system at the schools.

I followed a qualitative approach during the first phase of the research by conducting one-to-one interviews with teachers through a semi-structured questionnaire (see Appendix 1). The aim was to ascertain their perceptions regarding the characteristics and differences in thinking styles between learners selecting Mathematics and those selecting Mathematical Literacy as a subject.

During the second phase of the research, I used a quantitative research method: a survey (structured questionnaires) amongst learners. The aim of this phase was to compare thinking styles of a Mathematics learner compared to those of a Mathematical Literacy learner.

The questionnaire (see Appendix 2) was based on an existing standardised instrument, the thinking style inventory of Sternberg and Wagner (1992b), which aimed to determine the different strategies used by learners to solve problems, execute tasks or projects and make decisions. The questionnaire consisted of 13 thinking style dimensions divided into five categories. For each characteristic (e.g. self-management function: legislative) there were eight questions on a 1–7 point Likert scale, with 1 = *Not at all well* and 7 = *Extremely well*. Thus, for 13 thinking style dimensions, there were 104 questions. Scores were then averaged over each characteristic. The characteristic associated with each of these appears in Table 1 (Sternberg, 1994).

Data analyses

Tesch's protocol of data analysis (Creswell, 1994) was used to analyse the data from the interviews for the qualitative inquiry. Firstly, each interview was audio recorded and transcribed. Secondly, the transcriptions were read to obtain a holistic perspective, after which relevant answers were separated from irrelevant answers. Thereafter, Saldana's (2009) method of coding was used. According to this method, coding is a 'heuristic exploratory problem-solving technique without specific formulas to follow' (Saldana, 2009, p. 8) where a code in qualitative inquiry refers to a 'word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data' (p. 3). After coding was applied to the data, codes sharing the same characteristics were grouped into sub-themes. Similar sub-themes were then grouped together to form concepts or themes (Saldana, 2009). Table 3 summarises the themes, sub-themes and codes emerging from the data qualitative analysis.

TABLE 3: Themes, sub-themes and codes.

Theme	Sub-theme	Codes
Characteristics of a Mathematics learner and a Mathematical Literacy learner	Mathematics learner	Interest, motivation and perseverance
		Hard-working, sense of duty, reliable and punctual
		Logical and critical thinker
		Basic knowledge and insight
		Can focus and concentrate
		Independent and self-discipline
		Cannot function in a group
	Mathematical Literacy learner	Good general knowledge and social skills
		Enjoy reading and research
		Entrepreneurial skills
		Poor self-image and short attention focus
		Lack of basic knowledge and cannot comprehend
		Lack of perseverance, undisciplined, non-participation and no interest in Mathematics
		Unorganised, untidy and not reliable

The Statistical Package for the Social Sciences, edition 15 (SPSS 15) was used in collaboration with the Statistical Consultation Service at the university concerned, to conduct the quantitative data analyses. The quantitative data analysis included univariate descriptive measures, namely frequencies and percentages and cross-tabulations of the categorical variables and descriptive statistics of the scale variables (specifically the thinking style dimensions). Inferential statistics, namely independent sample t-tests (for the scales variables) and chi-squared tests of independence (for the categorical variables), were used in order to identify significant differences between the thinking styles of learners taking Mathematics and those taking Mathematical Literacy. A significance level of 0.05 was assumed throughout. The internal reliability of each of the thinking style dimensions was determined by the Cronbach α coefficient.

To analyse the research question, descriptive statistics for each of the group variables (the independent variable being Mathematics or Mathematical Literacy and the dependent variable thinking style) were used. For the purposes of classifying participants into thinking style categories, each participant's highest score for a given category was chosen to represent the category. For example, if a learner's scores on the 7-point Likert scale on average were for Legislative = 3.2, Judicial = 6.2 and Executive = 4.7, they would be categorised as judicial thinkers. This process was performed on all five thinking style categories.

Ethical considerations

The ethical committee of the education department at the university concerned granted ethical clearance for the study and permission was obtained from the Gauteng DOE, Gauteng West district and the schools in Gauteng West to conduct the research.

All the participants' contributions were recognised by proper referencing. The rights and interests of the participants were protected and sensitivity was shown towards them based on common trust (Mouton, 2001). Furthermore, all information supplied was treated with confidentiality and the outcomes of the research made available on request. Tape recordings and data were kept under lock and key and were destroyed after completion of the research study.

Sternberg granted permission for the usage of the thinking style inventory of Sternberg and Wagner (1992b) and the intellectual property rights were recognised. Furthermore, data obtained was personally analysed by means of statistical verified methods and procedures (Eiselen, 2006).

Reliability

The questionnaires were shown to colleagues for comments and responses, to ensure that the constructs were clearly conceptualised. Consequently, the questionnaires were amended with regard to timeframes, language, terminology, readability and clarity and piloted with one class group of 30 learners at a school that was not part of the sample before they were administered to the eight schools in the sample. The purpose was to ensure coherency and consistency of the questions. The questionnaires were administered under examination conditions.

The internal reliability of each thinking style dimension was determined by using the Cronbach α coefficient, after which descriptive statistics, namely averages and standard deviations, of each dimension were used. The Cronbach α coefficient is recommended for large samples where items are not scored right or wrong and was thus suitable for this study of 1046 learners. A score of 0.7 and higher was assumed as reliable for this study. The internal consistency of the five thinking style categories is presented in Table 4.

TABLE 4: Internal reliability of the thinking styles dimensions.

Category	Style	No. of items	Cronbach α
Functions	Legislative	8	0.736
	Executive	8	0.786
	Judicial	8	0.672
Forms	Monarchic	8	0.787
	Hierarchic	8	0.780
	Oligarchic	8	0.596
	Anarchic	8	0.675
Scope	Global	8	0.617
	Local	7	0.695
Levels	Internal	8	0.666
	External	8	0.767
Learning	Liberal	8	0.739
	Conservative	8	0.684

Some of the items on the original thinking style inventory could be ignored, namely the judicial, oligarchic, anarchic, global, local, internal and conservative thinking styles, because of the findings from the reliability analyses. However, due to the standardisation of the instrument, no item was deleted and the dimensions, as identified by Sternberg and Wagner (1992b), were calculated.

Validity

The characteristics and differences of the thinking styles of the Mathematics and Mathematical Literacy learners were measured by means of the thinking style inventory of Sternberg and Wagner (1992b), which is an existing standardised instrument that had already complied with all validity aspects. Therefore, no items were omitted and the dimensions as identified by Sternberg and Wagner were calculated.

Main findings

Findings from the document analysis

The basic principles of numeracy laid out in the General Education band develop in Grade 10 Mathematics, using more symbolic methods, such as numeric sequences and series (DOE, 2003c). In comparison, Grade 10 Mathematical Literacy does not include number systems, numeric or geometric patterns, but focuses on using numbers within contexts relevant to daily life, such as profits and losses, budgets, loans, commission and banking (DOE, 2003b). Furthermore, Grade 10 Mathematics includes mathematical modelling, linear, exponential and quadratic equations, linear inequalities, products and factorisation, trigonometry, coordinate geometry and Euclidean geometry, which do not appear in the Grade 10 Mathematical Literacy curriculum (DOE, 2003c), as displayed in Table 2.

From the above, it is evident that there is more mathematical content in the Grade 10 Mathematics curriculum than in the Grade 10 Mathematical Literacy curriculum. Hence, learners who choose Mathematics are likely to do many things with a 'hierarchic thinking style' (Sternberg, 1990, p. 369).

Mathematics requires that learners be able to think in terms of 'symbolic representation or abstract conceptualization' (Kolb, Boyatzis & Mainemelis, 1999, p. 3). Thus, learners should have a preference to create, discover and design ('legislative thinking style') (Sternberg, 1990, p. 38). This viewpoint is also supported by Bohlmann and Pretorius (2008, p. 43), who claimed that 'the conceptual complexity and problem-solving nature of Mathematics make extensive demands on the reasoning, interpretive and strategic skills of learners'.

Grade 10 Mathematical Literacy focuses more on contexts relevant to daily life. Thus, learners who prefer to work with other people, focus on the outside and are interdependent, with an 'external thinking style' (Sternberg, 1990, p. 38) should rather choose Mathematical Literacy.

Findings from the interviews

From the 16 personal interviews conducted with teachers, I could find no evidence that teachers consider the thinking styles of learners when they advise learners on their choice between Mathematics and Mathematical Literacy. Rather, teachers indicated that they use three other methods. In the following protocols the names of teachers are pseudonyms to protect their identity. All the protocols are from Spangenberg (2008, pp. 229–242).

Firstly, learners' *marks* obtained in Grade 9 are used as an indication of which subject to take. Matle mentioned that he is guided by 'the mark that the learner obtained in Grade 9'. Bana noted that 'if you performing poor in natural sciences you can see that you are not going to do Maths. You are going to do Maths Literacy'.

Samuel added:

> [I]f he gets 60% in Grade 9 and above then basically you are allowed to choose Maths. Anything less than 60% you wouldn't have a choice … That is like a policy in our school at the moment in time. (Spangenberg, 2008, p. 229)

Secondly, *tests* guide teachers when advising learners in their subject choices. Jack stated that 'we give them aptitude test in terms of Mathematics … If he pass … we just place him or her' and Mary alluded to 'some test that they do to test their ability to do Maths as it test their ability to do Maths Lit … we set an internal Maths paper and we use that as a guide'.

Lastly, *subject combination packages* and *future careers* are also indicators of the subjects learners should take. Rosen claimed that 'if a learner chooses a subject package, then the package makes provision for him in a certain direction', adding that for

> the science then we have included the pure maths in that package and if it has accounting we have include the pure maths in the accounting package and in all the other courses whereby the learner has the commerce fields or learning areas we have included the Maths Literacy in that package.

Jack referred to four streams:

> The first steam is for Maths and Science. The second one is Maths and Accounting. The third one is Maths Literacy and Economics. The fourth one is Maths Literacy and History … this learners who are doing Maths Literacy, most of them, they must consider this career opportunities of law, human resources, those that are not attached with Mathematics.

Bana explained that:

> I look at his or her ambitions, whether which career does he or she want to follow. If she wants to be a scientist, then I say okay Maths is good for you. If you want to be a lawyer I say Maths Literacy is good for you.

In addition, Sam argued that 'some of the learners choose it because of the career that they want to go in'.

Teachers could clearly distinguish between the characteristics of each type of learner. From their observations and perceptions, teachers described learners who choose Mathematics, firstly, as being *interested* in the subject. Sam explained that

> it will depend … on the interest of the learner. Maybe if he likes working with numbers, he can choose the Mathematics … but the learners that choose Maths … you see that these learners are interested in the subject.

These learners are perceived as self-disciplined and *diligent.* Santa mentioned that 'the learner must be dedicated', supported by Shisha that 'they tend to be the more conscientious student'. Christine argues further that Mathematics learners are motivated and *focused*. She noted that 'I would choose a learner who's able to focus … to concentrate'.

Zane added that these learners are *hardworking* by commending that 'most of them are quite conscientious workers, enthusiastic workers' and Carmen supported that 'those that choose Mathematics tend to be those that are very hard workers'.

Teachers also described Mathematics learners as having the *ability* to memorise in a *logical* manner. Geoff claimed that

> Mathematics is for the brainy … that there are those that are very intelligent and as a result they need to do Mathematics, because they can think far to their ability and then Mathematical Literacy is like it's made for those who are less able to do Literacy … but those who are very intelligent, they have to do Mathematics.

Shisha add that 'they are able to work logically' and noted that 'they understand theorems and them they are able to apply them immediately'. Lastly, teachers described learners taking Mathematics as independent workers, able to work on their own, thus displaying an 'internal thinking style' (Sternberg, 1990, p. 38). Sam stated that Mathematics learners are 'very independent … they can work on their own … they are very disciplined learners who are taking Maths seriously'.

On the other hand, teachers characterised Mathematical Literacy learners as having good *general knowledge*. Samuel noted that for Mathematical Literacy learners 'the most important thing is the knowledge of the outside environment that they are in'. He further continued that these learners are *socially adaptable*, by arguing that

> how you can be able to adapt in your everyday life and how you adapt in the environment you in … You don't have to be a good academic learner to be a good social person being … you just need to be well equipped to handle everyday experiences, have the grasp or basically knowing what's happening around you and being interesting.

Ilze described Mathematical Literacy learners as *entrepreneurial*, perceiving a Mathematical Literacy learner as 'a child who can stand on his own feet, a child who wants to start his own business'. She further added that these learners have an *interested in life and people*, noting that 'you learn him about the life' and 'more interested in the human being'. Shisha mentioned that Mathematical Literacy learners are able to *express themselves*, thus displaying an 'external thinking style' (Sternberg, 1990, p. 38) by claiming that 'a learner must be open-minded. Usually we're using the open-minded, especially the history learners, because they are used to expressing themselves'. In contrast, however, other teachers described these learners as *lacking discipline*. Hannah perceived a Mathematical Literacy learner as 'a guy who does not have discipline' and Bana added that 'they are not willing to learn. They are not willing to participating in classes'.

Hannah continued to describe a Mathematical Literacy learner as having a *short attention span*, by noting that 'he disappears in class, he loses concentration. He does also not have the ability to concentrate' and Carmen argued that Mathematical Literacy learners *lack an interest* in Mathematics, by stating that Mathematical Literacy learners are 'those that for any reason don't like Mathematics. They haven't enjoyed Mathematics'. Zane agreed that a Mathematical Literacy learner is

> one who just only doesn't want to choose Maths, but he is forced to do something in the Maths field now, because it is compulsory. So, he chooses Maths Literacy.

Lastly, teachers described Mathematical Literacy learners as having a *fear* of Mathematics. Rosen mentioned that 'some learners will choose it because of their fear for pure Maths' and Matle agreed: 'fear … many learners they've got this mentality that Mathematics is a difficult subject … there is a possibility that I will fail.'

It is, however, important to note that the above-mentioned findings were based on teachers' perceptions regarding the characteristics and differences in thinking styles between learners selecting Mathematics and those selecting Mathematical Literacy as a subject. The findings should thus not be generalised to all Grade 10 Mathematics learners or Grade 10 Mathematical Literacy learners.

TABLE 5: Descriptive statistics pertaining to the thinking style dimensions of learners taking Mathematics and Mathematical Literacy.

Category	Thinking style	Mathematics (N = 588)		Mathematical Literacy (N = 460)	
		X	SD	X	SD
Functions	Legislative	5.3095	0.88738	5.0713	0.95301
	Executive	5.1949	0.95755	4.8973	0.98888
	Judicial	4.6395	0.82793	4.4194	0.88665
Forms	Monarchic	4.6256	1.10803	4.6441	0.98406
	Hierarchic	5.1173	0.93658	4.8001	0.95987
	Oligarchic	4.6951	0.85636	4.5975	0.89014
	Anarchic	4.9031	0.88603	4.7869	0.94682
Levels	Global	4.3345	0.86228	4.2997	0.85161
	Local	4.7901	0.87187	4.5342	0.96353
Scopes	Internal	4.7010	0.93962	4.4961	0.98286
	External	4.9173	1.05198	4.8156	1.02982
Learning	Liberal	5.5013	0.94377	4.8691	0.97416
	Conservative	4.4627	0.96726	4.3951	0.97027
	Mean score	4.86092	0.93051	4.66357	0.95244

N, total number of learners; X, precise means.

TABLE 6: The independent sample test of learners taking Mathematics and Mathematical Literacy and their different thinking styles.

Category	Thinking style	t	p	df
Functions	Legislative	4.175	0.000	1046
	Executive	4.921	0.000	1046
	Judicial	4.139	0.000	1046
Forms	Monarchic	-0.267	0.789	1046
	Hierarchic	5.382	0.000	1 046
	Oligarchic	1.799	0.072	1046
	Anarchic	2.044	0.041	1046
Levels	Global	0.651	0.515	1046
	Local	4.501	0.000	1046
Scopes	Internal	3.433	0.001	1046
	External	1.567	0.117	1046
Learning	Liberal	3.058	0.002	1046
	Conservative	1.121	0.262	1046

p, probability value.
Correlation is significant at the 0.05 level.

Findings from questionnaires

Statistical analysis was undertaken to investigate whether differences between learners' thinking style dimensions and which subject they are studying (Mathematics or Mathematical Literacy) were significant. The precise means (X) and standard deviations (SD) pertaining to the thinking style dimensions (dependant variable) of learners taking Mathematics and Mathematical Literacy (independent variable) (according to the questionnaires constructed for this study) are indicated in Table 5.

The findings support the hypothesis about the comparisons between learners' thinking style dimensions and which subject they are studying (Mathematics or Mathematical Literacy). Table 6 shows the value of the test statistics in terms of the null hypothesis (t), the p-value for each case and the degree of freedom (df) where the variances were accepted.

Learners studying Mathematics and those studying Mathematical Literacy differed significantly at a 95% level in terms of eight of the 13 Sternberg thinking style dimensions, namely legislative (p = 0.000 < 0.05), executive (p = 0.000 < 0.05), judicial (p = 0.000 < 0.05), hierarchic (p = 0.000 < 0.05), anarchic (p = 0.043 < 0.05), local (p = 0.000 < 0.05), internal (p = 0.001 < 0.05 and liberal (p = 0.002 < 0.05).

It was found that Mathematics learners (average = 5.1949) are more likely than Mathematical Literacy learners (average = 4.8973) to like following instructions, to do whatever they are told to do and to prefer fixed structures (executive thinking style). Mathematics learners (average = 5.3095) are also more likely than Mathematical Literacy learners (average = 5.0713) to design and do things in their own ways (legislative thinking style). Furthermore, Mathematics learners (average = 4.6395) are also more likely than Mathematical Literacy learners (average = 4.4194) to be critical, in the sense that they like to judge people and to evaluate things (judicial thinking style).

Although the Mathematics learners on average obtained a slightly higher score than the Mathematical Literacy learners in terms of each of the three above styles, it was found that the legislative thinking style (average = 5.3095) on average measured the highest for the Mathematics group, followed by the executive thinking style (average = 5.1949), and lastly by the judicial thinking style (average = 4.6395). Even though these findings appear contradictory, it is important to note that, according to Sternberg (1990), the mind performs each of the legislative, executive and judicial functions, but one of these tends to be more dominant in a person.

In terms of the four forms of cognitive self-management distinguished by Sternberg (1990), namely hierarchic, anarchic, monarchic and oligarchic, the two groups only differed significantly in terms of the first two: Mathematics learners (average = 5.1173) are more likely than Mathematical Literacy learners (average = 4.8001) to do many things at the same time and to set priorities pertaining to what to do, at what time to do it and how much time and energy to spend on it (hierarchic thinking style). In contrast, Mathematical Literacy learners (average = 4.6441) are more likely than Mathematics learners (average = 4.6256) to do one thing at a time and spend almost all their energy and resources on it (monarchic thinking style).

In terms of the two levels of self-management, namely local and global, it was found that Mathematics learners (average = 4.7901) are more likely than Mathematical Literacy learners (average = 4.5342) to find detail, specifications and concrete examples to be important (local thinking style).

As far as the scope of self-management is concerned, described by Sternberg (1990) as being either internal or external, it was found that a Mathematics learner (average = 4.7010) is more likely than a Mathematical Literacy learner (average = 4.4961) to prefer to work alone, to focus inward and to be independent (internal thinking style).

Lastly, in terms of the distinction made by Grigorenko and Sternberg (1997) between two ways of learning, namely liberal and conservative, it was found that a Mathematics learner (average = 5.5013) is more likely than a Mathematical Literacy learner (average = 4.8691) to do things in new ways and to deviate from traditions (liberal thinking style).

The findings did not correspond with those of Sternberg and Grigorenko (1993), who found that the judicial and legislative styles correlated positively to academic achievement, whereas the executive, legislative, oligarchic and liberal styles tended to correlate negatively to academic success. It is, however, important to note that thinking styles are interrelated (Garcia & Hughes, 2000, p. 413). One must take into account that thinking style interrelationship is complex, since it is influenced by many variables, such as education, subject, age and gender (Sternberg & Wagner, 1992a), which should be researched in depth.

Discussion

This study characterised and compared the thinking styles of Grade 10 learners taking Mathematics and those taking Mathematical Literacy. It could not, however, find any evidence that teachers use thinking styles of learners to advise learners on their choice between Mathematics and Mathematical Literacy in the Gauteng West district.

Both the interviews with teachers and the survey of learners revealed differences between the two groups as far as characteristics and thinking styles are concerned. Even though the teachers' reflections on the difference between Mathematics learners' and Mathematical Literacy learners' characteristics suggest broad distinctions, these are not clearly mirrored in the learners' responses. Furthermore, the differences between Mathematics and Mathematical Literacy, as identified from the curriculum analysis, may not directly link to pedagogy and thinking styles. However, learners' thinking styles could be taken into consideration, as a guideline, when advising learners regarding their subject choices.

Both learners and teachers should be more aware of thinking styles if they are to make the right subject choice and thus minimise switching between subjects. If learners understand their thinking styles and how these match either with Mathematics or Mathematical Literacy, they are more likely to select the appropriate subject. Also, the pressure on teachers who have to deal with larger classes due to subject changes later during a year will decrease and they will not have to re-teach subject content to learners which switch subjects.

Based on the findings of this research, further research is required to develop a quantitative instrument to capture the backgrounds and thinking styles of Grade 9 learners to enable schools to provide learners with the necessary information to make an informed choice. In particular, the following information should be included in an instrument of this nature:

- age
- number of times retained in a grade
- perceptions of the quality of tuition they received in Mathematics in the past
- Grade 9 marks in Mathematics
- subject choice in Grades 10–12 (excluding Mathematics of Mathematical Literacy).

The findings also suggest that a shorter edition of the thinking style inventory (Sternberg & Wagner, 1992b) should be used. In particular, only the legislative, executive, judicial, hierarchic, anarchic, local, internal and liberal dimensions of the inventory need to be measured, as this study found differences in these thinking styles between learners taking Mathematics and those taking Mathematical Literacy.

Given the localised nature of this study, namely a single district in a single province in South Africa, the findings obtained should be confirmed through similar studies of this nature in other provinces and districts. In this way, a better understanding of the differences, both cognitive and non-cognitive, between Mathematics learners and Mathematical Literacy learners can be obtained.

The ways in which empirical realities manifest are much more complex than the broad groupings pointed to in the literature and curriculum analysis in this article. Further research in this regard should also be conducted.

Conclusion

The article focused on the characterisation and comparison of thinking styles of learners studying Mathematics and those studying Mathematical Literacy. This was an extract from a broader study on the placement of Grade 10 learners in either subject (Spangenberg, 2008). The aim was to establish which thinking styles are associated with learners studying these subjects, so as to develop guidelines that will contribute to the subject choice of either Mathematics or Mathematical Literacy by Grade 10 learners, and eventually to better performance in the two subjects. It was found that there is a relationship between learners' thinking style dimensions and which subject they are studying. Mathematics learners are more likely than Mathematical Literacy learners to execute instructions, to design and do things in their own way and to be critical. Where Mathematics learners are more likely to do many things at the same time and to set priorities pertaining to what to do, at what time to do it and how much time and energy to spend on it, Mathematical Literacy learners are more likely to do one thing at a time and spend almost all their energy and resources on it. This information about the thinking styles of learners could be used to help place learners more appropriately and possibly reduce the number of learners who make inappropriate choices. Also, this will ease pressure on teachers who have to deal with larger classes due to subject changes later during a year and may have to re-teach subject content. More learners will gain university exemption. In support, Borromeo Ferri (2004, p. 2) argued that thinking styles should 'not be viewed as being unchangeable, but they may change depending on time, environment and life demands'.

In conclusion, now that access to education and the right to learning have been established for most learners in South Africa, the time is ripe to set key priorities for the country's future. There is an urgent need to increase the number of learners with sufficient and well-established mathematical knowledge and skills, and so enable them to progress in the short, medium and long term to higher education, the business world and industry. There is a great demand for teachers in Mathematics and Mathematical Literacy to equip learners with the necessary knowledge and skills.

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Competing interest

I declare that I have no financial or personal relationship(s) which may have inappropriately influenced me in writing this article.

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Appendix starts on next page →

APPENDIX 1

Teachers' interview questions

1. Which criteria do you use to advise a learner in choosing between Mathematics and Mathematical Literacy?
2. Which method(s) or criteria does your school use to place Grade 10 learners in either Mathematics or Mathematical Literacy?

3.1 Which other factors influence the placement of learners in Mathematics or Mathematical Literacy?

3.2 Can you motivate why you made that statement?

4. Which thinking styles of learners do you use to advise learners on their choice between Mathematics and Mathematical Literacy?
5. Which characteristics would you attribute to learners that have chosen Mathematics?
6. Which characteristics would you attribute to learners that have chosen Mathematical Literacy?
7. Is there anything that you wish to add with regard to the placement oflearners in Mathematics or Mathematical Literacy?

APPENDIX 2

Sample of learners' thinking style questionnaire

Circle the number that best describes the way you do things. Use the following code:

		1 *Not at all well*	2 *Not very well*	3 *Slightly well*	4 *Somewhat well*	5 *Well*	6 *Very well*	7 *Extremely well*
1.	When discussing or writing down ideas, I like criticising others' way of doing things.	1	2	3	4	5	6	7
2.	I prefer to deal with specific problems rather than with general questions.	1	2	3	4	5	6	7
3.	I enjoy working on projects that allow me to try novel ways of doing things.	1	2	3	4	5	6	7
4.	When making decisions, I tend to rely on my own ideas and ways of doing things.	1	2	3	4	5	6	7
5.	When discussing or writing down ideas, I follow formal rules of presentation.	1	2	3	4	5	6	7
6.	When talking or writing about ideas, I stick to one main idea.	1	2	3	4	5	6	7
7.	When starting a task, I like to brainstorm ideas with friends or peers.	1	2	3	4	5	6	7
8.	I tend to base my decisions only on concerns important to my group or peers.	1	2	3	4	5	6	7
10.	I like to set priorities for the things I need to do before I start doing them.	1	2	3	4	5	6	7
11.	I like situations or tasks in which I am not concerned with details.	1	2	3	4	5	6	7
17.	I like to control all phases of a project, without having to consult with others.	1	2	3	4	5	6	7
20.	I like to do things in ways that have been used in the past.	1	2	3	4	5	6	7
27.	I stick to standard rules or ways of doing things.	1	2	3	4	5	6	7

Source: Sternberg, R.J., & Wagner, R.K. (1992b). *Thinking styles inventory.* Unpublished test. New Haven, CT: Yale University