A PROFILE OF FIRST-YEAR STUDENTS' LEARNING PREFERENCES AND STUDY ORIENTATION IN MATHEMATICS

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ABSTRACT

This paper reports on action research activities during 2000-2001, involving first-year engineering students in an extended study programme of the School of Engineering at the University of Pretoria. Students in the participating group were enrolled for a support course aimed at facilitating the fundamental concepts underpinning a study in calculus as well as complementing the development of personal, academic, communication and information skills. The thinking style preferences of three groups of students taking a first course in calculus were assessed and the study orientation in mathematics of the participating group was determined. The possible effects of thinking preferences and study orientation on performance in a first course in calculus were assessed. 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 between the thinking style preferences of science students and engineering students were also found. Analysis of data obtained from the Study Orientation Questionnaire in Mathematics shows that students of the participating group entered tertiary education with mathematics anxiety and a history of inadequate study environments. In this paper it is envisaged that freshman mathematics students can seemingly benefit from a learning facilitation strategy for mathematics that endorses a student-centred and a brain-based approach. Such a strategy is aimed at developing the mathematics potential of the learners, fostering awareness of thinking style preferences and improving study orientation in mathematics.

Keywords

Mathematics education; whole brain learning facilitation; thinking styles; learning styles; study orientation in mathematics.

Background

In 1994 the Five-year Study Programme was introduced in the School of Engineering at the University of Pretoria. This programme extends the minimum four years of engineering study to five years in that the first two years of the Four-year Programme are spread over five years. The purpose of the five-year Programme is to create an opportunity for students who have the potential to become engineers but who are academically at risk because of their educational background. Students involved in the five-year Programme are given extensive academic support in their first year engineering courses through a tutoring system that is administered by the different departments and conducted mainly by senior students.

In spite of this support, some of these students are still at risk on account of the varying levels of educational competency in South African schools. For these students an additional two-semester credit-bearing support course, Professional Orientation (JPO), is presented during the first year of study in the School of Engineering. The course comprises a mathematics component, the development of personal skills, academic skills, skills in information technology, communication skills and writing skills needed for engineering study. In the first semester the main focus is on the mathematics component. The mathematics component of the support course 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 in which computer graphing technology is used to visualize and explore the graphs of two-dimensional functions in an active learning environment (Carr & Steyn 1998; Greybe, Steyn & Carr 1998). Our previous research projects at the University of Pretoria have indicated that these activities endorse individualized instruction as well as co-operative learning and involve extensive communication in mathematics (both orally and written) (Steyn 1998; Steyn, Carr & De Boer 1999; Steyn & Maree 2002).

Teaching and learning facilitation principles

One of the main aims of the mentioned support course (JPO) 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.

Students arrive at tertiary institutions with established thinking style preferences and ensuing learning styles that influence all cognitive activities and consequently also conceptualisation of mathematical content (Felder 1993). Lecturers have established ways of thinking and so teaching styles interact with learning styles to encourage or discourage students 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 JPO course can be regarded as a "four-quadrant whole brain approach". This approach is based on ongoing research since the 1970s on the functioning of the human brain that indicated that specialised cognitive functions could be associated with different parts of the brain. 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. In the case of the other 10% of the people the location of these functions is transposed.

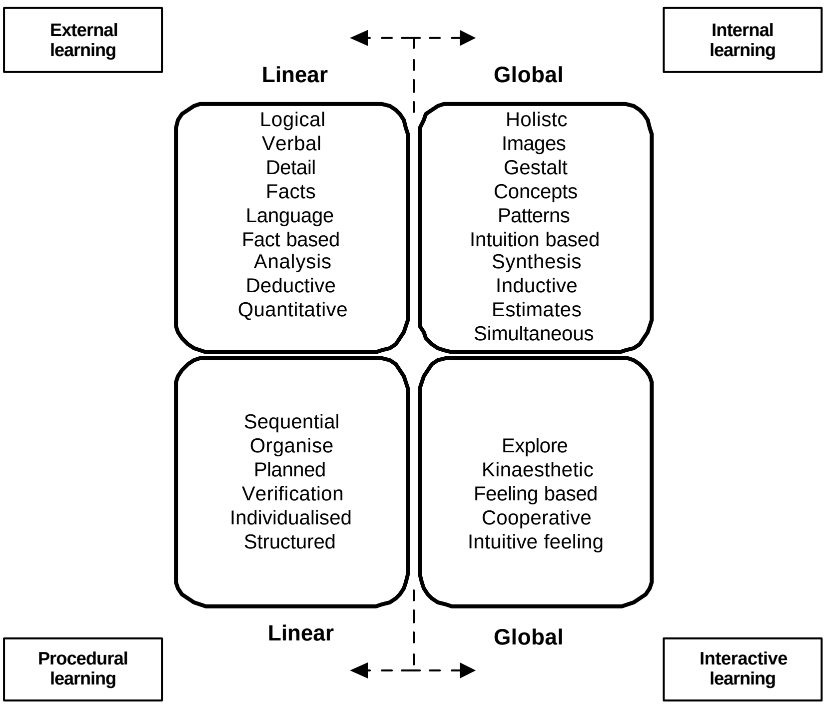
Herrmann's four-quadrant whole brain model

Herrmann (1995) combined this knowledge with how the brain is physiologically organised in order to develop a four-quadrant whole brain model. Figure 1 illustrates an adaptation of Herrmann's model that also includes the following four modes (Lumsdaine & Lumsdaine 1995) that describe student learning:

- *External learning* is related to learning through listening (lectures) and reading of 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).

Figure 1 A four-quadrant whole brain approach to teaching and learning facilitation



The Herrmann Brain Dominance profiles in Figure 2 are examples from the study reported here 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 in Figure 2A) means that a person favours activities that involve critical, logical, analytical and fact-based information. Individuals with a B-quadrant preference (lower left quadrant in Figure 2B) favour organized, planned and detailed information. A preference for the C-quadrant (lower right quadrant in Figure 2C) indicates favouring information that is interpersonal, feeling based and involves emotion. A preference for the D-quadrant (upper right quadrant in Figure 2D) is mainly characterized by a visual, holistic and conceptual approach in thinking.

Figure 2 Individual profiles showing thinking preferences according to the HBDI

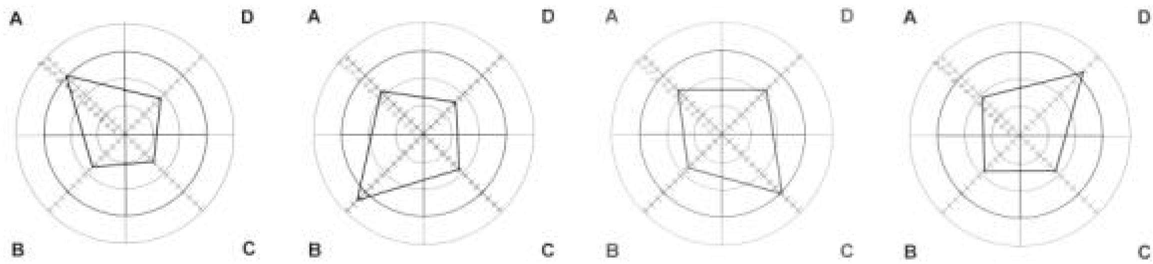


Figure 2A
Profile showing an A-quadrant thinking preference

Figure 2B
Profile showing a B-quadrant thinking preference

Figure 2C
Profile showing a C-quadrant thinking preference

Figure 2D
Profile showing a D-quadrant thinking preference

The diagrams in Figure 2 show the distribution of the individual profiles for each of the groups. The diagrams in Figure 2A and in Figure 2B both illustrate dominance in the distribution of profiles in the upper left A-quadrant. The diagram in Figure 2C illustrates dominance in the distribution of profiles in the lower left B-quadrant.

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

During 2000-2001 this developmental approach, based amongst others, on the principles of whole brain learning facilitation and active learning, was structured as an action research study that included the determining of the students' thinking style preferences and their study orientation in mathematics. In the following sections aspects of the study are discussed

Research project

The action research activities reported in this paper formed part of course activities and the students were never regarded as merely 'research objects'. Therefore references are to 'participating' students and 'other' students where the participating students represent those on the support course (JPO) in the School of Engineering.

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. During 2000 and 2001 the Study Orientation Questionnaire in Mathematics (SOM) (Maree 1997) as well as the Study Orientation Questionnaire in Mathematics Tertiary (SOMT) (Steyn 2002) were used to determine the students' study orientation in mathematics and to investigate whether either of the SOM or SOMT is a significant predictor of performance in mathematics.

Null hypotheses

The null hypotheses that were to be investigated by this study, were the following:

$H_0 1$: There is no difference between the arithmetic means of the scores of the students on the support course (JPO) and a group of first-year civil engineering students participating in 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 SOM and students' marks in mathematics.

$H_0 4$ There is no difference between scores in the different fields of the SOMT and students' marks in mathematics.

Instruments

The HBDI

The HBDI is an assessment tool comprising a survey of 120 questions that quantifies relative preference for thinking modes based on the hypothesized task-specialized 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.

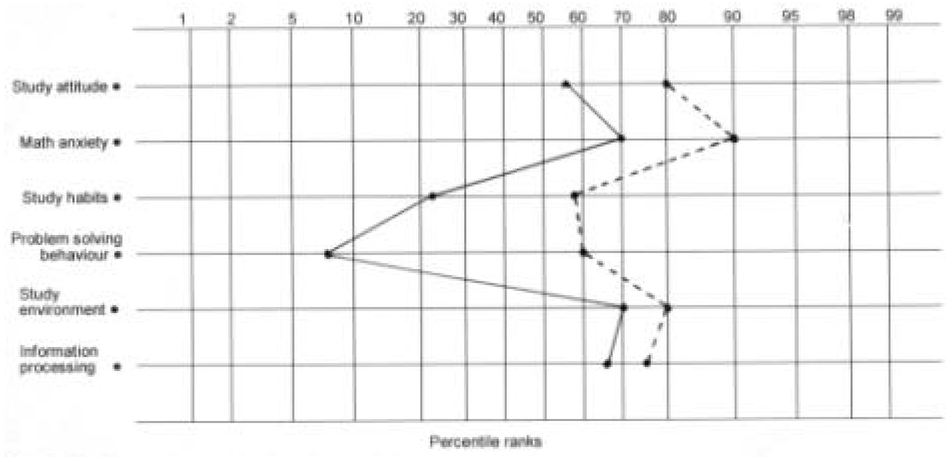
The SOM and the SOMT

The SOM and SOMT both comprise six fields including 92 statements that relate to how individuals feel or act regarding aspects of their achievement in mathematics. The SOM was developed in the mid-1990s for high school students but the scope of the questions is also applicable to first-year tertiary students. In the SOMT the terminology was adapted to represent a tertiary environment. These changes do not affect the scoring of the instrument. The six fields of the SOM and SOMT can be summarized as follows:

- *Study attitude* 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 anxiety* concerns an 'uncomfortable' feeling when such anxiety manifests itself in aimless behaviour (like excessive sweating, scrapping of correct answers and an inability to formulate mathematics concepts).
- *Study habits* addresses the displaying of acquired, consistent and effective study methods.
- *Problem-solving behaviour* in mathematics includes cognitive and meta-cognitive strategies in mathematics.
- *Study environment* includes factors relating to the social, physical and experience environment.
- *Information processing* reflects on general and specific learning, summarizing and reading strategies, critical thinking and understanding strategies such as optimal use of sketches, tables and diagrams.

Answers to the SOM and SOMT can be converted to percentile ranks after which profiles (as in Figure 3) can be drawn. Any shift (regarding any of the fields) to the right indicates a more favourable aspect of a learner's study orientation. Figure 3 is an example of the results of the SOM and SOMT of a student in the study. In this case the SOMT profile shows an overall improvement towards a more favourable study orientation compared with the student's SOM profile. It should be noted that a high percentile rank for 'mathematics anxiety' indicates that a learner is less anxious. For example, the SOM profile in Figure 3 indicates that the learner is less anxious than 70% of the relevant population.

Figure 3 Example of a SOM and a SOMT profile



•—— SOM •- - - - - SOMT

Participants

The research relating to the thinking style preferences using the HBDI involved 101 students. Of these students, 33 were taking 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 Science. The data relating to the HBDI of the latter group were determined in a research project in the Faculty of Science during 1999 (De Boer & Steyn 1999).

The research regarding the students' study orientation in mathematics involved only the students enrolled for the support course (JPO). In the year 2000, 30 students completed the SOM and 26 completed the SOMT. In 2001, 38 students completed the SOM and 24 completed the SOMT.

Method

Students did the HBDI towards the second half of the first semester. In both the 2000 and 2001 studies the SOM was done four weeks after the start of the academic year. The 2000 students did the SOMT in the middle of their second year and the 2001 group did it at the start of the second semester in the first year. Results according to all the instruments were given to the students individually and feedback explaining the instruments and results in general was given to the groups.

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). Furthermore, owing to limited resources, the study was carried out on a small sample of students.

Ethical considerations

Written permission for administering the HBDI, the SOM and SOMT was obtained from the School of Engineering and the Faculty of Science. 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 is given.

Table 1 Number of students with thinking preferences per quadrant

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

In Figure 4 the distribution of thinking style preferences per group is indicated.

Figure 4 Distribution of thinking style preferences per group

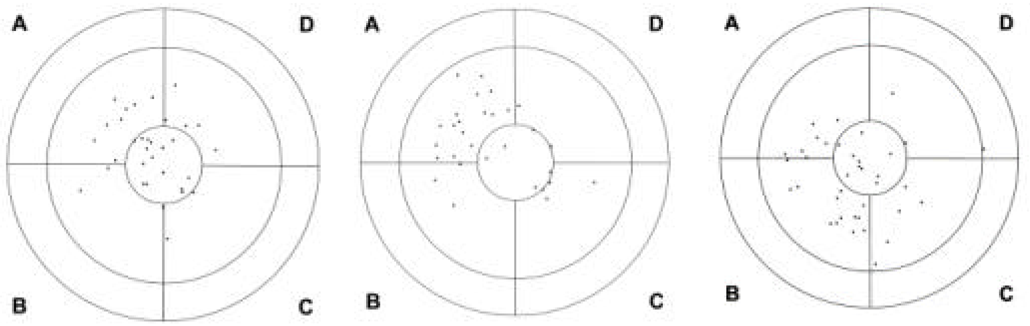


Figure 4A
Dominance map of the distribution of profiles for the JPO students in 2000

Figure 4B
Dominance map of the distribution of profiles for the civil engineering students in 2000

Figure 4C
Dominance map of the distribution of profiles for the science students in 1999

The two-sample non-parametric Wilcoxon Rank Sum Test (normal approximation) 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), Z-value and p-value regarding the quadrants of the HBDI for the JPO and civil engineering students and Table 3 indicates the same data for the engineering students on a support course and science students on a support course.

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

	JPO group (N=33)		**Civil engineering group (N=30)**		
HBDI	Arithmetic mean $\bar{x}$	Standard deviation s	Arithmetic mean $\bar{x}$	Standard deviation 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.

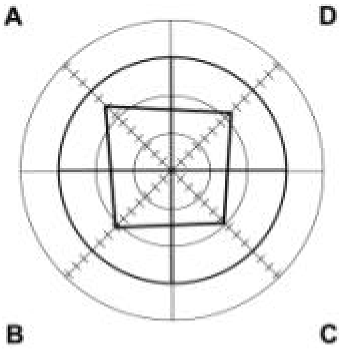
Table 3 **Wilcoxon scores for JPO and science students and the quadrants of the HBDI**

HBDI	JPO group (N=33) Arithmetic mean $\bar{x}$	JPO group (N=33) Standard deviation s	Science students (N=38) Arithmetic Mean $\bar{x}$	Science students (N=38) Standard deviation 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 5 illustrates the average Herrmann Brain Dominance profile of the engineering students on the support course.

Figure 5 **Average Herrmann Brain Dominance profile for the 2000 group enrolled for the support course**



Quadrant	**A**	**B**	**C**	**D**
Profile score	82	70	65	74

In Table 4 the results of a step-wise regression analysis taking the fields of the SOM as independent variables and the performance in the first semester calculus course as dependent variable are indicated for the 2000 and 2001 groups. In Table 5 the similar data are reflected with regard to the fields of the SOMT and performance in the first semester calculus course.

Table 4 **Step-wise regression model for the SOM and mathematics performance for 2000 and 2001**

Fields of the SOM	Parameter estimate	Partial coefficient of determination R^2	Model/Cumulative coefficient of determination R^2	P
Participants of 2000 (N=30):				
Information processing (IP)	0.2528	0.3918	0.3918	0.0002*
Problem-solving behaviour (PSB)	0.1428	0.0772	0.4689	0.0579#
Mathematics performance = $y_1 = 34.44 + 0.25$ IP + 0.14 PSB				
Participants of 2001 (N=38):				
Mathematics anxiety (MA)	0.2397	0.2515	0.2515	0.0013*
Mathematics performance = $y_2 = 45.65 + 0.25$ MA				

* Significant on a 5% level
# Significant on a 10% level

Table 5 Step-wise regression model for the SOMT and mathematics performance for 2000 and 2001

Fields of the SOMT	Parameter estimate	Partial coefficient of determination R^2	Model/Cumulative coefficient of determination R^2	P
Participants of 2000 (N=26):				
Problem solving behaviour (PSB)	0.2691	0.4241	0.4241	0.0003*
Mathematics performance = y_3 = 42.16 + 0.26 PSB				
Participants of 2001 (N=24):				
Study attitude (SA)	0.4243	0.2102	0.2102	0.0049*
Study habits (SH)	-0.2947	0.0853	0.2955	0.0539*
Study environment (SE)	0.2915	0.1653	0.4609	0.0037*
Mathematics anxiety (MA)	-0.1370	0.0528	0.5137	0.0761**
Mathematics performance = y_4 = 38.45 + 0.42 SA – 0.29 SH + 0.29 SE - 0.13 MA				

* Significant on a 5% level
** Significant on a 10% level

Discussion

Thinking style preferences

Regarding hypothesis $H_0 1$, it follows from Table 2 that in quadrant C, the means for the JPO 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-quadrant, the means for the engineering students on the support course 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, for instance, also associated with a preference for co-operative learning. Furthermore, Figure 5 illustrates the average Herrmann Brain Dominance profile of the engineering students on the support course which distinctly indicates that the preferences of the group, when combined, result in a profile that almost represents a generic whole brain profile with strong thinking preferences in all four quadrants (Herrmann 1995).

Table 1 shows that the majority of engineering students has 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.

Study orientation in mathematics

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

Conclusion

Although research has undoubtedly indicated that peer group learning works well, it seems as if students need to be trained to work in groups and the classroom 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 and science students on a support course whereas the distribution of thinking style preferences for both the groups of the engineering students is more similar. The fact that the preferences of the group, when combined, result in a profile that almost represents a generic whole brain profile with strong 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 SOM and the SOMT are concerned, it is clear that lecturers will be able to use the results of these tests 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 optimal achievements in Mathematics.

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