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Study orientation in mathematics and thinking preferences of freshmen engineering and science students

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Abstract

This article reports on results gained through action research activities during 2000-2002 at the University of Pretoria. The research involved first year engineering students on an extended five year study programme and first year civil engineering students on a regular four year study programme in the School of Engineering as well as first year science students on an extended study programme in the Faculty of Natural Sciences. The thinking style preferences of these groups of students, taking a first course in calculus, were assessed and the study orientation in mathematics of the engineering students on the extended study programme were determined. Analysis of the thinking style preferences of the students indicates a diversity representing an array of preferences distributed across all four quadrants as measured by the Herrmann Brain Dominance Instrument and differences were found between the thinking style preferences of science students and engineering students. Analysis of data obtained from the Study Orientation Questionnaire in Mathematics Tertiary gives an indication of the expected level of performance of students in a first semester course in calculus. It is envisaged that freshman engineering students on a support course can seemingly benefit from a learning facilitation strategy for mathematics that is aimed at developing the mathematics potential of the learners, fostering awareness of thinking style preferences and improving study orientation in mathematics.

Background

In 1994 the Five Year Study Programme (5YSP) was introduced in the School of Engineering at the University of Pretoria. This programme is structured in such a way that the academic courses of the first two years of the regular four-year study programme in engineering are spread over the first three years of the 5YSP. The purpose of the 5YSP is to create opportunities for students who have the potential to become engineers but who do not meet the entrance requirements for a four year study programme and/or are academically at risk because of their educational background. Students on the 5YSP are given extensive academic support in their first year engineering courses through tutoring by senior students.

In spite of the support through tutoring, some of the students on the 5YSP are academically still at risk of not succeeding at engineering study. Obvious factors that seemingly contribute to the attrition of these students are the varying levels of educational competency and a lack of exposure and access to technology (Du Plessis & Quagraine, 2000). For these students an additional two-module credit-bearing, Professional Orientation Support Course (POSC) is presented during the first year of study. The course comprises a conceptual mathematics component, the development of personal skills, communication skills and skills in information technology. In the first module the main focus is on the mathematics component.

The mathematics component of the POSC is done independently from the main stream calculus course (presented by the mathematics department) and in addition to it. The aim of the mathematics activities in the support course is twofold. This first objective is to ensure that students thoroughly understand two-dimensional functions, their properties and graphs and the second is that students gain insight into their own thinking and learning preferences (regarding mathematics) and their study orientation in mathematics. The first objective is met through a learning facilitation strategy using computer graphing technology to visualise and explore the graphs of two-dimensional functions in an active learning environment (Carr & Steyn 1998; Greybe, Steyn & Carr, 1998). Previous research projects at the University of Pretoria have indicated that these activities endorse individualised instruction as well as co-operative learning and involve extensive communication in mathematics (both oral and written) (Steyn, 1998; Steyn, Carr & De Boer, 1999; Steyn & Maree, 2002).

Learning facilitation principles

One of the main aims of the POSC is the development of each student's mathematical potential in order for him or her to pursue engineering studies successfully. Overall the educational activities in this course are viewed as "contributive learning" (Steyn, 1998) in the sense that faculty and students are participants in a dynamic process in which teaching and learning are improved through the contribution of both faculty and students to each other's learning. This learning is not confined to (mathematical) subject content and can be diverse including aspects of student learning as well as successes and pitfalls of instructional activities.

Whole brain learning facilitation

Students arrive at tertiary institutions with established thinking style preferences and ensuing learning styles that influence all cognitive activities including the conceptualisation of (mathematical) content (Felder, 1993). Lecturers have established ways of thinking and teaching and so teaching styles interact with learning styles to encourage or discourage students' learning depending on a match or mismatch of styles (Felder, 1993). In order to accommodate individual students' diverse thinking style preferences and to encourage the utilisation of their less preferred competencies, the teaching learning strategy in the POSC course can be termed as a "four-quadrant whole brain approach". This approach is based on research which has been ongoing since the 1970s, on the functioning of the human brain, that has indicated that specialised cognitive functions can be associated with different parts of the brain (Gazzaniga, 1998; Jensen, 1996). For approximately 90% of the population logical, analytical, quantitative and fact based knowledge is located in the left brain hemisphere whereas the right brain hemisphere predominantly supports and co-ordinates intuition, emotion, spatial perception and kinaesthetic feelings. For the other 10% of people the location of these functions is transposed.

Herrmann (1995) combined this knowledge with how the brain is physiologically organised in order to develop a four-quadrant whole brain model. Herrmann's model includes the following four modes (Lumsdaine & Lumsdaine, 1995) that describe student learning:

- *External learning* is related to learning through listening (lectures) and reading textbooks, scientific literature, etc.
- *Internal learning* is related to learning through insight, understanding concepts holistically and intuitively, synthesis of data and personalising content into context.
- *Interactive learning* comes from experience, hands-on activities, discussion and feedback.
- *Procedural learning* is characterised by a methodical approach, practice, repetition and testing.

If learning activities (in mathematics) are structured to include different modes of student learning (implying different thinking and learning preferences), a whole brain approach is followed and competence in mastering concepts is fostered. Furthermore, functioning in any professional capacity requires working well in all thinking style modes (Felder, 1996).

Thinking and learning preferences

The thinking preference profiles in Figure 1 are examples from the study reported here. These profiles were determined using the Hermann Brain Dominance Instrument (HBDI) and illustrate the tilt when a strong preference for the thinking mode associated with a specific quadrant is dominant. A preference for the A-quadrant (upper left quadrant as in Figure 1A) means that a person favours activities that involve critical, logical, analytical and fact-based information. Individuals with a B-quadrant preference (lower left quadrant as in Figure 1B) favour organized, planned and detailed information. A preference for the C-quadrant (lower right quadrant as in Figure 1C) indicates favouring information that is interpersonal, feeling based and involves emotion. A preference for the D-quadrant (upper right quadrant as in Figure 1D) is characterised mainly by a visual, holistic and conceptual approach in thinking.

Figure 1 Individual profiles showing thinking preferences according to the HBDI

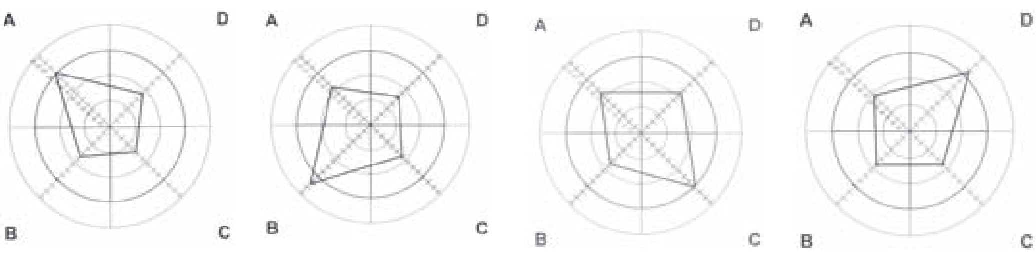


Figure 1A
Profile showing an A-quadrant thinking preference

Figure 1B
Profile showing a B-quadrant thinking preference

Figure 1C
Profile showing a C-quadrant thinking preference

Figure 1D
Profile showing a D-quadrant thinking preference

Active learning

In addition to the four-quadrant whole brain principle, active learning in mathematics is viewed as a further core pedagogical principle in the POSC. In this regard active learning involves activities that engage students in *doing* something instead of only observing what can or should be done.

Research project

The action research activities reported in this article formed part of course activities and the students were never regarded a merely 'research objects'. Therefore references are to 'participating' students.

Aim

During 2000 the Herrmann Brain Dominance Instrument (HBDI) (Herrmann 1995) was used to provide students with insight into their own thinking preferences and to measure the preferred thinking styles of the students. In 2000, 2001 and 2002 the Study Orientation Questionnaire in Mathematics Tertiary (SOMT) (Maree, 1997; Maree, 1999; Steyn 2003) was used to determine the students' study orientation in mathematics and to investigate whether the SOMT is a significant predictor for performance in mathematics.

Null hypotheses

The null hypotheses that were investigated in the study and that are discussed in this article, are the following:

$H_0$1: There is no difference between the arithmetic means of the scores of the students on the POSC and a group of first year civil engineering students on the four-year programme for the quadrants of the HBDI.

$H_0$2: There is no difference between the arithmetic means of the scores of first year engineering students on a support course and first year science students on a support course for the quadrants of the HBDI.

$H_0$3: There is no difference between scores in the different fields of the SOMT and students' marks in mathematics.

Inventories

The HBDI

The HBDI is an assessment tool comprising a survey of 120 questions that quantify relative preference for thinking modes based on the hypothesised task-specialised functioning of the physical brain. A thinking preference profile, compiled from scores on an inventory, is displayed on a four-quadrant grid. The higher a score in a quadrant, the stronger the preference for the thinking style related to that quadrant.

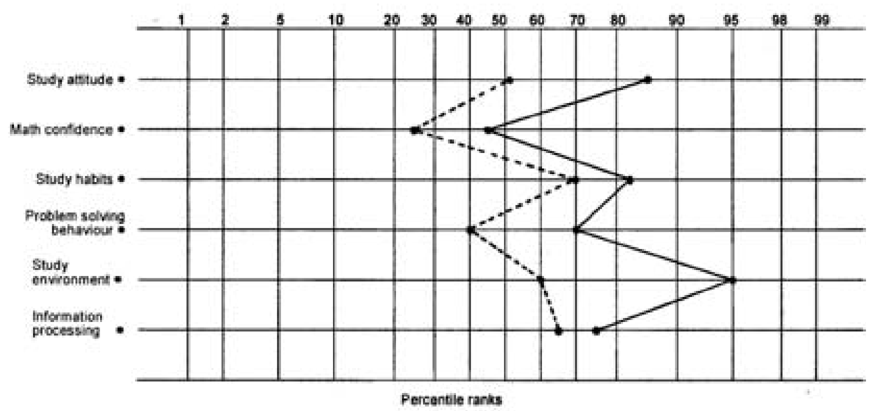
The SOMT

The SOMT comprises six fields including 92 statements that relate to how individuals feel or act regarding aspects of their achievement in mathematics. The six fields of the SOMT can be summarised as follows:

- *Study attitude* (SA) deals with feelings (subjective but also objective experiences) and attitudes towards mathematics that are manifested consistently and that affect students' motivation, expectation and interest with regard to mathematics.
- *Mathematics confidence* (MA) concerns an overall feeling of 'comfort' toward mathematics. An 'uncomfortable' feeling, on the contrary, can be associated with anxiety which manifests itself in insignificant behaviour (like excessive sweating, scrapping of correct answers and an inability to formulate mathematics concepts).
- *Study habits* (SH) addresses the displaying of acquired, consistent and effective study methods.
- *Problem solving behaviour* (PSB) in mathematics includes cognitive and meta-cognitive strategies.
- *Study environment* (SE) includes aspects relating to the social, physical and perceived environment.
- *Information processing* (IP) reflects on general and specific learning, summarising and reading strategies, critical thinking and understanding strategies like the optimal use of sketches, tables and diagrams.

Answers to the SOMT are converted to percentile ranks after which profiles (as in Figure 2) can be drawn. Figure 2 is an example of the results of the SOMT of a student in the study. In this case the profile at course end shows an overall improvement towards a more favourable study orientation compared with the profile at course beginning. Any shift to the right regarding any of the fields of a SOMT profile indicates a more favourable (improved) study orientation in mathematics.

Figure 2 Example of a student's SOMT profile at course beginning and at course end



.... Course beginning _________ Course end

Participants

Of these students, 33 were on the engineering support course, 30 were first year civil engineering students on the four-year programme and 38 were first year science students on a support course in the BSc extended programme in the Faculty of Natural Sciences. The data relating to the HBDI of the latter group were determined in a research project in the Faculty of Sciences during 1999 (De Boer & Steyn, 1999).

The research regarding the students' study orientation in mathematics involved only the students enrolled for the POSC. In 2000 30 completed the SOMT; in 2001 38 completed the SOMT and in 2002 50 students completed the SOMT.

Method

Students did the HBDI towards the second half of the first semester. The SOMT was done four weeks after the start of the academic year. The 2000 students did the SOMT again in the middle of their second year and the 2001 and 2002 groups did it at the start of the second semester in the first year. Feedback explaining the instruments and results in general was given to the students as a group. In addition, results on all the instruments were also given to students individually.

Limitations of the study

This was a limited, local study, and the findings reported in this article have limited generalisation value; they do, however, have naturalistic generalisation value (Cohen, Manion & Morrison, 2000).

Ethical considerations

Written permission for administering the instruments was obtained from the School of Engineering and the Faculty of Natural Sciences. In all cases the use of the instruments as part of course activities was transparent and clearly conveyed to all the students who participated. The research was thus carried out with the full consent of all participants and stakeholders.

Results

In Table 1 the number of students per quadrant of preference according to the HBDI is shown.

Table 1: Number of students with thinking preferences per quadrant

	A	B	C	D
POSC students	17	5	5	6
Civil engineering students	18	3	6	3
Science students	9	18	7	4

In Figure 3 the dominance in distribution of the individual Herrmann Brain Dominance (HBD) profiles of the POSC, civil engineering and science students is shown.

Figure 3: Distribution of HBD profiles for the different groups

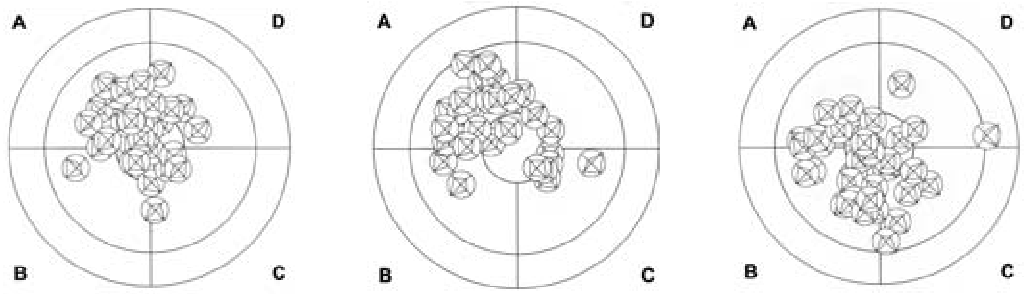


Figure 3A
2000 POSC students

Figure 3
BCivil engineering students

Figure 3C
Science students

The two-sample non-parametric Wilcoxon Rank Sum Test was used to compare the arithmetic mean score values between the different groups for each of the four quadrants of the HBDI. Table 2 shows the arithmetic mean ($\bar{x}$), standard deviation (*s*) and *p*-value regarding the quadrants of the HBDI for the POSC and civil engineering students and Table 3 gives the same data for the engineering students on a support course (POSC students) and science students on a support course.

Table 2: Wilcoxon scores for the POSC and civil engineering students and the quadrants of the HBDI

	POSC group (N=33)		Civil group (N=30)		
HBDI	$\bar{x}$	s	$\bar{x}$	s	p
A-quadrant	82.06	16.89	83.66	20.70	0.5489
B-quadrant	70.45	13.59	76.03	15.25	0.1194
C-quadrant	64.75	17.44	55.03	22.03	0.0200#
D-quadrant	73.06	17.41	76.46	17.59	0.6103

# indicates a p-value that is significant on the 5% level.

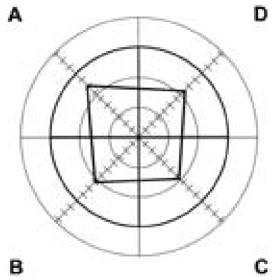
Table 3: Wilcoxon scores for the POSC and science students and the quadrants of the HBDI

	POSC group (N=33)		Sci Students (N=38)		
HBDI	$\bar{x}$	s	$\bar{x}$	s	p
A-quadrant	82.06	16.89	69.78	18.70	0.0066#
B-quadrant	70.45	13.59	83.86	16.68	0.0003#
C-quadrant	64.75	17.44	71.15	21.42	0.1964
D-quadrant	73.06	17.41	63.34	19.99	0.0180#

# indicates a p-value that is significant on the 5% level

Figure 4 illustrates the average HBD profile of the engineering students on the POSC.

Figure 4: Average HBD profile for the 2000 POSC students



Quadrant:	A	B	C	D
Profile score:	82	70	64	74

In Table 4 the results of a step-wise regression analysis taking the fields of the SOMT as independent variables and the performance in the first semester calculus course as dependent variable are shown for the 2000 and 2001 groups.

Table 4 : Step-wise regression model for the SOMT and mathematics performance

SOMT Fields	Parameter estimate	Partial coefficient of determination R^2	Cumulative coefficient of detemintaion R^2	p
2000 POSC group (N=30):				
IP	0.2528	0.3918	0.3918	0.0002*
PSB	0.1428	0.0772	0.4689	0.0579
Regression equation:	34.44 + 0.25 IP + 0.14 PSB			
2001 POSC group (N=38):				
MC	0.2397	0.2515	0.2515	0.0013*
Regression equation:	45.65 + 0.25 MC			
2002 POSC group (N=50):				
SE	0.2256	0.1203	0.1203	0.0146*
IP	-0.1540	0.0605	0.1809	0.0717
Regression equation:	63.14 + 0.23 SE – 0.15 IP			

* Significant at the 5% level

Discussion

Thinking style preferences

Regarding hypothesis $H_0 1$, it follows from Table 2 that in quadrant C, the means for the POSC students differ significantly from the means for the civil engineering students. However, no inference can be made regarding the means for the A-, B- and D-quadrants. Regarding hypothesis $H_0 2$, it follows from Table 3 that in the A-, B- and D-quadrants, the means for the engineering students on the support course (POSC students) differ significantly from the means for the science students on their support course. In this case, no inference can be made regarding the means for the C-quadrant.

The distribution of preferences indicates that in this study the students do not favour C-quadrant thinking, that is, *inter alia*, also associated with a preference for co-operative learning. Furthermore,

Figure 4 illustrates the average HBD profile of the POSC students, which distinctly indicates that the preferences of the group, when combined, result in a profile that almost represents a generic whole brain profile with thinking preferences in all four quadrants (Herrmann, 1995).

Table 1 and the diagrams in Figure 3 show that the majority of engineering students have thinking style preferences associated with the A-quadrant. This is in accordance with research that engineers (engineering students) typically favour A-quadrant thinking (Herrmann, 1995; Lumsdaine & Lumsdaine, 1995). On the other hand, the majority of science students on a support course have thinking preferences associated with the B-quadrant. Existing thinking preferences inevitably influence students' learning preferences (Felder, 1996; Herrmann, 1995; Lumsdaine & Lumsdaine, 1995).

Study orientation in mathematics

Regarding hypothesis $H_0 3$, it follows from Table 4 that most of the fields of the SOMT, although not simultaneously, can be regarded as significant predictors (on the 5% level) of performance in mathematics.

Conclusion

Although research has indicated that peer group learning works well, it appears as if students need to be trained to work in groups and that the classroom should be structured to foster interactivity. It seems as if there is a significant difference in distribution of thinking style preferences for the engineering students on a support course as opposed to science students on a support course, whereas the distribution of thinking style preferences for engineering students is similar. The fact that the preferences of a group, when combined, result in a profile that almost represents a generic whole brain profile with thinking preferences distributed across all four quadrants of the Herrmann model, endorses the necessity to structure learning facilitation of mathematics not only to accommodate different thinking styles, but also to develop less preferred thinking modes.

As far as the SOMT is concerned, the results of the inventory can be used to help students improve their study orientation in mathematics and consequently realise their mathematics potential at a higher level. Students can, *inter alia*, be helped to become acquainted with the basic principles of executive study in mathematics, as well as the important role of study conditions, including motivation and background factors, in academic success.

In summary, it can be stated that the combined use of the above-mentioned instruments with science and engineering students at first year level appears to be a potentially useful strategy to facilitate enhanced development of the mathematics potential of learners.

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