BACKGROUND FACTORS AFFECTING SUCCESS IN GEOMETRY

By

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Dedicated to my grandchildren, Joel, Heidi, Joshua, Jacob and Elise, who stand to gain the most from this research.

STATEMENT OF AUTHENTICATION

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in whole or in part, for a degree at this or any other institution.

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John H Brodie

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ABSTRACT

Mathematics plays a key role in bolstering a country's knowledge economy. Australia's knowledge economy is negatively affected by the underachievement of Australian school students in geometry. Research indicates a continuing decline in student performance in geometry and a distinct lack of geometrical knowledge and understanding on the part of students and teachers. To address this issue a theory of success in geometry that focussed on background variables and attitude, was developed. In the theory it was hypothesised that success in geometry can be understood in terms of predictor variables and that attitude mediates the effects of the variables on success in geometry. A model of success in geometry was developed to systematically determine the relationships of the variables.

Trainee teachers from the University of Western Sydney (n = 224) participated in the survey. Using Confirmatory Factor Analysis the use of one or two attitude scales was determined as were the items in the scales. Using Structural Equation Modeling (SEM) the relationships between the background factors (age, education, gender, left/right brain preference) on success in geometry (van Hiele level) mediated by attitude were determined.

When the effects of the factors in the model on success in geometry were controlled for, the effect of gender on van Hiele level (success in geometry), the effect of education on van Hiele level (success in geometry) and the effect of age on van Hiele level (success in geometry) were found to be significant. The absence of any effect of left/right brain preference on van Hiele level (success in geometry) was disappointing.

In addition, after controlling for other factors, the effect of attitude (as measured by the Semantic Differential Scale) on van Hiele level (success in geometry) was significant. After controlling for the effects of other factors on attitude, the effects of gender on attitude, and education on attitude, were found to be significant. The effects of age on attitude and left/right brain preference on attitude were found to not be significant.

No mediation of the background variables by attitude was found. The evidence, however, suggests that attitude is not only correlated with the measures of success in geometry (van Hiele levels) but that it may also be a predictor of success in geometry.

It was also hypothesised that attitude was composed of three analytically distinct factors (affective, cognitive and behavioural). The evidence suggests that this hypothesis cannot be rejected. This is an important finding as previous research has not been empirically able to distinguish these factors. Each of the hypothesised attitude factors were shown to be correlated. Importantly the affect factor was shown to be a predictor of success in geometry (behavioural factor). Clearly, attitude plays an important role in success in geometry.

It is clear that educational institutions that train teachers need to heed the findings of the present research concerning success in geometry. In order to improve the success of Australian school students in geometry and assist teachers to succeed and consequently improve Australia's knowledge economy, the present research indicates that: all trainee teachers should have their van Hiele level of geometry understanding determined; appropriate geometry courses should be a mandatory part of the curriculum for all preservice teachers whose van Hiele level is less than three; all trainee teachers should have a van Hiele level of three or four before they commence teaching; appropriate changes to the curriculum of trainee teachers should be made so that their stored general evaluative process produces a positive attitude to geometry, especially in female students; school students who intend to pursue a teaching career should complete mathematics courses with a geometry content.

Chapter 1

INTRODUCTION

“What year are you in at school, Zena?”

“Year 9”

“And what level of Mathematics are you studying?”

“Advanced”

“Do you like geometry?”

(Squirming) “No, I don’t understand it”.

… conversation between a school student and the researcher (2000)

Teaching and Learning

For hundreds of years educationalists have argued over the best way to extend the knowledge and understanding of students. The debate largely centres on two theories of learning. One theory, which has its roots in early Greek teaching, stresses the role of the teacher and the need for the teacher to impart a body of knowledge to the students, whilst keeping an eye on their future needs. The other theory stresses learning by doing and a concentration on the present interests of the student. Present day educationalists tend to use a composite of the two theories though the balance varies from one teacher to the next.

Constructivists believe that learning is an active process in which learners construct concepts based upon their current knowledge and experience. The learner transforms new information, constructs hypotheses and makes decisions using a cognitive structure to do so. Their cognitive structure gives meaning and organisation to experiences and assists the learner to increase his/her knowledge.

According to von Glasersfeld (1984), constructivism has two key principles that can be paraphrased as:

1. Knowledge is actively constructed by the learner.

2. Learning is a process of adaptation of information gained through the learner's experience of the world.

Kilpatrick (1987), referring to von Glasersfeld's first principle of constructivism, states "… almost no mathematics educator alive and writing today claims to believe otherwise" (p. 1).

There are two main types of constructivism recognised today:

1. *Cognitive Constructivism* is demonstrated in Piaget's work. It has two parts: an *age* part, which indicates what learners can do at different ages and a *theory of development* part, which suggests how learners develop cognitive abilities.

2. *Social Constructivism* is demonstrated in the work of Vygotsky and it places emphasis on the social context of learning. Both teachers and peers play very important roles in learning.

It is important to note that constructivism is not about teaching but about knowledge and learning.

Teaching is an intervention in the learning of another person. A necessary, though not sufficient, condition for intelligent teaching is to have a conscious theoretical model of the processes of human learning. Van Hiele and van Hiele-Geldof (1958) developed such a model (see Chapter 2). The van Hieles' philosophy of learning can be identified with constructivism. The mental models referred to as *structures* by van Hiele, are the constructivists' *cognitive structure* that gives meaning and organisation to experiences and assists the learner to increase his/her knowledge. In the van Hiele model, teaching is crucial to student development, especially in geometry.

Knowledge Economy

In a discussion paper by the Australian Bureau of Statistics (2003) it is suggested that various economic models are being used to attempt to explain the role of knowledge in the growth of a country, and to measure the knowledge economy of a country. The models are of two types: New Growth (Gera, Lee-Sing & Newton, 1998) and Evolutionary Economic (Bryant & Wells, 1998). Bryant and Wells, in an overview of the evolutionary economic theory suggest that social elements that are relevant to the knowledge economy of a country include the direct social effects of educational levels on knowledge processes. Pragmatically, then, a focus on geometry is important to the social wellbeing of Australian students and teachers as the next section reports on research that shows a steady decline in the understanding of geometry, and a dislike for the subject, by Australian students and teachers. The next section, which begins with a review of the history of geometry, also shows that, philosophically, a focus on geometry is important as it illustrates the link between geometry and all other mathematics.

Geometry

Kepler (1571-1630) stated that “where there is matter there is geometry” (World Book, 1999), and using geometry and the astronomical observations of Brahe, he showed that the planets travelled in elliptical and not circular orbits around the sun and in doing so destroyed a belief that was more than 2000 years old. Osserman (1998), mathematician and author, stated in the video *Shape of the World-Exploration*:

> All the centuries of progress of mapping the earth and with the mathematics associated with it allows us to think about mapping the universe and understanding the pictures that we come up with, to look out there you see the galaxies ... but you can't put them all together without the geometry to analyse what it is that you are seeing.

Weeks (1998), a mathematician, stated in the same video, "There are two domains of exploration here, there is the real universe that we explore physically with telescopes and there is the mathematical universe we explore with our minds". All 20th century cosmology grew out of Riemann's idea of higher dimensional curved space geometry and, 75 years after Riemann's geometry was developed, Einstein used it to explain his theory of relativity and thus the physics of the universe (Corbitt (Ed), 1999).

Euclid (330? - 270? BC) is often referred to as the father of geometry. His textbook, *"Elements",* has probably had more of an influence on scientific thinking than any other work. In *Elements* Euclid began with five axioms or postulates (statements accepted as true without proof) and used them logically to demonstrate 467 propositions of plane and solid geometry. Euclidean geometry forms the basis of engineering today and is used, for example, in architecture, carpentry, navigation, metalwork, art and sport. At the Australian Open, in 2001 Pam Schriver, a professional tennis player, commentating on a match where one of the players was placing her shots to get the maximum advantage over her opponent stated that “this [game] is a good case for never giving up geometry” (Channel 7 coverage of the Australian Open Tennis Competition, 2001).

Geometry (geo - earth; meter - to measure) may be Euclidean or non-Euclidean depending on the postulates used. For example, Riemann’s non-Euclidean geometry uses the first four of Euclid’s postulates but has a different fifth postulate and Analytic geometry uses the same postulates as Euclidean geometry but uses algebraic methods in working with figures and this is important in trigonometry and calculus. Euclidean geometry involves the studying of the shape, size and position of both plane shapes, such as triangles, and solids, such as cubes, and includes congruence, similarity and parallel lines.

Geometry has always been associated with practical situations. The Babylonians, Egyptians and Greeks all used geometry to create structures and measure land areas. Thus, it is only reasonable that geometry is today mainly associated in the minds of most individuals, with practical situations. Geometry, however, is also a logical system that uses deductive reasoning to develop new truths from accepted facts, for example, understanding the geometrical properties of the universe continues today in the work of Weeks (1998) and others.

It is reasonable to conclude, therefore, that whether we look to the past, the present or the cutting edge mathematics of the future imbedded in it all, is geometry. This conclusion is not new, however, for the UNESCO publication *New Trends in Mathematics Teaching* (1973) stated:

> The reasons for the omnipresence of geometrical language in today's mathematics, however, is not only due to historical tradition but also to the fact that language is tied to concept formation. The geometric terminology that occurs in algebra and analysis shows the manner in which geometric intuition penetrates all of mathematics (p. 25).

This importance of geometry to the study of mathematics was recognised by the Russians in the 1960s then by the Americans in the 1970s (Hoffer, 1988; Teppo, 1991), who, having accepted the importance of geometry in the study of all mathematics, increased its prominence in all levels of mathematics study in schools (NCTM, 1989). Unfortunately, the feelings expressed above by Zena in the opening quote of this chapter are prevalent in our schools today and are common to both the staff and students.

What effect dislike of geometry has on educational standards and hence the knowledge economy of a country has not been quantified. What is known, however, is that this dislike of geometry and this inability to "understand it" have been around for a long time. Mitchelmore (1982) undertook a geometry research project in Jamaica and at the conclusion of the research reported that only eight out of the seventy teachers interviewed at one school put geometry as their preferred mathematics topic and that teachers saw geometry as “complicated and uninteresting” (p. 39) and did “not like or enjoy teaching geometry” (p. 38). Fey (1984) stated that geometry was “the most troubled and controversial topic in school mathematics today” (p. 31). Suydam (1985), supported Fey’s statement on geometry stating “Nevertheless, geometry seems to be ‘the most troubled and controversial topic in school mathematics today’ “ (Fey 1984, 31). (p. 481). Brodie (1992) surveyed 22 primary schools in an educational region in New South Wales and found “a significant difference in teacher attitude to number and geometry; teacher attitude to geometry being significantly less positive than teacher attitude to number” (p. 30). Lawrie (1998), when handing out a test to students who had no prior knowledge of the topic, noted that, “On finding that the subject of the test was geometry, there was perceptible dismay among the students indicating a degree of anxiety concerning the subject” (p. 69).

As noted above, the document *Curriculum and Evaluation Standards for School Mathematics* (1989) produced by the National Council of Teachers of Mathematics (NCTM) announced the beginning of a renewed interest in Geometry education in the United States of America. The document indicated that geometry: related to a child’s world and is of intrinsic interest; improves spatial ability or “spatial sense”; is a vehicle for developing other mathematical concepts; is a rich source for mathematics problems and is of value in improving overall problem-solving ability. Also stated was:

> children who develop a strong sense of spatial relationships and who master the concepts and the language of geometry are better prepared to learn number and measurement ideas as well as the other advanced mathematical topics (p. 48).

In their revised work *Principles and Standards for School Mathematics (2000),* the NCTM reinforced the importance of geometry. They stated that “Geometry has long been regarded as the place in the school mathematics curriculum where students learn to reason and to see the axiomatic structure of mathematics” (p. 40), and that “Geometry offers a means of describing, analysing, and understanding the world and seeing beauty in its structures” (p. 309). Supporting their 1989 statement that geometry was useful for the learning of other branches of mathematics and problem solving, the NCTM further stated in 2000 “Geometric ideas can be useful in other areas of mathematics and in applied settings” (p. 309).

In 1989, the Department of School Education in NSW agreed that geometry had to play a major role in mathematics programs in K-6 and recommended an increase in the time devoted to geometry in their new K-6 Mathematics Syllabus. In the introduction to the syllabus it states: “Mathematics K-6 responds to considerable recent research concerning how students learn mathematics....“ (NSW Department of Education, 1989, p. v).

The research referred to included that of van Hiele and van Hiele-Geldof (1958), Hoffer (1981), Mitchelmore (1982) and Thiessen (1989). Whilst each of these researchers indicated that geometry was integral to the learning of Mathematics, the most significant research was that of van Hiele who concluded that students operate at one of five levels of understanding when doing geometry. These levels are detailed in Chapter 2. The NSW K-6 Mathematics Outcomes and Indicators Document (Board of Studies, 1998) continued the support for geometry (space) education and reinforced the need for students to discover geometrical properties by investigation. The use of the term “space” instead of “geometry” highlighted the shift from the formal treatment of geometry used in secondary schools to an informal treatment of geometry in primary schools and the early years of secondary schooling. The latest Mathematics syllabus K - 10 (Board of Studies, 2002) continues this informal treatment of geometry well into secondary schooling.

Unfortunately, in 1989, the NSW Department of Education supplied limited documentation to improve teachers’ understanding of the latest research into the teaching of geometry or the work of van Hiele. As a consequence the majority of teachers taught the new syllabuses using old methods (Brodie, 1992) and therefore students continued to rote learn geometry and gain poor results. Since the introduction of the 2002 syllabus only limited documentation has been made available to teachers to date.

The Third International Mathematics and Science Study (TIMSS) was the largest study of educational achievement ever undertaken. The study, in 1994, involved forty-eight countries and one million students and followed the First (1959 - 1967) and Second (1976 - 1987) International Mathematics Studies. Rosier (1980) compared the 1964 and 1978 results and concluded that there had been a slight decline in student performance, especially in geometry. The first results of the third study released in 1996 indicated that geometry was still a problem area and that there is a positive correlation between liking Mathematics, that is, having a positive attitude to Mathematics, and achievement in Mathematics. This research supports these results. Supporting the existence of problems in geometry in a number of countries, the International Commission on Mathematical Instruction (1995), referred to in Chinnappan (1998), stated that “students do not seem to perform as well as expected in tasks involving the solution of geometry problems (p. 27).

The TIMSS 1994 study was repeated in 1998 (TIMSS-R) and the Australian results from this were released in 2002 (Zammit, Routitsky & Greenwood). These results indicate that Australian students were above international average in all areas of mathematics except geometry and that teachers felt confident teaching 11 of the 12 course content areas. The report stated (2002):

> Geometric figures, symmetry, motions and transformations, congruence and similarity was the topic for which Australia ... reported the lowest percentage

> of teacher confidence. Geometry was also the content area where ... [Australia] had the lowest scale score (p. 145).

It needs to be noted that Ellerton and Clements (1994) and Clarke (2002) have challenged cross-country comparison validity. However, the results are still interesting if the focus is kept within a country. This focus supports the TIMSS's 1994 and 1998 initial conclusions about geometry in Australia, and indicates **a continuing decline in student performance in geometry and a distinct lack of geometrical knowledge and understanding on the part of students and teachers.** This claim will be strongly supported in the following chapters.

Despite the TIMSS's data the universities include few dedicated courses on geometry in their teacher training. Brodie (1992) concluded that teachers rated geometry the least liked strand out of number, measurement and geometry and Lawrie's (1998) results indicated that university students who were soon to be primary school teachers had little understanding of the processes involved in learning geometry and had a dislike for it.

Implications of Teacher Knowledge of Geometry and Attitude to Geometry

Brodie (1992) believed that the key to improving the understanding of geometry by school students lay in improving student teachers' and teachers' knowledge of, and attitude to, geometry. His belief is supported by the following quote from the report of the National Commission on Teaching and America's Future (1996) in *Principles and Standards for School Mathematics (2000),* "To be effective, teachers must know and understand deeply the mathematics they are teaching and be able to draw on that knowledge with flexibility in their teaching tasks" (p. 17) and by the report in 2002 on TIMSS-R (1998) in which it is stated, "… that effective teaching depends on the pedagogical content knowledge of teachers" (p. 160). It is also supported by the work of van Hiele and van Hiele-Geldof (1958) in which it is suggested that teaching is crucial to student development in geometry.

Noteworthy, is the work of Fuys, Geddes and Tischler (1988) who, at the end of their extensive research into the van Hiele levels, declared that "it is not surprising that results of research on the [van Hiele] levels should have implications for research on classroom teaching of geometry - namely, curriculum and instruction" (p. 188). Pegg and Davey (1991) have done extensive research in Australia. They suggest that the van Hiele levels are basic to improving the teaching of geometry. "… student growth in Geometry takes place in terms of identifiable levels of understanding and … instruction is most successful if it is directed at the student's level" (p. 10).

For some years researchers (Suydam & Weaver, 1975; Relich, Way & Martin, 1994) and others (NSW Department of Education, 1989) have suggested that the attitude of teachers to a subject had an effect on the attitude of their students to that subject. Phillips (1973) found that teachers with a positive attitude to mathematics caused favourable attitudes to mathematics in their students, and Bishop and Nickson (1983) suggested that a positive teacher attitude resulted in high achievement in their students. TIMSS-R (1998) indicates that teacher attitude to geometry is poor and its results support the findings of earlier researchers, namely, that attitude is linked to success.

Given van Hiele's belief in the importance of teachers to student knowledge of geometry (1955), the suggested link between knowledge of geometry and knowledge of mathematics (NCTM, 1989, 2000), and the existence of poor teacher attitude to geometry (TIMSS-R, 1998), it is appropriate to investigate the relationship between Australia's future primary school and secondary school teachers' (especially those who are to teach Mathematics) attitude to, and success in, geometry. Clearly prior research and theory have identified attitude as an important variable in the learning and teaching of geometry. In the present study the research interest is on the part that attitude plays as an intervening variable between student teacher characteristics brought to the classroom (e.g., gender, age, education) and success in geometry. An intervening variable is any variable that affects the influence of independent variables (such as gender) on a dependent variable (knowledge of geometry). Therefore, the investigation needs to determine whether attitude acts as an intervening variable between other factors and success in geometry. The results of the investigation may help to produce a base line to use for determining the training course requirements of future teachers so that the continuing decline in geometry standards of Australian school students, and the effects that the decline has on the knowledge economy of Australia, can be addressed.

In order to research the relationship between preservice teacher attitude to geometry and success in geometry it is necessary to validate a measure of preservice teacher attitude to geometry. The following section briefly introduces the measurement of attitude and introduces research on the link between attitude and achievement. Chapter 3 provides a more comprehensive review of the measurement of attitude.

Attitude Measurement and Attitude and Achievement.

1. Attitude Measurement.

There have been many attempts to define attitude. (Thomas & Znaniecki, 1918; Thurstone & Chave, 1928; Campbell, 1950; Aiken, 1970; Fishbein & Ajzen, 1975; Leder, 1992; Eagly & Chaiken, 1993). According to Leder (1992) the definitions imply three assumptions about attitude which are accepted today, namely, attitude is learned (this is known as the cognitive component of attitude), it predisposes an individual to a favourable or unfavourable response (this is known as the behavioural component of attitude) and it causes response consistency (this is known as the affective component of attitude).

The search for a reliable instrument to measure attitude that takes these three components into consideration began with Fechner (1860) in the latter part of the nineteenth century. He had an interest in psychology and physics and performed experiments to determine the relationship between the mind and the body, sensation and stimulus. Other psychophysicists such as Muller (1878) and Titchener (1904), attempted to determine how physical intensity was related to psychological intensity. Thurstone and Chave (1928), took an interest in the work of these social psychologists and suggested that their methods could be used in contexts where there was no physical dimension to go with the psychological dimension under investigation. From that time, research was carried out to develop a reliable instrument to measure attitude. The present search for a valid and reliable instrument to measure attitude resulted in a number of measures used today, the most common of which are the Semantic Differential Scale and the Likert Scale (see Chapter 3). The present research used this knowledge to construct and validate psychometric affective and cognitive measures of attitude.

2. Attitude and Achievement

The assumption that a relationship between attitude and achievement exists is supported by the TIMSS results in 1996 and 2000 and the belief in the existence of such a relationship over many years is illustrated by this statement of Suydam and Weaver (1975):

> Teachers and other mathematics educators generally believe that children learn more effectively when they are interested in what they learn and that they will

> achieve better in mathematics if they like mathematics. Therefore, continual attention should be directed towards creating, developing, maintaining and reinforcing positive attitudes (p. 45).

The relationship between the affective and the cognitive domain has been the subject of research for some time (Aiken, 1970; Neale, Gill & Tismer, 1970; Haladyna, Shaughnessy & Shaughnessy, 1983; McLeod, 1992; Ma & Kishor, 1997). Attitudes, beliefs and emotions are the major descriptors of the affective domain and knowledge and thinking are descriptors of the cognitive domain.

There is disagreement amongst researchers (Krathwohl, Bloom & Masia, 1964; Snow & Farr, 1987; Eagly & Chaiken, 1993) as to how strong the relationship between the affective domain and the cognitive domain is. Perhaps the varying research results of the relationship between the domains is due to the instruments which have been used to measure the affective domain (attitude) and the cognitive domain (knowledge), being unreliable or inappropriate. In the present research the importance of the affective and cognitive attitude domains are explored using advanced statistical methods. The results suggest that each is important in a different context with the affective being more related to knowledge of geometry than the cognitive.

Other Constructs

Other constructs have been examined in the context of educational outcomes, for example, social factors such as significant others and ability beliefs such as self-efficacy. Bandura (1986) is the father of the ability belief concept. He showed that students' self-beliefs about their academic capabilities were predictors of subsequent achievement. In later research Zimmerman, Bandura and Martinez-Pons (1992) showed that parents' expectations influenced students' self-efficacy and subsequent school achievement. Clearly this shows an important link between students' self-beliefs, significant others and achievement. These results were in accord with Vygotsky's social theory of learning (Vygotsky, 1978).

Like ability beliefs, attitudes are influenced by significant others. However, there has been much research concerning ability beliefs but far less concerning attitudes and, in particular, attitudes as they relate to knowledge of geometry. The present research focuses on the relationship of attitude to knowledge of geometry.

Background Factors

Previous researchers (Fennema & Leder, 1993; Chouinard, Vezeau, Bouffard & Jenkins, 1999; Nosek, Banaji & Greenwald, 2002) suggest that gender is of significant interest to the research and teaching communities. Given that a large percentage of pre secondary school teachers are female (79.1% ABS 2002) and that an increasing percentage of secondary teachers are female (56.1% ABS 2002) it is important to establish any link between gender and attitude and knowledge of geometry.

The research of others (Frykholm, 1994; Ahuja, 1996) noted a link between previous education and success in geometry. Those who had previously studied courses containing geometry topics tended to have more success in geometry. Research, to confirm these findings, is appropriate as the findings have implications for courses studied at school and university by preservice teachers.

Piaget and van Hiele disagree as to the place that age takes in learning. Piaget believes that progress in learning occurs at various stages that are linked to age. However, van Hiele (1986) argues against Piaget's strict adherence to a link between stage and age stating "The age of children is important, [only] in so far as they must have had sufficient time to go through the necessary learning processes" (p. 65). Any relationship between age and success in geometry needs to be established as it has implications for teaching.

Still other researchers (Broca, 1869; Bastian, 1880; Turkowitzg, Gordon & Birch, 1965; Gazzaniga, 1974; Richards, 1984; Kitchens, Barber & Barber, 1991; Fiez, Raichle, Miezin, Petersen, Tallal & Katz, 1995) have indicated that different sections of the brain are involved in different learning tasks and that learners can be categorised into left or right brain learners. This assertion has been the basis of lively debate for many years and has implications for teaching and learning and therefore it is appropriate that it form part of this research.

In the present research the importance of age, gender, previous education, left/right brain preference and attitude to success in geometry is explored using advanced statistical methods. The results suggest that not all factors are important to success in geometry.

In the following section the relationship of brain-based education and success in geometry is briefly described. This relationship is extensively discussed in Chapter 4.

Brain-based Education

Recent research (Harris, Silberstein, Pipingas & Pressing, 1999) into the activity of the brain during task completion has supported the concepts of left/right brain theory first advanced by Albertus Magnus (1193 - 1280). In this theory the left side of the brain is considered to be the site of analytic, verbal cognition and the right side of the brain as the site of the holistic, affective and perceptual processes. This theory has important implications for the teaching of mathematics in general and the teaching of geometry in particular as geometry involves both analytic and perceptual processes. Indeed, in 1983 Williams stated that "The brain has two hemispheres but too often the education system operates as though there were only one" (p. 7) and it was argued by Kitchens et al.

(1991) that many otherwise gifted students were failing to achieve in mathematics and were suffering from mathematics anxiety as a result of teachers failing to acknowledge the left/right brain theory. They suggested that teachers' early emphasis on rules and linear, sequential tasks inhibited the development of creativity, problem solving and spatial ability as they appealed to students who were "left-brained". Ellis (1985) indicated that Einstein, von Braun and Edison went on to achieve greatness in their chosen fields of study despite being labelled "failures" at school due to their right brain tendencies.

The term "brain-compatible," was first used by Leslie Hart (1983) in his book *Human Brain and Human Learning*. Hart suggested that brain research indicated that the traditional approach to teaching and learning was brain-antagonistic and that before education could be brain-compatible changes to the teaching/learning paradigm needed to occur. From that time on, educators endeavoured to produce what is today known as Brain-Based Education.

According to brain-based educators (Edelman, 1992; Staso, 1997; Schiller, 2000) neuroscience has shown that the brain has the ability to change its structure and function in response to outside experiences and they refer to this as the plasticity factor. They believe that learning consists of the development of connections between neural networks and that this development can be brought about by education.

While the body of research in both neuroscience and brain-based education continues to grow dramatically, little if any, research has been done on the left/right brained preference of teachers and whether teachers who are right brained teach differently to teachers who are left brained. No research has been done to see if a teacher's disposition to being right or left brained affects their attitude to geometry, their success in geometry or their ability to teach it.

Conclusion

Geometry is important to success in mathematics. In light of the latest research that shows a continuing decline in geometry achievement and apprehension on the part of teachers teaching it, research needs to be undertaken to determine the causes of this decline and teacher apprehension about geometry, as this decline and apprehension have the potential to affect the success in mathematics of Australian school students and therefore the knowledge economy of Australia. An appropriate focus for this present research is preservice teachers as they hold the key to the future success of school students. Research that involves preservice teachers and their knowledge of geometry, influential background factors and intervening variables may produce results that allow the decline in standards in geometry to be halted and help solve the question as to why there is this dislike of geometry and an inability to "understand it".

The term “intervening variable” needs to be considered. For many researchers (Locke, Cartledge & Knerr, 1970; McCombs & Marzano, 1990; Pressley & Ghatala, 1990) the psychology of the individual is seen as an intervening variable. For others (Henderson, 1981), *significant others* is seen as an intervening variable and others, like Bandura, focus on a particular psychological construct, or set of psychological constructs, say ability beliefs, as an intervening variable. Whilst these are important, the present research does not look at the effects of social factors such as these. Instead, attitude is the construct that has been chosen as the intervening variable over the others as the literature has identified it as important, because attitude is malleable and because there is little research on the role of attitude as an intervening variable or mediator of background factors such as gender on success in geometry, or its relationship to success in geometry, as measured by the van Hiele levels.

Clearly, there are many constructs that can be considered to be influential background variables. However, gender, age, education and left/right brain preference have been identified as important in the literature and therefore are used in the current research.

Specifically, the current research is undertaken to determine the interrelationships of background factors (gender, age, education and left/right brain preference), attitude and success in geometry. In the present research attitude is examined as an intervening or mediating variable in the process of acquiring geometric knowledge. To facilitate the research a statistical model depicting all these factors is constructed and subjected to rigorous testing to determine the relationships of the factors.

The results suggest that there exists a relationship between the background factors, affective and cognitive attitudes and knowledge of geometry. Accepting that attitude is critical to optimising knowledge acquisition of geometry, these findings are significant in terms of teacher education. Clearly if teachers lack obvious enthusiasm for their subject then we can hardly expect students to be enthusiastic about the subject.

The results of the present research are important in a further aspect. They provide empirical evidence for the concept that attitude comprises three analytically distinct constructs: the affective, the cognitive and the behavioural domains. There is a need for further research based on these findings to develop teacher education strategies the aim of which should be to develop in future teachers a theoretical model of the processes of human learning in geometry. This would better equip them to teach geometry, enable a positive attitude towards, and an increased understanding of, geometry. In turn this will contribute to an improvement in the overall level of achievement in mathematics by students including the *Zenas* of the world.

In the present research the following research questions are therefore empirically examined:

1. Do the background factors, attitude to geometry and acquisition of geometric knowledge comprise a theoretical model of the processes of human learning in geometry?

2. What is the relationship of the background factors to the acquisition of geometric knowledge?

3. What is the relationship of attitude to the acquisition of geometric knowledge?

4. After controlling for the effects of the background factors does attitude intervene between the background factors and the level of acquisition of geometric knowledge?

Chapter 2

THE VAN HIELE THEORY

Let no one ignorant of geometry enter my doors

... Plato (inscription he carved above the entrance to his academy).

This chapter reviews the literature concerning the van Hiele theory on the levels of understanding in geometry. The chapter introduces a number of important concepts and issues that need to be considered when success in geometry is to be evaluated. The chapter also summarises the background to van Hiele's work, his levels of understanding, a comparison with the SOLO taxonomy, Piaget's and Vygotsky's work and the transition between the van Hiele levels.

Introduction

In Chapter 1 this researcher pointed out that teaching is an intervention in the learning of another person and that a necessary, though not sufficient, condition for intelligent teaching is to have a conscious theoretical model of the processes of human learning. It was also stated that Pierre van Hiele and Dina van Hiele-Geldof developed such a model.

Pierre van Hiele and Dina van Hiele-Geldof as teachers in Montessori secondary schools were concerned about the difficulties their students were having with their studies of geometry. It became apparent to them that secondary school geometry involved a high level of thinking and primary school geometry involved lower levels of thinking. After observation and discussion of their students' progress, the van Hieles concluded that in learning geometry, the students seemed to progress through a sequence of five reasoning levels, from wholistic thinking to analytical thinking to rigorous mathematical deduction. They also concluded that to progress from one level to the next, students seemed to pass through five phases from an inquiry phase through to an integration phase.

The van Hieles supported this composite approach of levels and phases to teaching by defining the subject matter to be learned but at the same time defining the role of the teacher as a helper who guided the student through levels of understanding of the subject matter. Fuys, et al. (1988, p 4) stated "Their [the van Hieles'] research work focused on levels of thinking in geometry and the role of instruction in helping students move from one level to the next" and van Hiele (1986, p. 39) quoted from his 1955 work and stated: " The attainment of the new level cannot be effected by teaching, but still, by a suitable choice of exercises the teacher can create a situation for the pupil favourable to the attainment of the higher level of thinking."

As a consequence of their observations the van Hieles challenged the current methods of teaching that solely involved the imparting of facts and methods which were often not understood by students. They determined that teachers should concentrate on the development of insight in their students helping them move from one level of thinking to another higher level by learning *structures* rather than facts. Van Hiele (1986), stated:

> I had understood that the learning of facts could not be the purpose of teaching mathematics, I was convinced that development of insight ought to be the purpose. ... I learned that insight might be understood as the result of perception of a structure (pp. 4-5).

Structures

According to van Hiele (1986):

> Structure is an important phenomenon: It enables man and animal to act in situations that are not exactly the same as those they have met before. Structure saves man and animal from a never-ending life of trial and error. Structure enables people to understand each other. People see the same structure and they can express their harmony by continuing the structure in the same way (p. 24).

Structures were considered to be *strong* or *feeble* by van Hiele depending on their rigidity. Strong structures were those that could only be extended in one way and hence could be continued with certainty whereas feeble structures were those that could only be continued with uncertainty with mistakes often being made. It should be noted here that van Hiele considered mathematical structures to be very rigid and therefore strong if the rule of the structure was given.

Van Hiele (1986) relied on Gestalt psychology to develop his ideas of structure and he believed that structures had four important properties. He (1986) stated:

> 1. It is possible to extend a structure. Whoever knows a part of the structure also knows the extension of it. The extension of a structure is subjected to the same rules as the given part of it.
>
> 2. A structure may be seen as a part of a finer structure. The original structure is not affected by this: the rules of the game are not changed, they are only enlarged. In this way it is possible to have more details take part in the building up of the structure.
>
> 3. A structure may be seen as a part of a more-inclusive structure. This more-inclusive structure also has more rules. Some of them define the original structure.

> 4. A given structure may be isomorphic with another structure. In this case the two structures are defined by rules that correspond with each other. So if you have studied the given structure, you also know how the other structure is built up (p. 28).

To clarify these four points van Hiele (1986) illustrated them with reference to the human skeleton. He pointed out that having looked at a skeleton “The extension of the structure may happen when we realise that we have such a skeleton ourselves” (p. 29). He suggests that a finer structure, as explained in point 2, is developed when we give names to parts of the skeleton and the third point occurs when “we begin to study skeletons of animals and to compare them with the human skeleton” (p. 29). Finally he suggests that point four is illustrated by the comparison of the skeleton of man with the skeleton of animals.

Van Hiele believed that the first and fourth properties of a structure are self-revealing and are innate in mankind whereas the second and third properties required study. He concluded that if education was to produce the development of insight then pupils should be stimulated to develop their recognition and use of the second and third properties of structure. Van Hiele argued that, if insight and hence understanding is to be achieved, it is essential that the student develops an understanding of the nature of structures.

Hence, the model of learning according to van Hiele is:

Perception of a Structure ⟶ Insight ⟶ Understanding

Therefore, the purpose of teaching should be the development of insight. It should be noted here that van Hiele (1986) summarised his concept of insight as follows:

1. Insight can be observed when there has been an adequate action in a new situation.

2. Insight can be ascertained when there has been action on the strength of an established structure from which the answers to new questions can be read.

3. The best examples of insight happen unexpectedly; they are not brought about by planning (p. 154).

But he insisted that *intention* must produce the *adequate action* in a new situation for insight to be gained.

The Van Hiele Levels

According to the van Hieles the student passes through five hierarchical levels of thinking. Originally the van Hieles numbered the levels basic or 0, and 1 to 4. Wirszup (1976) kept the five levels but renumbered the levels so that Level 0 became Level 1, Level 1 became Level 2 etc. The names used for the levels were first used by Hoffer (1979) as the van Hieles did not name the levels. In 1986 Pierre van Hiele started to use the 1 to 5 scale and consequently most researchers today use the same scale. As van Hiele was a teacher of mathematics he used examples from geometry to illustrate his levels though he did not restrict his theory to Mathematics.

It is important to note that when van Hiele was commenting on his 1955 work entitled “De Niveau’s in het Denken, Welke van Belang Zijn Bit het Onderwijs in de Meetkunde in de Cerste Klass van bet V.H.M.O.”, in his 1986 work, he stated that the “Tracing of levels of thinking that play a part in geometry is not a simple affair, for the levels are situated not in the subject matter but in the thinking of man” (p. 41). It should be understood here that there is some disagreement as to what the actual number of van Hiele levels should be. Hence, it is important for educators to understand how students think, the way in which brain functioning influences a student’s ability to learn and the rationale behind brain-based education.

Level 1 (Recognition)

The student operates on geometric figures, such as triangles, and parallel lines by identifying, naming and comparing them according to their appearance. Perception is visual only. A student who is reasoning at level 1 recognises certain shapes wholistically without paying attention to their component parts. For example, a rectangle may be recognised because it looks “like a door” and not because it has four straight sides and four right angles as there is no appreciation of these properties. Shape is important and figures can be identified by name.

Level 2 (Analysis)

The student discovers properties/rules of a class of shapes empirically, such as folding, measuring, analysing figures in terms of their components and relationships among components. At this level component parts and their attributes are used to describe and characterise figures. For example, a student who is reasoning analytically would say that a square has four “equal” sides and four “square” corners. The same student, however, might not believe that a figure can belong to several general classes and have several names, eg, the student may not accept that a rectangle is a parallelogram. A figure at this level presents as a totality of its properties. A student may be able to state a definition but will not have understanding.

Level 3 (Ordering)

By following or giving informal arguments the student logically interrelates previously discovered properties or rules. The student operates with these relationships both within a figure and between related figures. There are two general types of thinking at this level. Firstly a student understands abstract relationships among figures, eg, the relationship between a rectangle and parallelogram and secondly a student can use deduction to justify observations made at level 2. The role of the definition and the ability to construct formal proofs are not understood at this level though there is a comprehension of the essence of geometry.

Level 4 (Deduction)

The student proves theorems deductively and establishes interrelationships among networks of theorems. The student can manipulate the relationships developed at level 3. The need to justify relationships is understood and sufficient definitions can be developed. Reasoning at this level includes the study of geometry as a formal mathematical system rather than a collection of shapes.

Level 5 (Rigour)

The student establishes theorems in different postulation systems and analyses and compares these systems. The study of geometry at level 5 is highly abstract and does not necessarily involve concrete or pictorial models. At this level the postulates or axioms themselves become the object of intense rigorous scrutiny. Abstraction is paramount.

According to the van Hieles, a learner passes through these levels when assisted by appropriate instructional experiences, and that a learner cannot achieve one level of thinking without passing through the previous levels. If a teacher tries to teach a student at one level when the student has not passed through the previous level the student will not understand the teacher and resort to rote learning. A teacher may try to present the new information at a lower level than is required by the information in order to assist students who are not operating at the appropriate level to learn. A teacher may also present the new information at a lower level than is required by the information due to the teacher's own lack of knowledge of geometry. This is known as level-reduction which causes the student "to lose sight of the real relation between levels" (Structure and Insight, van Hiele, 1986, p. 53). Level reduction is a significant factor in the poor teaching of geometry and has incredible implications for teachers of geometry in particular and mathematics in general. It would appear that unless a teacher is aware of the van Hiele levels of learning and can recognise the levels at which their students are operating little real geometry will be taught or learnt in the classroom.

It is noteworthy that in van Hiele's 1986 work he refers to there being three levels, two levels and five or more levels. He also refers to an alternative set of three levels. Teppo (1991) suggests that Pierre van Hiele currently characterises his model in terms of three rather than five levels and Lawrie (1998) stated that "The existence of this latter model of only three levels was confirmed in personal communications in 1994 with Dr van Hiele at the Hague and again at the University of New England, Armidale" (p. 9). The three latter model levels with the 1 to 5 level system in parentheses are Visual (Level 1), Descriptive (Level 2 and Level 3) and Theoretical (Level 4 and higher). Pegg and Davey's (1998) description of these three levels is favoured by Lawrie (1998) over that of Fuys, et al. (1988), as she felt that when the composition of the original levels is examined with regard to the understanding of geometry, Pegg and Davey's approach was more logical. Pegg and Davey's (1998) description of the three levels of the alternative model are:

Visual Level: decisions are guided by a visual network.

Descriptive Level: the elements and relations are described.

Theoretical Level: deductive coherence is prominent; geometry generated according to Euclid is considered.

The van Hieles (1958) identified properties of the levels to which Usiskin gave the names adjacency, distinction and separation. Inherent in the van Hiele theory is the belief that in understanding geometry a person must go through the levels in order. Hence Usiskin added a fourth property which he named fixed sequence. He (1982) stated:

> It is inherent in the van Hiele theory that, in understanding geometry, a person must go through the levels in order. We call this the fixed sequence property of the levels.
>
> Property 1: (fixed sequence) A student cannot be at van Hiele level *n* without having gone through level *n-1*.
>
> Property 2: (adjacency) At each level of thought what was intrinsic in the preceding level becomes extrinsic in the current level.
>
> Property 3: (distinction) Each level has its own linguistic symbols and its own network of relationships connecting those symbols.
>
> Property 4: (separation) Two persons who reason at different levels cannot understand each other (pp. 4-5).

Whilst the interest in the categorisation of the levels is ongoing it is important to note that there is a consensus of opinion amongst researchers that the levels exist and are hierarchical and that they do measure cognitive development. However most of the ongoing research uses the original five levels renumbered 1 to 5.

Summarising the preceding information, it appears that the major characteristics of the van Hiele levels are:

- the levels are sequential
- each level has its own set of symbols, network of relations and terminology
- what is implicit at one level becomes explicit at the next
- material taught to students above their level is subjected by them to a reduction of level
- progress from one level to the next is more dependent on instructional experience than on age or maturation
- one goes through various “phases” in proceeding from one level to the next.

Phases that Lead to a Higher Level

The van Hieles defined five phases in the learning process through which they believed students must pass before “jumping” to the next level. They believed the levels were discrete, stating:

> The discontinuities are ... jumps in the learning curve, these jumps reveal the presence of levels. The learning process has stopped; later on it will start itself once again. In the meantime, the pupil seems to have "matured". The teacher does not succeed in further explanation of the subject. He and ... the other students who have reached the new level seem to speak a language which cannot be understood by the pupils who have not yet reached the new level. They might accept the explanation of the teacher, but the subject taught will not sink into their minds. The pupil himself feels helpless; perhaps he can imitate certain actions, but he has no view of his own activity until he has reached the new level. At the time the learning process will take on a more continuous character. Routines will be formed and an algorithmic skill will be acquired as the prerequisites to a new jump which may lead to a still higher level (1958, pp. 75-76).

Fuys, et al. (1988) paraphrased van Hiele-Geldof's original definition of the phases and gave examples, stating:

> According to van Hiele (1955/1986), progress from one level to the next involves five phases: information, guided orientation, explicitation, free orientation, and integration. The phases which lead to a higher level of thought, are described as follows with examples given for transition from level 1 to level 2.

Information or Inquiry: The student gets acquainted with the working domain (e.g. examines examples and non-examples).

Guided Orientation: The student does tasks involving different relations of the network that is to be formed (e.g. folding, measuring, looking for symmetry).

Explicitation: The student becomes conscious of the relations, tries to express them in words, and learns technical language which accompanies the subject matter (e.g. expresses ideas about properties of figures)

Free Orientation: The student learns, by doing more complex tasks, to find his/her own way in the network of relations (e.g. knowing properties of one kind of shape, investigates these properties for a new shape, such as kites).

Integration: The student summarizes all that he/she has learned about the subject, then reflects on his/her actions and obtains an overview of the newly formed network of relations now available (e.g. properties of a figure are summarized) (pp. 7-8).

According to van Hiele, memorisation occurs at the end of the fifth phase and ordinary learning occurs. He believes that whilst the attainment of a new level cannot be effected by teaching, a teacher can create, by a careful choice of exercises, an environment that enables the student to attain the higher level of thinking. He went on to say that "You can say somebody has attained a higher level of thinking when a new order of thinking enables him, with regard to certain operations, to apply these operations on new objects" (1955, p. 289).

It appears that many researchers (Pegg & Davey, 1991; Frykholm, 1994; Whitman, 1994; Ahuja, 1996; Lawrie, 1998) believe that in the learning of geometry the van Hiele levels are useful. However, the research on the levels is aimed at the students and is often an attempt to verify van Hiele's work and to draw conclusions on the implications for curriculum planning. Van Hiele states that "The transition from one level to the following is not a natural process; it takes place under the influence of a teaching-learning program" (1986, p. 50). Teachers hold the key to this transition from one level to the next. Unfortunately, Brodie (1992) showed that primary school teachers in one region of NSW are generally not aware of van Hiele's research and that they dislike geometry. It is reasonable to suggest that the lack of knowledge about the van Hiele levels and the dislike of geometry by teachers contribute to poor student achievement.

Piaget, Vygotsky and van Hiele

Piaget (1896 - 1980) was a genetic epistemologist who was the first to introduce the concept of levels of learning. He believed that progress from one level to the next was due to biological changes and that the higher level was innate and was attained when students became aware of it. According to Piaget (1970), mathematical structure was the basis of, and defined, the whole structure underlying cognitive development. Piaget's four levels of development are: Sensorimotor (0-2 years); Preoperational (2-7 years); Concrete operational (7-11 years) and Formal operational (11-adult).

Vygotsky (1896 - 1934) was a contemporary of Piaget. In an attempt to understand cognitive processes, Vygotsky tried to work out the formation of intellect by focussing on its process of development. He concluded that individual intellectual development could not be understood without reference to the social and cultural context within which the development occurs. Vygotsky stressed the importance of language in learning development. He did not focus on stages of development like Piaget but rather focussed on development throughout life and, in doing so, was perhaps the first advocate of lifelong learning.

There has been much debate about the relationship between the ideas of Piaget and Vygotsky. Generally speaking, the debate centres on the fact that Piaget believed that children constructed knowledge through their actions on the world whereas Vygotsky claimed that understanding was social in origin. Cole and Wertsch (1996) believe that “in principle, Piaget did not deny the co-equal role of the social world in the construction of knowledge” (p. 1) and that “Vygotsky, contrary to another stereotype, insisted on the centrality of the active construction of knowledge” (p. 2). They concluded that the major difference between the work of Piaget and Vygotsky did not lie in the sociogenesis of mind but in the role that cultural artifacts play in constituting the two poles of the individual-social antinomy. Vygotsky sees the artifacts playing a central role in determining what and where the mind is and in doing so focuses on issues that do not have any corresponding concepts in the work of Piaget.

Even though van Hiele (1986) stated: “an important part of the roots of my work can be found in the theories of Piaget” (p. 5), he disagreed with much of Piaget’s theory. Van Hiele believed that Piaget’s psychology was one of development and not one of learning and he was concerned that Piaget’s two levels (preoperational and concrete operational) could not accommodate learning in geometry, which according to him, required more than two levels of understanding. Indeed, van Hiele (1986), suggested that “Some of Piaget’s results would have been more intelligible if he had distinguished more than two levels”(p. 5). The fact that Piaget did not acknowledge the important role that language (as did Vygotsky) played in moving from one level to another, was also of concern to van Hiele.

Van Hiele was particularly concerned that Piaget did not understand that structures of a higher level were the result of study of the lower level. In van Hiele’s theory if a structure, which is a given thing obeying certain laws, was a strong structure it was usually possible to superimpose a mathematical structure onto it whereas in Piaget's theory the mathematical structure always defined the whole structure.

Piaget believed that children were born with the higher structure and needed only to become aware of it whereas van Hiele believed that the rules of the lower level became the structure of the higher level. For van Hiele structure is everything. However, it was his interest in the work of Piaget that ultimately led him to identify the role of language in learning, levels of thinking and the way in which students moved from one level of understanding to the next.

Whilst there has been much comment on the relationship between Piaget's and Vygotsky's work (Cole & Wertsch, 1996; Nicholl, 2002) and some comment on the relationship between Piaget's and van Hiele's work (Brodie, 1992) there appears to be no research on the relationship between van Hiele's and Vygotsky's work. Van Hiele believed that cognitive growth occurs through a series of stages or levels whereas Vygotsky did not. However, both van Hiele and Vygotsky accepted the importance of language in the development of the intellect. Van Hiele (1986) stated "Piaget did not see the very important role of language in moving from one level to the next" and Vygotsky (1978) stated "the child begins to perceive the world not only through its eyes but also through its speech. And later it is not just seeing but acting that becomes informed by words" (p. 32).

Similarly, van Hiele and Vygotsky unlike Piaget, accepted the need for teaching to improve the learning of a student. Van Hiele (1986) stated "The transition from one level to the following is not a natural process; it takes place under influence of a teaching-learning program" (p. 50) and Nicholl (2002) stated "Vygotsky's approach of scaffolding and guided discovery suggests that a guiding hand by the teacher is critical for effective learning".

Van Hiele and Vygotsky were both contemporaries of Piaget and all three were constructivists. Van Hiele, and Vygotsky saw the role of the teacher and the role of language in the construction of knowledge by an individual as crucial while Piaget did not. However, in a Piagetian classroom the teacher's role is to provide a rich environment for the spontaneous exploration of the child. Piaget and van Hiele believed that individuals passed through levels of learning but Vygotsky did not. Piaget did not consider society or its culture to be crucial to learning but Vygotsky considered it essential.

The Structure of the Observed Learning Outcome (SOLO) Taxonomy

Whilst the work of Piaget, Vygotsky and van Hiele needs to be considered when determining the best approach to the teaching of Geometry it should be noted that Pegg (perhaps the most knowledgeable researcher in Australia on van Hiele's work) and Davey (1989), determined that a comparison between the level descriptors of the van

Hiele theory and the SOLO taxonomy should be researched. They used descriptions of common two-dimensional geometric shapes written by students in grades three to seven as the basis for the comparison. Before commenting on the results a brief look at the SOLO taxonomy is appropriate.

Biggs and Collis (1982) first described the SOLO taxonomy. In 1986 Courtney suggested that the SOLO taxonomy was “a five level hierarchy which was designed to help teachers evaluate the quality of students’ thinking” (p. 47). The stages of the taxonomy, together with the age at which the SOLO modes can be expected to emerge given an appropriate teaching/learning environment, are:

1. **Prestructural:** pre-operational developmental base stage - 4-6 years old.

2. **Unistructural:** early concrete developmental base stage - 7-9 years old.

3. **Multistructural:** middle concrete developmental base stage - 10-12 years old.

4. **Relational:** concrete generalisation developmental base stage - 13-15 years old.

5. **Extended Abstract:** formal operations developmental base stage - 16+ years old.

Each of the levels is defined in term of *capacity, relating operation* and *consistency, and closure.* Biggs and Collis (1982) stated:

> **Capacity** ... refers to the amount of working memory or attention span ... **Relating Operation** ... refers to the way in which the cue and the response interrelate ... [and] **Consistency and Closure** ... refer to two opposing needs felt by the learner: one is the need to come to a conclusion (to close) and the other is to make consistent conclusions so that there is no contradiction either between the conclusion and the data, or between different possible conclusions (pp. 26-27).

The van Hiele theory explores the manner in which students develop understanding of a topic whereas the SOLO taxonomy provides a method of evaluating the learning that has taken place.

According to Pegg and Davey (1989), however, the results of their research indicated that the SOLO taxonomy more accurately described the quality of student thinking when compared to the van Hiele theory. This conclusion resulted from Pegg's belief that "The SOLO taxonomy identifies the concentration on 'one aspect' as unistructural where the van Hiele theory does not" (p. 25) and because Pegg believed that it was possible that van Hiele saw the identifying of one property and of many properties as horizontal growth whereas his research indicated that "there was a 'vertical' growth associated with the move from identifying one property to that of identifying many properties of a figure” (p. 25). However, a consideration of van Hiele’s work, indicates that he defined five phases in the learning process through which he believed students must pass to move from one level to the next.

Courtney (1986) concluded that the SOLO taxonomy had broad curriculum applicability and could make a substantial contribution to improved teaching and learning. While his work does not specifically refer to geometry (it actually was written for the Australian Geography Teachers Association) it complements the research by Pegg and Davey as he saw the SOLO taxonomy as relevant to all teachers. Biggs and Collis (1982) devote a chapter to the SOLO taxonomy and mathematics. Whilst not specifically mentioning geometry, they stated:

> ...it would appear reasonable that in content-process areas we would expect mainly unistructural responses in the early years of elementary school, multistructural in the later years of elementary school, relational in early and middle high school, and extended abstract only from those at the upper levels of high school who have chosen to put a lot of effort into mathematics. ... The teacher faced with a particular student at a particular time working on a specific problem needs to be able to ascertain the real level of functioning and work from that point and not subsume the individual child under the general rubric (pp. 90-91).

Units of Work Based on van Hiele's Levels

There have been attempts to develop units of work based on van Hiele levels but the validity of the units has not been tested. Flores (1993) developed a unit of work on Pythagoras' theorem in the context of the van Hiele levels. He showed that at each of the van Hiele levels it was possible to develop an understanding of Pythagoras' theorem. As the complexity of the application of Pythagoras' theorem increased, the higher the van Hiele level needed to understand the application, for example, at van Hiele level 1 (Recognition), Flores illustrated the theorem with tangrams and at van Hiele level 4 (Deduction), he used the proof of Euclid's Proposition 47. Craine and Rubenstein (1993) produced a hierarchical structure of quadrilaterals to illustrate the learning of a geometric concept by moving from the van Hiele levels of visualisation and analysis through the level of informal deduction to the level of formal deduction. They developed a quadrilateral hierarchy chart that required van Hiele level 1 understanding and extended the chart using understanding associated with each van Hiele level so that the properties of the quadrilaterals were discovered or recognised by the students and the students' concept of definition and its role in a formal system was expanded and strengthened. Pegg and Davey (1991) produced three activities; descriptions, minimum properties, and class inclusion to assess the van Hiele level of students' geometric understanding. They found that students provided different descriptions as they grew in geometric understanding and that the activities they developed could be used to determine a student's van Hiele level of understanding and as such were a useful tool for teachers.

With increased student access to computers, software based on the van Hiele levels is being developed. In America the second edition of the book *Discovering Geometry* (Serra, 1997) is based on the van Hiele levels in keeping with the *Curriculum and Evaluation Standards for School Mathematics (1989)* developed by the National Council of Teachers of Mathematics. It leads students to discover and master concepts and relationships before they are introduced to formal proofs and it makes use of software developed for use with the book.

Van Hiele Levels and Three-Dimensional Geometry

Saads and Davis (1996) investigated the van Hiele levels using three-dimensional geometry and the spatial abilities of a group of pre-service secondary teachers in Southampton, England. They gave a written test to 25 students enrolled in secondary initial teacher training. The test consisted of seven questions containing sub-questions and was designed to access Del Grande’s spatial perception categories. Del Grande (1987) suggested that associated with geometric understanding is a developing sense of general spatial perception. He proposed seven spatial abilities that seemed to be of greatest relevance in academic development in geometry. Five of these: perceptual constancy, figure ground perception, position in space perception, visual discrimination and spatial relationships were used in Saads and Davis’ test. The test reliability was measured using the Kuder-Richardson inter-term reliability method. This method produces a reliability coefficient between 0 and 1 for each item. As the reliability coefficient for question 5 was very low it was removed from the test scores.

A modification of the Gutiérrez, Jaime and Fortuny (1991) coding system was used by Saads and Davis to construct a table of the results. These results showed that the van Hiele levels could be applied to 3-dimensional geometry, supported the hierarchical structure of the van Hiele levels and supported the non-hierarchical structure of the Del Grande Spatial Perception categories.

This research is interesting to the researcher as it linked the van Hiele levels of geometry with preservice teachers and because it indicates that a van Hiele level test may be coded in more than one way. Hence, the coding to use in the present research will have to be determined after careful consideration of the research available for each of the coding methods.

The Transition between the van Hiele Levels

Gutiérrez, et al. (1991) concluded that the van Hiele levels were not discrete and suggested a way of identifying students who were in transition between the van Hiele levels. They based their conclusion on the fact that:

> Although most students show a dominant level of thinking when answering open-ended questions, a large number of them clearly reflect in their answers the presence of other levels, and there are some students whose answers show two consecutive dominant levels of reasoning simultaneously (p. 237).

In support of their conclusion they quoted the work of Fuys, et al. (1988) who assigned a student to Level 1-2 to indicate that the student used both levels of reasoning for a certain activity.

Gutiérrez, et al. (1991) suggested that the acquisition of a specific van Hiele level did not happen instantaneously but rather took months or even years to attain. They quantified the acquisition by using a scale of 0 to 100 divided into five periods which were characterised by the qualitatively different ways in which the students reasoned. Below is a representation of the scale. It should be noted that the values assigned to the limits by the researchers were subjective.

Table 2.1:

Degrees of Acquisition of a van Hiele Level according to Gutiérrez, Jaime & Fortuny (1991)

Period	Range
No Acquisition	0 to 15
Low Acquisition	>15 to 40
Intermediate Acquisition	>40 to 60
High Acquisition	>60 to 85
Complete Acquisition	>85 to 100

To explain their conclusion, Gutiérrez et al. (1991) reasoned that initially students were not conscious of the thinking methods specific to a new level and hence had *No Acquisition* of this level of reasoning but once students were aware of the methods of thinking at a particular level they tried to use them but failed due to their lack of experience and hence returned to the lower level. Such students were said to have *Low Acquisition* of the level. They believed that the students then progressed through an *Intermediate and High Level of Acquisition* as their experience grew until the students attained *Complete Acquisition* of the new level at which time they had complete mastery of this way of thinking and used it without difficulty.

To assign students to a specific degree of acquisition of a level the researchers assessed the students using a series of open-ended items and criteria for evaluating their responses to each item. For each item the student's response was assigned a score related to the acquisition scale. The criteria were divided by Gutiérrez et al. (1991) into eight types as in Table 2.2 below.

Table 2.2:

Degrees of Acquisition of a van Hiele Level Scale according to Gutiérrez, Jaime & Fortuny (1991)

Type	Criteria
Type 0	No reply or answers that cannot be codified
Type 1	Answers that indicate that the learner has not attained a given level but that give no information about any lower level
Type 2	Wrong and insufficiently worked out answers that give some indication of a given level of reasoning: answers that contain incorrect and reduced explanations, reasoning processes or results.
Type 3	Correct but insufficiently worked out answers that give some indication of a given level of reasoning: answers that contain very few explanations, inchoate reasoning processes, or very incomplete results.
Type 4	Correct or incorrect answers that clearly reflect characteristic features of two consecutive van Hiele levels and that contain clear reasoning processes and sufficient justifications.
Type 5	Incorrect answers that clearly reflect a level of reasoning; answers that present reasoning processes that are complete but incorrect or answers that present correct reasoning processes that do not lead to the solution of the stated problem.
Type 6	Correct answers that clearly reflect a given level of reasoning but that are incomplete or insufficiently justified.
Type 7	Correct, complete, and sufficiently justified answers that clearly reflect a given level of reasoning

The weightings from the “*Degrees of Acquisition of a van Hiele Level Scale*” were assigned as in table 2.3 below.

Table 2.3:

Weights of Different Types of Answers as suggested by Gutiérrez, Jaime & Fortuny (1991)

Type	Weight
0	0
1	0
2	20
3	25
4	50
5	75
6	80
7	100

The open-ended test items were produced using 3-dimensional geometry and were related to a particular van Hiele level. A vector (level, type) was assigned to each answer where “level” is the van Hiele level and “type” is the type of answer. If “type” was zero, “level” was considered empty. The degree of acquisition of a van Hiele level by a student was determined by calculating the arithmetic average of the weights of the vectors for all the items that could have been answered at that level.

The subjective application of a rating to the acquisition scale and its subsequent use in the calculating of an arithmetic average is questionable. Earlier it was noted that van Hiele suggested that progress from one level to the next involved moving through five phases. It is possible that the five periods of Gutiérrez et al. (1991) are just another way of viewing van Hiele's five phases. The need for the *complete acquisition* stage to be reached before a student is classified as operating at the higher level supports this assumption. It could be concluded, therefore, that this research does not necessarily discredit the discreteness of the van Hiele levels but rather reinforces the van Hiele theory.

Comments

The van Hiele levels have generally been accepted as a reasonable explanation as to how students learn geometry. The van Hiele theory, originally developed using 2-dimensional Euclidian geometry has been shown to apply to other areas of geometry. Whilst there is some disagreement on the number of levels and what they should be named the last or highest level has proven to be difficult, or impossible, to measure in a test.

It appears generally accepted by educationalists and psychologists that students pass through phases as they pass from one van Hiele level to another. Research and analysis of the phases was completed by de Block-Docq (1992) in a doctoral thesis in which she replicated Dina van Hiele-Geldofs lessons.

Units of work based on the van Hiele levels have proved useful to students and teachers. More use of software seems to hold the key to meeting the needs of some of the new curriculums produced both in Australia and overseas.

As indicated by Pegg and Davey (1989), the SOLO taxonomy continues to be useful to teachers of geometry. Their research on the overlap of van Hiele’s levels with the taxonomy, however, appears to be the only research that has been done in this area.

The work of Piaget and van Hiele suggests that students proceed through levels of understanding. Van Hiele believes that Piaget’s first two levels are not sufficient to explain the way in which students learn geometry. Vygotsky and van Hiele believe that language and teacher intervention is crucial to learning.

Fuys, et al. (1988) suggested that the transition by a student from one van Hiele level to another involved the student passing through five periods. Van Hiele suggested that students pass through five phases as they move from one level to another. It is possible that the five periods of Fuys, et al. (1988) are just another way of viewing van Hiele’s five phases.

Conclusion

Van Hiele believes that teacher intervention is crucial to student achievement of levels of understanding in geometry. He also believes that if individuals operate at different levels that ineffective rote learning occurs. Pegg and Davey believe that the van Hiele levels are basic to improving the teaching of geometry. Therefore, it is important then, that preservice teachers have an understanding of van Hiele's model and are aware of their level of understanding in geometry. This would allow them to teach effectively the subject matter by guiding their students through the phases of each level and through the levels themselves. Failure to do this would result, according to van Hiele, in rote learning in which students memorise the *right* answer without understanding.

As noted before (see Chapter 1), teachers must know and understand the mathematics that they are teaching if they are to be effective teachers. According to van Hiele, it is only at level 3 that an individual has a comprehension of the essence of geometry. Therefore, to teach geometry effectively, a teacher needs to be at least at van Hiele level 3. Hence, it is important to determine the van Hiele level of the preservice teachers in this research. This data may lead to a reduction in the current apprehension about geometry in teachers and their students. Such a reduction may lead to more success in geometry in Australian school students and an improvement in Australia's knowledge economy.

Van Hiele believes that level of understanding in geometry is not related to a particular age even though he believed that age was important to understanding. He stated (1986): “It would, however, be a deplorable error to suppose that a level is attained as the result of a biological maturation” (p. 65) and “The age of the children is important, in so far as they must have had sufficient time to go through the necessary learning processes” (p. 65).

Hence, the relationship between van Hiele level and age should also be examined as the result of this research may indicate the need to change current teaching methods in geometry.

These conclusions generate the following research questions:

1. What is the van Hiele level of preservice teachers?

2. What affect does gender, age and education have on the acquisition of geometric knowledge by an individual?

Chapter 3

THE MEASUREMENT OF ATTITUDE

Some painters transform the sun into a yellow spot, others transform a yellow spot into the sun ... Picasso

In this chapter the researcher reviews the existing definitions of attitude and the methods of measuring attitude in order to determine a valid and reliable way to measure the attitude of student teachers towards geometry. The chapter contains the history of attitude measurement, definitions of attitude, the effects of attitude, methods of measuring attitude and attitude scales.

The History of Attitude Measurement

In the latter part of the nineteenth century, according to Boring's (1929) *"A History of Experimental Psychology",* Fechner (1860), who had an interest in psychology and physics, performed experiments to determine the relationship between the mind and the body, sensation and stimulus. He and other psychophysicists such as Muller (1878) and Titchener (1902), attempted to determine how physical intensity was related to psychological intensity. They tried, for example, to determine how the physical intensity of light measured in foot candles was related to its psychological brightness and how the physical intensity of a noise measured in decibels was related to its psychological loudness. The problem was how to measure “psychological brightness” or “psychological loudness”. According to Dawes (1972), the most common method developed to do this was the *just noticeable difference* method (later called the method of limits). In this method a stimulus was defined to be just noticeably different from another if it was actually perceived by subjects to be more intense than the other with a probability of 0.5. Thus a stimulus that was just noticeably more intense than another was judged to be more intense with probability 0.75, calculated by adding 0.5 (the subject’s probability of choosing the correct stimulus) to 0.25 (probability of guessing whether it was more intense or not (0.5 X 0.5)). These just noticeable differences (j.n.d’s.) were regarded as units of psychological intensity. Other methods included the method of right and wrong cases (later called the constant method) and the method of average error. Each of the methods was both an experimental procedure and a mathematical treatment. Due to his work Fechner is credited with being the founder of experimental psychology.

Thurstone and Chave (1928), took an interest in the work of the social psychologists and suggested that the *just noticeable difference* method could be used in contexts where there was no physical dimension to go with the psychological dimension under investigation. Dawes (1972) stated:

> He [Thurstone] argued that although we happen to be able to measure physical intensity of light in terms of foot candles, this ability is in no way essential to our constructing a psychological brightness scale by the method of just noticeable differences. Such a scale could be equally well constructed if we did not have any idea of how to measure the physical intensity of light (p. 5).

Thus Thurstone proposed that the *just noticeable difference* method could be used to measure the psychological intensity of any stimuli, including the intensity of attitudes, on any dimension of interest. For example, using probabilities two crimes may be positioned on a dimension of “judged seriousness”. In doing this Thurstone provided a way for educational researchers to measure the attitude of an individual to a range of items. Hence, whilst the measurement of attitude had been a concern of social psychologists for many years, its adoption by educational researchers through the work of Thurstone occurred very soon after the social psychologists showed an interest in it.

The Effects of Attitude

This researcher believes attitudes are important in our current society. The attitudes of any one group of people can profoundly affect the lives and successes of another group of people. The influence of teachers on their students is well documented (Deighan, 1971; Phillips, 1973; Bishop & Nickson, 1983; Haladyna et al. 1983; Bobis &

Cusworth, 1995; Zammit, et al., 2002) and the attitudes of teachers to their teaching subjects can have a profound effect on the attitudes and success of their students. Also, it has long been believed that teacher enthusiasm for the subject has a positive affect on the learning of their students. For example, Suydam and Weaver (1975) stated:

> Teachers and other mathematics educators generally believe that children learn more effectively when they are interested in what they learn and that they will achieve better in mathematics if they like mathematics. Therefore, continual attention should be directed towards creating, developing, maintaining and reinforcing positive attitudes (p. 45).

> Although it is certainly unfair to indict teachers too strongly as creators of negative student attitudes towards mathematics, the results of research have suggested that the teacher, perhaps even more than the parents, is an important determiner of student attitudes (p. 589);

Cockcroft (1982) put it this way:

> During every mathematics lesson a child is not only learning, or failing to learn, mathematics as a result of the work he is doing but is also developing his attitude towards mathematics. In every mathematics lesson his teacher is conveying, even if unconsciously, a message about mathematics which will influence this attitude. Once attitudes have been formed, they can be very

> persistent and difficult to change. Positive attitudes assist the learning of mathematics; negative attitudes not only inhibit learning, but … very often persist into adult life … (p. 101);

and the NSW Department of School Education (1989) stated: “Students’ feelings are often strongly influenced by their teacher’s attitude towards mathematics. This is well documented in the case of girls. (p. 18);

McLeod (1992) stated, “affective issues play a central role in mathematics learning and instruction” (p. 575) and Grootenboer (2003) stated, “There has been concern for some time that preservice primary school teachers hold negative views of mathematics and their views influence their mathematical teaching practice (p. 413).

Hence, if teachers do not have a positive attitude towards a subject, it is likely that this will influence the success of their students who will tune into the teacher’s non-positive attitude. In 1974 the Oregon Department of Education considered the fostering of positive attitudes toward learning so important that they legislatively mandated the fostering of positive attitudes towards learning in their minimum standards for public schools.

The belief, however, that there exists a strong relationship between attitude towards mathematics and success in mathematics is not shared by all as whilst there has been much research into the relationship between attitude towards mathematics and success in mathematics the results of the research are not conclusive. Antonnen (1969), after a six year study, found there was a statistically significant correlation between the two and Enemark and Wise (1981) concluded that achievement in mathematics is significantly influenced by attitudinal variables. However, Robinson (1975) concluded that attitude towards mathematics accounts for, at best, 15% of the variance in achievement in mathematics. Neale, Gill and Tismer (1970), found significant correlations between attitudes and achievement in a range of school subjects including arithmetic but Cockcroft (1982) cautioned against “overoptimism in assuming a very direct relation between attitude and achievement” (p. 61).

Significantly, the report in 2002 on TIMSS-1998 stated: “Across countries and in Australia, more positive attitudes were related to higher achievement scores, so the fostering of more positive attitudes towards mathematics … is to be encouraged” (p. 163).

After reviewing data linking Attitude To Mathematics (ATM) and Achievement In Mathematics (AIM), Ma and Kishor (1997) suggested that:

> One point that deserves emphasis is that the small effect sizes of both the general and the causal ATM-AIM relationship implicitly indicate that the current attitude measures are very crude approximations to “true” attitudes, and that researchers should put more effort into substantially refining these measures. ... Perhaps the best solution, before more advanced attitude

> measures are developed, is to measure specific attitudes towards certain mathematical areas or activities (e.g., arithmetic, problem solving) rather than a generalized attitude towards mathematics as a whole. (p. 38)

Ma and Kishor's research raises two issues. One is that attitude scales studied in their 1997 research were primitive and the other is that reliability of an attitude measure should improve if an attitude to a section of mathematics is found rather than attitude to mathematics in general. This proposition was raised as early as 1975 when Fishbein and Ajzen strongly supported the concept of measuring *attitude to* a target topic so that the particular attitude being measured was related to a narrower definition of the topic rather than a global definition of the topic. The first point that Ma and Kishor make could be a result of their ignorance of the existence of the various methods used to measure attitude as they do not mention the actual scales nor indicate a familiarity with them. Hence it is difficult to determine if their criticism of them being primitive is justified or not. Also, the analysis of the scales of today are supported by much more powerful computer software programs that enable better scales to be produced and interpreted. However, it would be true to say that the attempt to close the gap between definition and measurement of attitude is an ongoing challenge. Ma and Kishor's second point is worthy of support as "mathematics" is such a broad term to measure *attitude to* and it is difficult to determine what is actually being measured. Today, there has been a move from global attitude measurements to specific attitude measurements, for example, the Fennema-Sherman Mathematics Attitude Scales.

Allport (1935), quoted in Dawes (1972), stated “attitudes today are measured more successfully than they are defined” (p. 2). Fishbein and Ajzen (1975) reviewed research on attitudes published between 1968 and 1970 and found that there was little agreement about what constituted an attitude. This is still true in 2004. However, even though it is suggested that it is easier to measure attitude than to define attitude, it does not follow that it is easy to measure attitude *successfully* especially considering Ma and Kishor’s criticisms. Dawes (1972) stated that “simply asking a man whether he supports his president or requiring him to put a check mark on a rating scale does not necessarily result in anything being measured, especially not the man’s attitude” (p. 2). In making this statement, however, Dawes appears to ignore the research of Osgood, Suci and Tannenbaum (1957), and Heise (1969). Later research (Heise, 1970; McCallum & Brown, 1971; Schibeci, 1982; Leder, 1985) does not support Dawes’ statement as their research indicates strong support for the use of rating scales.

The aim in the present research then is to review the existing definitions of attitude and the methods of measuring attitude to develop a valid and reliable way to measure the attitude of student teachers to geometry.

Definitions of Attitude

The Macquarie Dictionary (2nd. Edition) defines attitude as *"manner of behaviour, or disposition, with regard to a person or thing"* (p. 147). Early definitions of attitude include:

A: a process of individual consciousness which determines real or possible activity of the individual in the social world (Thomas & Znaniecki, 1918, p. 22).

B: the sum total of a man's inclinations and feelings, prejudice or bias, preconceived notions, ideas, fears, threats, and convictions about any specific topic (Thurstone & Chave, 1928, p. 532).

C: a mental and neural state of readiness, organised through experience, exerting a directive and dynamic influence upon the individual's response to all objects and situations with which it is related (Allport, 1935, p. 810).

D: an enduring organisation of motivational, emotional, perceptual, and cognitive processes with respect to some aspects of the individual's world (Krech & Crutchfield, 1948, p. 152).

E: a syndrome of response consistency with regard to social objects (Campbell, 1950, p. 31).

F: a learned predisposition or tendency on the part of an individual to respond positively or negatively with moderate intensity and reasonable intensity to some object, situation, concept, or other person (Aiken, 1970).

Later definitions of attitude listed below, have retained the important features of these definitions:

A: an idea charged with emotion which predisposes a class of actions to a particular class of social situations (Triandis, 1971, p. 2).

B: a learned predisposition to respond in a consistently favourable or unfavourable manner with respect to a given object (Fishbein & Ajzen, 1975, p. 6).

C: a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor (Eagly & Chaiken, 1993, p. 1).

These later definitions imply three assumptions about attitude (see Figure 3.1):

1. It is, generally speaking, learned (the **cognitive** component ... the idea)
2. It predisposes an individual to a favourable or unfavourable response (the **behavioural** component ... the action)
3. It causes response consistency (the **affective** component ... the emotions)

Social scientists (Katz & Stotland, 1959; Rosenberg & Hovland, 1960; Eagly & Chaiken, 1993) suggest that responses that express evaluation, and therefore reveal people's attitudes, should be divided into three classes: cognitive, affective and behavioural. This is illustrated in figure 3.1 below.

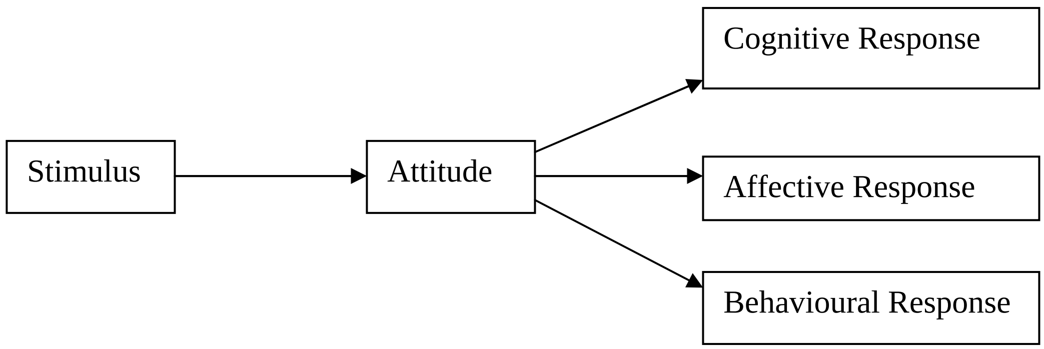

Figure 3.1: Attitude with evaluative responses divided into three classes.

Instruments commonly used to measure attitude to mathematics attempt to take into consideration the cognitive, behavioural and affective components and according to Dwyer (1993) researchers reflected these three components of attitude in their studies (Chein, 1950; Greenwald, 1968; Hassan & Shrigley, 1984).

Dwyer (1993), commenting on the work of Triandis (1971), stated that:

> The cognitive component of attitude was described ... as the ideas or beliefs that subjects have about an attitudinal object, the object, in this context, being the focal point of the attention. The affective component was described as the emotions or feelings about the attitudinal object, while the behavioural

component was described as predisposition to action with regard to the same object (p. 2).

The important point here is that it appears that any attempt to measure attitude should, if possible, take these three components into consideration. The behavioural component could possibly be measured by observation or through analysis of verbal statements whilst the cognitive and affective components could possibly be measured through self-report methods. However, if attitude is to be simply measured as a single dimension and reported as a single score, it appears to this researcher that the measurement of the affective part of the attitude concept, even though it cannot account for the full complexity of attitude, should give the most accurate results.

In the past some attempts to measure attitude have included methods which rely on the combination of results. Unfortunately, the moment an individual’s total score has been calculated it assumes a mystical significance of its own even though some combinations yield quantifiable data which is meaningless. One study to determine the attitude of students to science relied on the combination of the students’ attitude to scientists, attitude towards science and attitude to understanding the scientific method, but at no time in the research did the researcher justify his belief that attitude to these items could be combined to give a student’s attitude to science in general. This study (Selmes, 1971, reported in Gardner, 1975b) thus demonstrates the importance of a clear theory detailing the conceptualisation of attitude. Gardner (1975a) believes that many attitude scales suffer from this defect in that they “attempt to reduce multi-dimensional attributes to single scores" (p 101). Fortunately, today the use of Structural Equation Modelling (SEM) allows the analysis of multi-dimensional scales thus enabling the determination of the relative contribution of each dimension to an outcome without the need for a total single score.

Today, the observation method and the self-report method are used to measure attitude. The remainder of this chapter is devoted to an outline, and discussion of, both methods.

The Observation Method

As noted above, observation of an individual's behaviour can be used to measure that individual's attitude to a topic. This conclusion is based on the assumption that attitude can be inferred from the observation of overt behaviour. However, there are problems with this method. For example, an individual's affective characteristics can incorrectly be inferred from the individual's behaviour and difficulties can occur when determining which behaviour to observe and how to record the behaviour. Also, it is possible for an observer to misrepresent the behaviour of an individual.

Anderson (1981), cited in Dwyer (1993), proposed solutions to these problems with the observation method. In response to the first problem he suggested that correct inferences are more likely to be made when multiple observations are made of the same behaviour in the same setting over time and in response to the second problem he suggested that if the affective characteristics are clearly defined and care is taken to only observe these in an appropriate context, then correct conclusions should be drawn. To overcome the third problem Anderson suggested using teams of trained observers in the same setting to minimise misinterpretation.

Purkey, Cage and Graves (1973) produced an interesting research design which paired observational research with quantitative research methodology to assess affective characteristics of students at two elementary schools in Florida using observation and self-report methods. However, they found only a modest relationship between the two results.

The Self-report Method

The self-report method involves rating scales and physiological measures both of which involve individuals responding to questions or statements about a topic or indicating how descriptors best describe their feelings towards a topic. Responses are usually scored in terms of positiveness towards the topic and in some instances the responses are summed to attain a total score.

It is appropriate to note here at the outset some problems of the self-report method. One problem is that individuals may supply answers that they think the researcher wants or answers that are socially acceptable rather than answering how they truly feel about the subject. Another problem involves what is known as acquiescence, where an individual who is unsure of his/her response has a tendency to agree with the question.

Thurstone and Chave (1929) offered the following advice to researchers on these two problems:

> All that we can do with an attitude scale is to measure the attitude expressed with the full realization that the subject may be consciously hiding his true attitude or that the social pressure of the situation made him really believe what he expresses ... All we can do is minimise as far as possible the conditions that prevent our subjects from telling the truth, or else to adjust our interpretation accordingly (p. 10).

Other researchers studied these problems which were given the term *Evaluation Apprehension* (Silverman & Shulman, 1970; Fishbein & Ajzen, 1975; Warshaw, Calantone & Joyce, 1986). Silverman and Schulman (1970) suggested that when evaluation apprehension was produced by the experimental setting, the subject tended to respond in a manner that enhanced their self-presentation irrespective of the perceptions concerning the experimenter's expectation. Warshaw et al. (1986) reported that "the finding suggests that self-presentation considerations might cloud self reports when socially desirable behaviour like blood donation is investigated" (p. 136).

However, Fishbein and Ajzen (1975) grouped the reactive effects of conducting experimental manipulations into three broad processes and regarded the separation of an experimental situation from the non-experimental as a false one, and one that inhibited the findings being applied to other settings. Their argument was based upon the observation that the processes and characteristics were not found only in experimental situations, “Since the same processes are likely to operate in any situation, reactive effects in an experiment can be viewed as specific instances of the kinds of variables that influence behaviour in general” (p. 121). Hence Fishbein and Ajzen argued that experimental situations were not atypical, but in fact were representative of most social situations.

1. Rating Scales

Rating scales attempt to assess an individual’s attitude by asking the individual to express that attitude in terms of a categorical or numerical rating. Hence, rating scales consist of categories, numbers or lines. The individual whose attitude is being measured is asked to choose a category or a number or to place a mark along a line.

(i) Attitude Scales: Many scales or methods have been developed to measure attitude. These include the Thurstone Scale developed by Thurstone and Chave in 1929, the Likert Scale developed by Likert in 1932, the Guttman Scale developed by Guttman in 1944 and the Semantic Differential Scale developed by Osgood et al. in

1957. The Thurstone and Guttman Scales are the least used today and a description of each is given below.

a) The Thurstone (equal-appearing interval) Scale. According to Thurstone the essential characteristic of his method of equal-appearing intervals is a series of evenly graduated opinions or statements so arranged that equal steps or intervals of the scale seem to most people to represent equally noticeable shifts in attitude. Briefly the method involves a group of individuals termed “judges” sorting statements about an attitudinal object which have been collected from literature and designated samples about a topic, into eleven piles which represent an evenly graduated series of attitudes from extremely negative (pile one) to extremely positive (pile eleven) towards the topic.

Using the results from the “judges” and some graphical analysis each statement is allocated a Q value (calculated by subtracting the lower quartile score of the item from the upper quartile score of the item) and either accepted or rejected depending on this value. The Q value is considered to be a measure of ambiguity and also a measure of dispersion of judgments for an item. The items not rejected are included in an attitude scale which as far as possible approximates a uniformly graduated series of scale values. Subjects are asked to tick each statement with which they agree and a measure of their attitude to the topic is calculated by either summing the scale value of each item ticked and calculating the arithmetic mean or summating the rank assigned to each item ticked and calculating the arithmetic mean of the ranks.

These are examples of statements from a Thurstone Scale developed by Dutton (1962) to measure attitude to arithmetic: *“I avoid arithmetic because I am not very good with figures”; “I think about arithmetic problems outside of school and like to work them out”.*

The “judges’ ” biases may have the potential to influence their ratings and could be built into a Thurstone Scale. Others such as Leder (1985) share this concern.

b) The Guttman Scale. A Guttman Scale is constructed using attitude statements which have a common content and which are ordered along a continuum from least positive to most positive. Agreement with a given attitude statement implies agreement with every other less positive statement along the continuum. Subjects are asked to tick each statement with which they agree. Agreement scores a 1 and disagreement scores an 0. The subject’s total score is the sum of their scores and indicates the subject’s attitude towards the attitudinal object. Data, from the subjects, are then analysed using a coefficient of reproducibility. Edwards (1957) suggested that the Guttman Scale is more a procedure for evaluating a set of statements about a topic rather than an actual attitude scale.

The scales most commonly used today are the Likert Scale and the Semantic Differential Scale. Most of the scales reported in Shaw and Wright (1967) are Likert Scales and some of the many studies done using them have been by Ray (1979), Ray and Miller (1987), Godfrey and Waugh (1998), Cavanagh and Dellar (2001), and Waters and McCabe (2003). Some of the many studies using the Semantic Differential Scale have been done by Welch (1973), Schibeci (1977), Milson (1979), Robinson (1980), Fry and Gard (1997), Clyne (1998), Godfrey and Waugh (1998) and Kelly (2002).

c) The Likert Scale. This is a popular scale for measuring attitude and it is less laborious to produce than either of the two previous scales. The scale was developed by Rensis Likert in 1932. Likert's primary concern was to develop a scale that measured a unidimensional construct, that is, all items were to measure the same thing. Likert (1932) stated that "Each statement should be of such a nature that persons with different points of view, so far as a particular attitude is concerned, will respond to it differently" (p. 44). Dwyer (1993), commenting on the work of Edwards (1957) and Sellitz, Jahoda, Deutsch and Cook (1959) referred to:

> ... the Likert scaling technique as the method of summated ratings because the total score for each subject is obtained by summing the subject's response to each item. The summated score, therefore, represents the degree of favourable or unfavourable attitude toward the object under consideration (p. 11).

In this method, statements that are clearly favourable or unfavourable to a topic are written or selected from literature and "judges" are asked to rate the statements as positive, negative or neutral with regard to the topic. Items that are classified as neutral by the majority of the judges are eliminated and a scale is produced using the remaining items. The criterion of internal consistency is used to determine the final make up of the scale. The criterion is applied by correlating item scores with total scores so that any item with a non-significant item to total score is eliminated.

There is some disagreement as to the ratio of favourable to unfavourable items in the original scale. Lemon (1973) suggested using a one to one ratio. Eagly and Chaiken (1993) also suggested a one to one ratio to “correct for acquiescence sets” (p. 76), but Hassan and Shrigley (1984) favoured using more negative than positive statements as they believed that more negatively stated items are eliminated in the consistency analysis thus leaving the final scale with approximately even numbers of positive and negative statements. Each argument indicates the need to carefully consider the use of negatively worded statements in a scale.

Subjects are asked to respond to each item using a fivepoint scale: 1. Strongly Disagree, 2. Disagree, 3. Undecided, 4. Agree and 5. Strongly Agree. (Actually any number of responses from two to seven can be used. An even number is used if the researcher wishes to eliminate the neutral position). The total score for each subject is obtained by summing the subject’s response to each item. The responses are weighted so that the most favourable response to a statement carries the highest weight. Hence the summated score represents a measure of the subject’s attitude to the topic.

The scale is administered to a sample population and the data is analysed to validate the scale. A revised final scale is constructed based on an analysis of the data collected.

Examples of statements from a Likert Scale developed by Trochim in 1997 to measure an individual's level of self-esteem (attitude) on a job are: *"I feel good about my work on the job"; "On the whole I get along well with others at work"; "I can tell that other people at work are glad to have me there".*

Eagly and Chaiken (1993) suggest that the Likert Scale has two disadvantages. One is that the scale does not have any internal checks for its representative measurement properties and the other is that the scale has no built-in tests of dimensionality. However, they state that with improved statistical methods these disadvantages could be overcome. Among many researchers today the preferred method for addressing this issue is to use Structural Equation Modelling. In Chapter 5 a more detailed description of Structural Equation Modelling is provided.

d) The Semantic Differential Scale. This scale measures the reaction of subjects to pairs of bipolar adjectives with meanings as nearly opposite as possible, for example, *good - bad*. The assumption is that overt responses to a stimulus are mediated by a set of conditioned responses that constitute the connotative meaning of the stimulus for the individual. The scale had its origin in research on synesthesia, which is defined in Osgood (1976) as:

> a phenomenon characterizing the experiences of certain individuals, in which certain sensations belonging to one sense or mode attach to certain sensations of another group and appear regularly whenever a stimulus of the latter type occurs (p. 26).

The developers of the Semantic Differential Scale determined that “the imagery found in synesthesia is on a continuum with metaphor, and that both represent semantic relations” (Osgood, 1976, p. 30). As a result of this understanding they produced three hypotheses which led to the development of the Semantic Differential Scale as a tool for measuring attitude to a concept. Osgood lists the hypotheses as:

> 1. The process of description or judgment can be conceived as the allocation of a concept to an experiential continuum, definable by a pair of polar terms.
>
> 2. Many different experiential continua, or ways in which meanings vary, are essentially equivalent and hence may be represented by a single dimension.
>
> 3. A limited number of such continua can be used to define a semantic space within which the meaning of any concept can be specified (p. 31).

Many studies into the attitude of individuals towards certain topics are concerned not only with whether the individual is favourably or not-favourably disposed towards the topic but also with the strength of feeling towards the topic. The Semantic Differential Scale provides the researcher with information on both these issues because positions on the seven point rating scale which are usually used, are allocated a weighting from -3 to +3, (though scales from 1 to 7 have been used) and hence both the direction and intensity of a reaction to a topic can be measured. The Semantic Differential Scale is relatively easy to develop due to the large quantity of research that has accumulated over four decades on the pairs of words, for example, the pair “good-bad” has been firmly established as a reliable evaluative pair (Yamamoto, Thomas & Karns, 1969; McCallum & Brown, 1971; Schibeci, 1977) and is frequently used today (see scale example below).

Factor analysis by the developers of the scale revealed that there were three basic dimensions of response: **evaluation** (a quality such as goodness or badness)**,** **potency** (“toughness” of feelings) and **activity** (expressing motion or action). It is usual for scales to contain items from all three dimensions, for example, good - bad (evaluation), hard - soft (potency) and fast - slow (activity). In constructing a scale the topic (attitudinal object) is placed at the top of the scale and is usually followed by ten bipolar word pairs separated by the seven point scale on which respondents place a mark to indicate how closely their feelings for the topic are represented by each of the pairs of words. “Research has shown that S-D scales with seven intervals are usually optimal” (Oppenheim, 1992, p. 237). The scores are summated and analysed to produce a measure of an individual's attitude to the topic. The issue of summated scores is addressed later.

The Semantic Differential Scale below is part of the one used by Godfrey and Waugh (1998), to measure school students' attitudes to cheating (p. 11):

CHEATING

Worthless –:–:–:–:–:–:– Valuable

Unnecessary –:–:–:–:–:–:– Necessary

Absurd –:–:–:–:–:–:– Intelligent

Beautiful –:–:–:–:–:–:– Ugly

Strong –:–:–:–:–:–:– Weak

Satisfactory –:–:–:–:–:–:– Unsatisfactory

Good –:–:–:–:–:–:– Bad

The semantic differential cannot be applied across all classes of evaluative responding as it relies on connotation not denotation. However, due to the use of adjectives heavily saturated with evaluative meaning it permits the researcher to obtain an attitudinal index quickly without the need to produce and scale belief items beforehand.

(ii) Inventories and Checklists: These are two examples of subjective rating scales. Inventories consist of a list of activities, hobbies or careers and the individual is asked to indicate which items are of particular interest to them. By studying the items chosen the researcher determines the attitude of the individual to certain topics. Adjective check lists require the individual to indicate the adjectives that they consider most applicable to themselves and are usually used to obtain self-descriptions. From these descriptions the researcher draws conclusions about the attitude of the individual to a topic.

(iii) Projective Techniques: These represent an indirect approach to attitude measurement. The technique involves an individual either completing sentences, or doing a word association or picture preference test or telling a story once given a cue.

2. Physiological Measures

Some research has been done on observing the relationship between physiological responses and affective states (Aiken & Dreger, 1957; Milliken & Spilka, 1962). This research usually involved the use of Galvanic Skin Response (electrical conduction of the skin), Pupillography (change in pupil size) or measurement of blood pressure and/or heart rate and/or breathing rate/breathing depth. However, because of the difficulties associated with obtaining these measurements, their use is limited. Also, researchers using these physiological measures, concluded that whilst extreme attitudes could be measured this way less strong attitudes were difficult to detect.

Discussion

The self-report method is most commonly used by those who wish to measure an individual's attitude (Leder, 1985). This is possibly due to the fact that the method is easier to apply and control than the observation method. The self-report method generally used today is the attitude scale with the Likert Scale and the Semantic Differential Scale being the ones most commonly used. Earlier researchers seemed to agree that the Semantic Differential Scale "may not be as sensitive as the Likert Scale" (Schibeci, 1982) and there is anecdotal evidence that attitude to terms like "racism" would be better measured with a Likert Scale whereas attitude to terms like "number" would be adequately measured using a Semantic Differential Scale. Today there is debate as to whether the scales actually measure the same construct (Eagly & Chaiken (1993). This research suggests that they do not.

Osgood et al. (1957) listed three hypotheses that formed the logical basis of the semantic differential scale and as a result believed that the content of many complex linguistic assertions such as "I don't think these politicians are to be trusted" could be reduced to the allocation of a concept to a scale, for example,

POLITICIANS

trustworthy __:__:__:__:__:_X_:__untrustworthy and that the greater the intensity of particular assertions such as “These Politicians are completely untrustworthy”, the more extreme became the allocation toward one or other of the bipolar terms. They also believed that the specific scale *trustworthy - untrustworthy* was an essentially evaluative judgment as the same speaker might well have said, “Politicians are no good”, and that it was this characteristic of language and thinking that made the development of a quantitative measuring instrument feasible.

Osgood et al. (1957) went on to show that some limited number of dimensions, or factors, was sufficient to differentiate among the meanings of randomly selected concepts. They determined that as the scale system finally selected satisfied the usual criteria of measurement, the data obtained with a semantic differential became an operationally defined index of meaning. Thus some variant of factor analysis was their basic methodology.

The Semantic Differential measures the connotative rather than the denotative meaning of concepts in semantic space. Osgood et al. (1957) comments on this as follows:

> This is a limitation. Both SIMON LEGREE and WAR might be allocated to approximately the same point in semantic space by our method. This would indicate similar connotative meaning, to be sure, but it would not indicate that these signs refer to the same object. Our differential will draw out the *hard, heavy, cold, ugly, threatening* connotations of the sign HAMMER, but it will

> not indicate that HAMMER is an "instrument for beating, breaking, driving nails, etc., with solid (usu. steel) head at right angles to handle" (The Concise Oxford Dictionary, 5th Ed., 1964). In part this limitation stems from our method of selecting descriptive scales in terms of frequency of usage rather than in terms of a logically exhaustive coverage (p. 35).

Osgood's semantic space has dimensions like a box. Just as boxes can be compared by their length, breadth and height so *perceptions of / attitudes to,* a topic can be measured using the dimensions of evaluation, potency and activity. Two socially different groups may score the same overall score on a semantic scale but the individual dimensions of the groups may differ.

There has been considerable investigation into the three factors associated with the Semantic Differential Scale to determine if each was a valid measure (Heise, 1969; Klemmack & Ballweg, 1973; Piotrowski & Dunham, 1984). The results indicate that the evaluative factor is the most reliable. Piotrowski (1983) stated:

> If the present findings can be generalized to other populations and concepts, it appears that the method of analysis ... is relatively unimportant for the Evaluation dimension (Factor I), but very important for the other dimensions (p. 288).

This view of the stability of the evaluative factor is common to reports on the Semantic Differential Scale but the data gained from the potency factor and the activity factor has been called into question (Norman, 1959; Piotrowski & Dunham, 1984). Hence, any analysis of data from a Semantic Differential Scale should involve separate analyses of the data from the evaluative, potency and activity bipolar pairs.

Table 3.1:

Bi-polar Pairs, in order, that best represent the Evaluative, Potency and Activity Factors

Evaluative	Potency	Activity
Good – Bad	Large – Small	Active – Passive
Nice – Awful	Strong – Weak	Sharp – Dull
Beautiful – Ugly	Heavy – Light	Hot – Cold
Honest – Dishonest	Thick – Thin	Angular – Rounded
Fragrant – Foul		Fast - Slow
Sweet – Sour		
Fair – Unfair		
Clean – Dirty		
Kind – Cruel		
Pleasant – Unpleasant		
Sacred – Profane		
Sweet – Bitter		
Valuable – Worthless		
Tasty - Distasteful		

When Osgood et al. (1957) became aware of these factors during their research they set out to choose those pairs which best represented the factors. After extensive analysis these pairs (Table 3.1 above) were shown to best represent, in order, each of the factors.

Osgood et al. (1957) noted that many of the pairs that rated highly on the potency and activity factors also rated well on the evaluative factor. They concluded that it was probably a characteristic of all cultures that potency and activity, rather than weakness and passivity, are positive values.

The Semantic Differential Scale is the simplest attitude scale to develop as the bipolar pairs have been extensively investigated, are freely available and have been used successfully in a variety of studies. The fact that a team of “judges” is not required to determine the appropriateness of a series of statements and the ease with which the data from the scale is interpreted also implies that such a scale is the best to use to measure attitude. The scale only measures the affective component of an individual’s attitude. However, as noted earlier, the affective component should give the most accurate results.

Some critics of the semantic differential technique believe that the adjective pairs may not seem to be related to the concept. Brodie’s (1992) scale was criticised by one respondent who could not see how *Hot - Cold* could in any way be related to Geometry. Brodie noted that the respondent did complete the scale and an analysis of the respondent's results yielded similar scores to the other respondents who did not criticise the scale. Osgood believed that the apparent irrelevance is in fact a strength, as it limits the tendency of a respondent to produce socially accepted responses. Fishbein and Ajzen (1980) reject the criticism of treating the complexity of attitude in a bipolar fashion suggesting that there is widespread agreement that the essence of attitude is contained in an individual's evaluation.

Comment

Considering the research on attitude measurement to date, the self-report method appears to be the most commonly used method in attitude measurement today. If the attitude of an individual is to be measured as a single dimension and reported as a single score, a Semantic Differential Scale can be used with confidence. Such a scale would give a reasonable measure of the strength of an individual's attitude to a topic even though it would only measure the affective component of the individual's attitude.

In a review of the use of the Semantic Differential Scale in attitude research, Heise (1970), concluded: "Most studies provide confirmation that the SD can be used to measure attitudes". (p. 247*).* Other research (Welch, 1973; Schibeci, 1977; Milson, 1979; Robinson, 1980; Fry & Gard, 1997; Clyne, 1998; Godfrey & Waugh, 1998; Kelly, 2002) indicates that SD ratings can be used in a variety of situations and yield valid results.

The Semantic Differential Scale needs to include bipolar pairs from the evaluative, potency and activity lists but would need to contain more evaluative pairs than pairs from the other two factors. Whilst it is usual to use ten bipolar pairs in the ratio E:P:A = 5:3:2 in light of the above it appears that it would be better to use twelve pairs in the ratio E:P:A = 6:3:3. This ratio maintains the 50/50 split of the ten bipolar pair scale.

The data from the three factors, if necessary, could be analysed separately and together and a consistency test applied to the results. To control the *halo* effect (Oppenheim, 1992, p. 231), that is, a tendency for a person answering to place crosses one under the other, the bipolar pairs' polarity would need to be randomised as would their order in the scale.

Given the comments of McCallum and Brown (1971), Schibeci (1977) and Ma and Kishor (1997), it seems that it would be appropriate to measure attitude in at least two ways so that the results can be compared. Hence, development of a Likert Scale as a second attitude instrument would be appropriate. It should be noted that the limiting of the measurement of attitude to a single concept, i.e., geometry, is in keeping with the findings of Ma and Kishor, (1997), for a Likert Scale.

McCallum and Brown (1971), Schofield and Start (1978), and Visser (1983) used Semantic Differential Scales and Likert Scales to measure students' attitude to mathematics. McCallum and Brown (1971) and Schofield and Start (1978) reported positive correlations between the scores on the two scales, and Visser (1983) reported that all the scales were reliable and valid.

Should it become necessary in this research to compare attitude to geometry with attitude to number and measurement as the researcher did in 1992, the attitude of the research participants to number and measurement will also be measured. As was done in 1992 the Semantic Differential Scale will be used.

The addition of the results obtained from the Semantic Differential Scale to produce an overall measurement of attitude and the addition of the results obtained from the Likert Scale to produce an overall measurement of attitude has been criticised by researchers (Gardner, 1975; Oppenheim, 1992). Oppenheim states:

> The most serious criticism levelled against this type of scale [Likert] is its lack of reproducibility (in the technical sense): the same total score may be obtained in many different ways. This being so, it has been argued that such a score has little meaning or that two or more identical scores may have totally different meanings. Often, for this reason, the pattern of responses becomes more interesting than the total score (p. 200).

Therefore, confirmatory factor analysis (CFA) using LISREL will be undertaken on the Likert and Semantic Differential Scales' items, the responses to which will be analysed using Structural Equation Modelling. Confirmatory factor analysis is a method whereby multi-dimensional scales are tested to determine if items load on the factor on which they are designed to load. For example, in the present research it is expected in CFA that items designed to measure, say, the affective component will significantly correlate only with like items while items designed to measure the behavioural component will correlate only with like items. In this way we can have confidence that the items discriminate between factors.

Conclusion

The attempt to close the gap between definition and measurement of attitude is an ongoing challenge. However, the Likert and Semantic Differential Scales have proven over four decades to be appropriate and valid instruments provided that the problems of a summated result, internal validity, acquiescence and the halo effect are addressed. Importantly, there is some discussion as to whether the scales actually measure the same construct.

Research into the relationship between attitude to mathematics and success in mathematics (Neale et al. 1970; Robinson, 1975; Enemark & Wise, 1981; Ma & Kishor, 1997; TIMSS-R, 1998) indicate attitude is an important variable in teaching and learning. “Attitudes [of students] are derived from teachers’ attitudes”, (Cockcroft, 1982, p. 61). Given the research (Phillips, 1973; Suydam & Weaver, 1975; Bishop & Nickson, 1983; McLeod, 1992; Relich, Way & Martin, 1994;TIMSS-R, 1998) linking teacher attitude to student success in, or knowledge of, a subject and linking preservice teachers' previous educational experiences with attitude, and the research (Thompson, 1992; Borko & Putnam, 1996), linking preservice teachers' attitude with how successfully they learn from teacher education experiences, it is important to validate a measure of attitude and to determine a student teacher's attitude to geometry. The relationship between the student teachers' attitude to geometry and their knowledge of geometry (as measured by their van Hiele levels) may help address the problem Australian teachers and students are having with geometry. The answer to whether the student teachers' attitudes to geometry mediates the effect of other factors such as gender, on their success in geometry may also assist in addressing Australian student underachievement in geometry.

The preceding raises a number of questions of which the foremost concerns the relationship of the three components of attitude (affective, cognitive and behavioural). While the present research does not control for the time factor, clearly behaviour has an impact on cognitive and affective processes and these in turn impact behaviour. Nevertheless, it is important to empirically establish that there is a relationship between these factors. The present research sets out to do this. As indicated above, it is unclear from a review of the research if there are measurement instruments that distinguish the affective and cognitive components of attitude. Hence, in the present research it is first necessary that this distinction be empirically validated. This issue is addressed in Chapter 5. In the present research the van Hiele levels are used as a measure of behaviour. Finally, a further issue touched on above is the relationship of gender, age and education with attitude. This issue is further addressed in Chapter 5.

Specifically then,

1. What is the attitude of preservice teachers to geometry?

2. Can affective and cognitive processes related to geometry be empirically differentiated?

3. What is the relationship of these factors with the behavioural factor of attitude as measured by the van Hiele levels of success in geometry?

4. What is the relationship of age, gender and education with the three components of attitude?

Chapter 4

BRAIN-BASED EDUCATION

A mind that is stretched by a new idea can never go back to its original dimensions.... Oliver Wendell Holmes

This chapter begins with a link to Chapter 2 that consists of an examination of the neurological basis for stages of cognitive development. The question as to whether the left/right brain preference of an individual could influence their knowledge of geometry is posed.

The chapter is divided into the following sections: the neurological basis for stages of cognitive development; education and left/right brain theory; brain-based education; the decade of the brain; a biological basis for intelligence; the 4-mat test for left/right brain preference; comments; conclusion.

A Neurological Basis for Stages of Cognitive Development

Van Hiele and Piaget believe that individuals pass through stages of cognitive development. Van Hiele puts little emphasis on maturation whereas Piaget believes that a major component in cognitive development is maturation. However, the two approaches need not be mutually exclusive if maturation is thought of in terms of “brain” maturation rather than “physical” maturation. (A type of “old head on young shoulders”).

Gazzaniga (1974) assumed that a young child was a split-brained individual as the neural fibres connecting the two hemispheres are the last to develop. As a result he believed that there was little interhemispheric communication until two years of age and that a young child laid down engrams (the residual effect of an experience in memory) in both hemispheres until eight years of age. At eight he believed that the specialisation process commenced. Witeson and Rabinovitch (1972) supported Gazzaniga’s views stating that: “The clinical literature indicates that in the first years of life speech representation is bilateral, but that lateralization of language does start in the preschool years and becomes permanently established during adolescence” (p. 412).

Brown and Jaffe (1975) believed that cerebral lateralisation continued throughout life. Turkewitz, Gordon and Birch (1965) suggested that evidence indicated that the right hemisphere of infants was specialised to process visuo-spatial stimuli. They found that 88% of newborn infants turned their heads to expose the left ear and left visual field to the environment thus indicating that the right hemisphere may be set at birth to process non-linguistic sounds and visual information. As much early learning is visuo-spatial the right hemisphere appears to be the most active hemisphere in prelinguistic life. As there is a wealth of research indicating that the left hemisphere is dominant in adults

(Wheatley, Frankland, Mitchell & Kraft, 1978; Richards, 1984; Kitchens et al. 1991) the shift in the ratio of use from right to left hemisphere must occur during childhood.

In light of this it would appear that van Hiele's Level 1 (Piaget's preoperational) and Level 2 (Piaget's concrete operational) children would differ little in hemisphere use on spatial tasks but that the Level 2 children would use their left hemispheres much more than Level 1 children on logical tasks. As children move to Level 3 (Piaget's formal operational) a further change in hemispheric asymmetry would occur with the left hemisphere predominating during activities in Mathematics.

The following section discusses the link between brain laterality theory and teaching and learning.

Education and the Left/Right Brain Theory

1. Brain Laterality and Teaching and Learning

In the eighties and nineties educators attempted to link the existing knowledge on brain laterality with teaching and learning. Williams (1983) stated: "The brain has two hemispheres but too often the education system operates as though there were only one" (p. 7). As a result of teachers failing to acknowledge the left/right brain theory it was argued by Kitchens et al. (1991) that many otherwise gifted students were failing to achieve in Mathematics, were suffering from Mathematics anxiety and that early emphasis on rules and linear, sequential tasks inhibited the development of creativity, problem solving and spatial ability. Ellis (1985) indicated that Einstein, von Braun and Edison went on to achieve greatness in their chosen fields of study despite being labelled “failures” at school due to their right-brain tendencies.

In these decades it was held, generally speaking, that mathematics teachers tended to emphasise language and verbal processing and in doing so failed to stimulate the right side of the brain and thus discriminated against right-brain dominant individuals. Referring to the understanding of the functions associated with each hemisphere, it was believed that to not stimulate the right side of the brain when teaching mathematics was a grave mistake as both problem solving and creativity, two very necessary traits of good mathematicians, reside in the right side of the brain. It was further believed that the goal of each Mathematics teacher should be to help each child experience whole brain learning, and that continued emphasis on one hemisphere instruction would lead to failure in Mathematics of many intelligent students. Since young children are predisposed to spatial methods of learning, it was held that teachers should provide significant opportunities for students to explore, to use non-verbal expression, to use multi-sensory situations and that they should teach using visual models rather than just words. The implication here is the necessity for teachers to be aware of left/right brain theory.

Noting that the left hemisphere processed information in a verbal, linear, sequential and logical manner whereas the right hemisphere processed information in a nonverbal, global and intuitive manner (Richards, 1984; Kitchens et al. 1991), the problem with education was simply that traditional education systems placed greater value on left hemisphere learning. Reading, writing and mathematics were taught in most classrooms of the day as a left hemisphere activity only and, as a result, right hemisphere students were not learning efficiently and were therefore disadvantaged. Rubenzer (1982) stated that “The learning disabled child is often likely to be an example of a right-brained child in a left-brained educational system” (p. 1) and Partridge (1983) stated: “It is generally conceded that our schools have adhered (and still do) to a left-hemispheric approach”. (p. 2)

According to Richards (1984) there are three main dichotomies in learning modes.

1. Verbal vs Non-verbal and Visuo-spatial

2. Sequential and Temporal vs Simultaneous, Spatial, Gestalt, and Synthetic

3. Rational vs Emotional (p. 3)

A brief look at these dichotomies indicates a link between them and left/right brain theory (the first mentioned being associated with the left brain and the second mentioned being associated with the right brain) and also indicates why right-brain students were considered to be disadvantaged. It was felt that instructional methods that integrate both modes of learning needed to occur in the classroom and, for this to happen, teachers needed to be aware of the left/right brain theory, their own left/right brain tendencies and those of their students.

The following quote from Miller, (1988, in Kitchens et al. 1991), illustrates how concerned educators were about the results of continuing to ignore the need to teach mathematics in ways that involve the whole brain and even suggests the need for students themselves to be made aware of the left/right brain theory:

> There is ample evidence that math students at all levels should be taught brain lateralization at the same time mathematics is taught and that well designed studies should monitor their experience. It is possible that college mathematics beyond algebra becomes particularly difficult because LB dominant students, who were encouraged by previous successes in algebra which emphasizes LB skills, have difficulty with the visualizations which become necessary in higher mathematics. Accordingly, RB dominant students may avoid higher mathematics after being discouraged by previous difficulties with sequential processes. They may never reach the courses which would show their strength in spatial ability, and spatial ability “has been positively correlated with higher level mathematical ability” (Miller, 1988, p. 7).

Geometry requires the use of spatial ability and the above quote could indicate why the "successful" students who become mathematics teachers have "a dislike for it" (Brodie, 1992) and have difficulty in teaching it.

2. Left/Right Brain Indicators

Richards (1984) listed 26 characteristics of right-brain dominant students. She cautioned, however, that laterally balanced students will display both left-brain and right-brain characteristics and that not all right-brain dominant students will display all the 26 characteristics. These cautions are in keeping with modern thought that there is a continuum from very left-brained through laterally balanced to very right brained students.

According to Richards (1984), the characteristics of right-brain dominant individuals are:

1. Appears to daydream
2. Talks in phrases or leaves words out when talking
3. Uses their fingers to count
4. Draws pictures on the corners of their homework papers
5. Has difficulty following directions
6. Makes faces or uses other non-verbal communication

7. Displays fine motor problems (cutting, writing, pasting) when asked to conform or do structured tasks. Fine motor problems rarely appear when the child is doing something they have selected
8. Is able to recall places and events but has difficulty in recalling symbolic representations such as names, letters and numbers
9. May have difficulty in phonics or decoding skills
10. Is on the move most of the time
11. Likes to work part way out of his seat or standing up
12. May exaggerate when retelling an event in which they have been involved
13. Often has a messy desk
14. Has difficulty in completing his work on time
15. Likes to take things apart and put them back together again
16. Displays impulsive behaviour
17. Tries to change the world to meet his own needs
18. Likes to touch, trip and poke when relating to other children
19. Goes to the pencil sharpener often
20. Gets lost coming to the classroom
21. May forget what they went to their room to do
22. May be very good in athletics but poor in subjects such as English
23. Will give the right answer to a question but will be unable to tell you where it came from
24. Will often give responses that are unrelated to what is being discussed
25. May be a leader in the class

26. May chew their tongue while working (p. 15)

The suggestion is that if teachers are aware of these characteristics they will be able to adjust their teaching to suit the student and thus decrease the number of those students who "fail" due to inappropriate left-brain dominant teaching methods.

As a consequence of the discussions in the eighties and early nineties on the link between brain laterality theory and Piaget and van Hiele's work and the suggestion that brain laterality theory and existing methods of teaching were inconsistent and led to failure in many students, and new developments in neuroscience, brain-based education came into being in the mid nineties.

Brain-Based Education

1. Brain Compatible

The term, "brain-compatible," was first used by Hart, (1983) in his book *Human Brain and Human Learning*. He determined that brain research indicated that the traditional approach to teaching and learning was brain-antagonistic and that before education could be brain-compatible changes to the teaching/learning paradigm needed to occur. From that time on, educators endeavoured to produce what is today known as Brain-Based Education. In brain-based education, according to Valiant (1997),

> the role of the teacher changes from that of a purveyor of information to one akin to a symphony conductor, bringing different elements of the orchestra to the attention of the audience at appropriate times, creating an atmosphere conducive to learning and encouraging the development of students' feelings and emotions. Using current learning theory, teachers will create events and introduce materials and ideas into the classroom that will encourage the development of neural network connections in their students. (p. 1)

According to brain-based educators (Gardner, 1982; Cohen, 1995; Sousa, 1995; Sylwester, 1995; Kotulak, 1996; Valiant, 1997; Schiller, 2000) neuroscience has shown that the brain has the ability to change its structure and function in response to outside experiences and they refer to this as the plasticity factor (Edelman, 1993). They believe that mental concentration and effort alters the physical structure of the brain (Edelman & Tononi, 1996), that learning consists of the development of connections between neural networks and that this development can be brought about by education.

This belief is supported by the Theory of Neuronal Group Selection (TNGS) which was proposed by Edelman (1992). The central idea of TNGS is that selective processes operate in the nervous system of individuals to generate working circuitry that adapts to the needs of an individual in an econiche. In *A theoretical framework for understanding brain function*, The Neurosciences Institute (1998) states that:

> the TNGS proposes that brain function is based on: (1) selectional events occurring among interacting cells in the developing embryo to form neuroanatomy; (2) further selectional events occurring among populations of synapses to enhance neuronal responses having adaptive value for the organism; and (3) reentrant signals exchanged via massively parallel connections to integrate response patterns among functionally segregated brain areas. (p. 1)

The TNGS is consistent with current knowledge of neuroanatomy and physiology.

Hence, the above research indicates that attitudes are learned and are malleable. Given the interest in attitude and learning (see Chapter 3), the research has important implications for teaching and learning. Some research (Thompson, 1992; Borko & Putnam, 1996) has already been done on this link.

2. Windows of Opportunity

The term “windows of opportunity” appeared in an instalment of the series on the brain in the Los Angeles Times in 1996 (THE BRAIN: A Work in Progress: Earlier

Nurture for Young Minds; Research shows how critical are the first years in brain growth, 16th October 1996). In *Windows of Opportunity for Infants and Toddlers* (Staso, 1997) it is suggested that there is a time-limited opportunity for parents to affect ways in which their child's brain may be structured.

In a paper (Start Smart: Early Brain Development and its Implications 2000) to a group of Early Childhood teachers in Sydney in June 2000, Schiller stated:

> … long before birth (somewhere around the 25th day after conception) the brain is building neural pathways (connections) that will be responsible for everything from our breathing to our abilities to speak, think and reason. Although genetically the structure is in place, it will be up to the environment to strengthen and grow the pathways. The brain is the only unfinished organ at birth. It will continue to grow and develop our entire life. (p. 1)

Studies on this proposition are referred to in *Experimental Neurobiology* by The Neurosciences Institute:

> The ability of neurons to modify their signalling capacity as a result of experience is being approached at the cellular level by electrophysiological studies in cortical tissue slices and also in studies of dynamic changes in synaptic morphology in cell culture. (p. 2).

The debate which has gone on for many years as to whether our learning depends on nature or nurture is no longer important to brain-based educators as they believe that whilst a complex system of brain circuitry is laid down at birth, the circuitry is wired by external forces such as nutrition, surroundings and stimulation. They also believe that there are critical periods that are conducive to developing specific skills. These periods are referred to as windows of opportunity during which the brain is efficient at specific types of learning. It is accepted by brain-based educators that most of the wiring of the brain is complete by age ten years. The following table, from *Early Brain Development and its Applications*, by Schiller (2000), quantifies this consideration:

Table 4.1:

Schiller's Windows of Opportunity

Window For	Wiring Window	Greatest Opportunity	Further Opportunity
Emotional Intelligence	0 – 48 months	4 – 8 years	At any age
Motor Development	0 – 24 months	2 – 5 years	Decrease with age
Vision	0 – 24 months	2 – 6 years	
Early Sounds	4 – 8 months	8 months – 10 years	
Music	0 – 36 months	3 – 10 years	
Thinking Skills	0 – 48 months	4 – 12 years	At any age
Reading Skills	0 – 24 months	2 – 7 years	At any age
Second Language	0 – 60 months	6 10 years	Decrease with age

Schiller's strategies for enhancing attention, processing, memory and retention in early childhood, are summarised below.

1. use activities that evoke emotion whilst learning
2. use diet high in protein
3. connect new information to old
4. provide contexts for what is to be learnt
5. use novelty situations
6. frequently revise what has been previously learnt
7. practise over a period of time what has been learnt

The development of thinking skills is important to the learning of geometry. Schiller suggests that these skills are best learnt between 4 and 8 years and hence highlights the importance of appropriate teaching of geometry in the early years of schooling.

Not all researchers, however, were convinced that brain-based education had the neurological support that it claimed. In 1999 Bruer produced an article entitled *In Search of … Brain-based Education.*

The Decade of the Brain

Bruer (1999) disagrees with the claim that brain-based education and the left/right brain theory are supported by neuroscience. He describes the nineties as the "Decade of the Brain" as during this decade many organisations such as government agencies, foundations and advocacy groups in America did all they could to raise public awareness about brain research advances. Consequently, the interest of educators in the brain increased and led to brain-based education.

According to Bruer these brain-based educators saw neuroscience as the best way to finally put to rest older traditional methods of education in which experts create knowledge, teachers disseminate it and students absorb it and are graded on how much they retain of it as they believed that their understanding of how the brain worked and how students learned now had a scientific basis. However, according to Bruer, their critique of traditional education is nothing new and is "actually based on a cognitive and constuctivist model of learning that is firmly rooted in more than 30 years of psychological research" (p.1).

For many years psychology (the science of the mind) developed independently from neuroscience (the science of the brain). Psychologists were interested in how we learn, remember and think or the software of the brain, whereas neuroscientists were interested in how the brain develops and functions or the hardware of the brain. Hence, Bruer suggests that any evidence that brain-based educators actually have for teaching for meaning and understanding comes from cognitive and developmental psychology not brain research.

Brain-based educators (Sylwester, 1995; Schiller, 2000) firmly believe that the two have come together today. They believe that brain science has given them the biological data and explanations for which they previously had only psychological data.

Bruer (1999), concedes that cognitive neuroscientists

> are beginning to study how our neural hardware might run our mental software, how brain structures support mental functions, how our neural circuits enable us to think and learn (p. 2).

However, he believes that the brain science database is so limited that those who would use it to support their views on education are taking the results beyond their actual scientific basis. Recent developments in brain imaging technology (Functional Magnetic Resonance Imaging, Steady-State Visually Evoked Potential and Steady-

State Probe Topography), however, indicate support for the views of educators who believe that different parts of the brain are involved in different types of learning.

As stated earlier, brain-based education grew out of the research on brain laterality and the concept of “windows of opportunity”. Its supporters believe that neuroscientific research supports the psychological research from both areas of study. Bruer, however, is convinced that there is insufficient data from neuroscientific research to support the brain-based educators’ views that their conclusions are supported by neuroscientific research. Bruer suggests that brain laterality has been dismissed by psychologists and brain scientists and suggests that the belief in “windows of opportunity” for learning are based on an incorrect conclusion drawn from one research paper by Chugani, Phelps and Mazziota, (1987).

Bruer illustrates his belief that brain laterality is not supported by brain research with three examples associated with the work of Sousa (1995) who developed teaching strategies to cater for left-brain and right-brain learners. The first involves spatial tasks, the second visual imagery and the third number recognition. Psychologists divide spatial reasoning into two types, categorical and coordinate. Categorical spatial reasoning involves grouping objects and coordinate spatial reasoning involves computing and retaining precise distance relations between objects. Sousa believes that spatial reasoning is a right-brain activity but Bruer, referring to the work of Chabris and Kosslyn (1998), states that brain science research has shown that a subsystem in the brain’s left hemisphere performs categorical spatial reasoning and a subsystem in the brain's right hemisphere performs coordinate spatial reasoning.

Generating and using visual imagery is considered to be a right-brain function by brain-based educators. However, Bruer suggests that

> Generating and using visual imagery is a complex operation that involves, even at a crude level of analysis, at least five distinct mental subcomponents: 1) to create a visual image of a dog, you must transfer long-term visual memories into a temporary visual memory store; 2) to determine if your imagined dog has a tail, you must zoom in and identify details of the image; 3) to put a blue collar on the dog requires that you add a new element to your previously generated image; 4) to make the dog look the other way demands that you rotate your image of the dog; and 5) to draw or describe the imagined dog, you must scan the visual image with your mind's eye (p. 4).

He suggests that the study of brain damaged people and those who have had their corpus callosum surgically severed indicates that the ability to generate visual imagery depends on the left hemisphere, particularly its rear portion, and that brain-imaging studies of people performing imagery tasks show that both hemispheres are active in these tasks.

Referring to the work of Dehaene (1996), Bruer disagrees with supporters of left/right brain theory that the site of number recognition is the left hemisphere. The brain-recording techniques used by Dehaene indicated that number words are identified by a system in the brain's left hemisphere, numerals are identified by using areas of both the right and left hemispheres and a distinct neural subsystem in the brain's right hemisphere compares magnitudes named by the two number symbols.

These examples indicate, according to Bruer, that neuroscience does not support brain-based education principles but refutes them. He believes that it "makes no scientific sense to map gross, unanalyzed behaviours and skills... onto one brain hemisphere or the other" (p. 6).

Bruer believes that brain-based educators are also incorrect in assuming that neuroscience supports their belief that there are periods in brain development, until a child is around 10 years old, that assist a child to learn more easily. These "windows of opportunity" are described by Sousa, cited in Bruer, (1999)

> These so-called "windows of opportunity" represent critical periods when the brain demands certain types of input to create or consolidate neural networks, especially for acquiring language, emotional control, and learning to play music. ... what the child learns during that window period will strongly influence what is learned after the window closes (p. 6).

Bruer accepts that there is a considerable amount of literature and a quantity of articles on critical periods of learning and he also acknowledges that Chugani, the author of the research that started it all, has publicly stated in 1998 that “the biological ‘window of opportunity’ when learning is efficient and easily retained is perhaps not fully exploited by our education system”. However, he believes that the conclusions drawn by Chugani et al. (1987) and all those that have quoted his work are incorrect.

Chugani injected 29 epileptic children, ranging in age from 5 days to 15 years, with radioactively labelled glucose and using Positron Emission Tomography (PET) scans measured the rate at which specific areas of the brain took up the glucose. A study of the scans revealed that metabolic levels of glucose reached adult values at about 2 years of age, reached twice adult levels at 3 or 4 years of age and stayed at these elevated levels until around 9 years of age.

To understand the significance of these plateau levels Chugani and his associates referred to the work of Huttenlocher (1979) in which he measured how the number and density of synaptic connections changed in the human brain throughout life by measuring densities in brain tissue removed during autopsies. Huttenlocher found that up to the age of 3 the brain formed synapses very rapidly so that synaptic densities in young children’s brains were 50% higher than those in adult brains and that the levels stayed this way until puberty when they reduced to adult levels.

It was known that the maintenance of synapses and their neural structures accounted for most of the glucose that the brain consumed. Chugani reasoned that as the density and number of synapses changed, so too, did the rate of brain-glucose metabolism and hence his PET scans provided indirect evidence of brain development that supported the direct evidence from the study of brain tissue removed during autopsies.

Bruer’s rejection of the existence of neuroscientific support for windows of opportunity is based on two facts. The first is that Chugani never showed that elevated brain metabolism and synaptic densities are related to the ease, rapidity and depth of a child’s learning and the second is that no other neuroscientist has studied such a relationship. He also suggests that the whole debate on critical periods of learning is based on an unproven implicit assumption namely, “that children actually learn faster, more easily, and more deeply between the ages of 4 and 10” (p. 9).

Bruer criticises educators for stating that neuroscientific data supports their learning theories. He goes to great lengths to disprove this alleged support by reference to both brain laterality and windows of opportunity, two concepts that are the basis of today’s brain-based education programs.

The Missing Link (A Biological Basis for Intelligence)

However, if consideration is given to the following quotes from Bruer, it appears that there is more neuroscientific support for brain laterality than he cares to admit, but not necessarily as we interpret it today. What is certain, is that specific sections of the brain are involved in specific tasks.

> "... the research does point to differences in the information-processing abilities and biases of the brain hemispheres ..." (p. 3); " ... brain scientists have concluded that the ability to generate visual imagery depends on the left hemisphere" (p. 4); "... different brain areas are specialized for different tasks" (p. 4); " ... we identify number words using a system in the brain's left hemisphere, but we identify Arabic numerals using brain areas in both the right and left hemispheres" (p. 5).

Whilst it is true that there is less neuroscientific support for *windows of opportunity* it should be noted that there is no neuroscientific evidence that disputes the claims of the brain-based educators. Indeed, Bruer himself suggests that "There are certainly critical periods for the development of species-wide skills, such as seeing, hearing, and acquiring a first language ..." (p. 9).

Perhaps there is a parallel here with brain laterality theory. Bruer suggests that brain laterality is much more specific than the early broad brush theory and he quotes recent neuroscience data to support his assertion. Critical periods of learning theory can be considered to still be in the broad brush state such as seeing and hearing. All that is needed is neuroscientific data to provide the *missing link* of proof for the finer version that educators are suggesting exists.

Recent imaging techniques used by neuroscientists appear to be providing that *missing link* as they are bringing together behavioural scientist's conclusions about the brain and the neuroscientists' study of the brain by linking observations about cognitive behaviour with the actual physical processes that support such behaviour. In 2000 researchers at the University of Colorado showed that the neocortex processes more slowly than the hippocampus, overlaps categories and attempts to find patterns and structure of the material whereas the hippocampus uses completely separate representations to code facts and details of specific events and is less prone to interference. That is, the hippocampus memorises and the neocortex learns.

The imaging techniques include Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI), Magnetic Resonance Spectroscopy (MRS), Functional Magnetic Resonance Imaging (fMRI), Steady-State Visually Evoked Potential (SSVEP) and Steady-State Probe Topography (SSPT). Each has inherent benefits and drawbacks but each allows the neuroscientist to "see" the brain actually working whilst doing some cognitive task. A discussion of these imaging techniques is found in Appendix A.

What is important here is the fact that there is, despite Bruer's reservations, increasing evidence that brain activity during learning can now be directly observed. The results of these observations indicate that when learning is occurring, different areas of the brain are involved.

The 4-Mat Left/Right Brain Test

Given the preceding discourse the determination of the left/right brain preference of preservice teachers is important due to the alleged link between it and teaching and learning. The search for a suitable valid pencil and paper test led to the 4MAT test which consists of 32 word-pairs each separated by five spaces similar to a Semantic Differential test.

Lieberman (1986) developed the Hemispheric Mode Indicator (HMI) or 4MAT test. He reviewed the existing literature of brain hemispheric dominance and developed 40 word-pair items that reflected themes that had been attributed to right or left hemisphere laterality. The word-pairs covered a range of dimensions of thought, behaviour and feelings, for example, Analysis … Synthesis, Deductive … Inductive and Heart … Head.

To validate the test an empirical test of the left/right scoring of each question was performed on the original items by correlating each item with the total test score, corrected by removing that item’s score from the total. Thirty-two items produced responses that corresponded to the expected direction of scoring.

The 32 items were further analysed and the total scores from the 32 items were correlated with the Torrance measure, SOLAT-C, Your Style of Learning and Thinking, Form C to check concurrent validity of the test. Forty-nine subjects were used and the Spearman rank correlation coefficient was 0.819 and the Pearson Product Moment correlation was 0.659. Lieberman concluded that the Hemispheric Mode Indicator (HMI) test measure to be similar to the Torrance measure but not identical to it.

Items were re-scored so that high negative scores were related to left hemispheric mode and high positive scores were related to right hemispheric mode to check internal consistency. Each choice was awarded a score of -2, -1, 0, +1, +2. A score of nought was interpreted as no preference or equal preference to each mode. A frequency distribution of the 76 subjects who took the HMI test clustered near the centre or to one side rather than a U-shaped curve. Cronbach’s alpha was 0.90. To check reliability, a sample of 47 subjects was given the HMI test two months apart. “The Pearson Product Moment Correlation coefficient between the two testings was 0.904” (Lieberman 1986, p. 2) indicating that the test was reliable.

Lieberman indicated that an application of the HMI test to 2000 individuals most of whom were teachers, resulted in a statistically significant relationship between left/right brain preference and gender (Chi-Square = 42.18, $p<0.01$), with males being over-represented in the left-brain preference and females in the right-brain preference. Given the number of females in the teaching service the relationship between left/right brain tendency and gender is also examined in this research.

Whilst there appears to be no further research on the validity of the test there has been research (Scott, 1994) on the 4MAT Model of teaching that relies on the test. In his abstract Scott states:

> Legitimation of the model has come through academic discussion and widespread use of 4MAT concepts. … The professional literature indicates that the 4MAT model is capable of comprehensive use, for developing instructional units for discursive as well as non-discursive disciplines, for secondary as well as elementary education, … (p. 1)

Comments

Laterality research in the nineteenth century was started by the French and to a lesser extent the Germans. This research resulted from an interest in comparative neuroanatomy, anthropology and personality disorder called hysteria that is today termed dissociative personality disorder. Brain localisation theory was used to provide insight into mind-brain relations, the intelligence of an individual and madness.

In the early twentieth century the nineteenth century findings on brain laterality and asymmetry were largely ignored. However researchers in the United States rediscovered brain laterality and asymmetry in the sixties due to the behaviour of patients who had their corpus callosum severed to try to stop their epilepsy. The concept of duel lateralisation appealed to the masses and was a source of cultural and psychological speculation.

Western Society was deemed to have overdeveloped its left-brain while Oriental Cultures were considered to have a better left/right brain balance. Neglecting the right hemisphere was blamed for the rise of National Socialism as the left hemisphere was said to ignore a holistic approach to life.

Today, generalisations about lateralised functioning have been replaced by attention to individual differences and the functional difference of the right-left lateral axis tends to be qualified by frontal-caudal (front-back) and cortical-subcortical (outer layer-inner layer of the cortex) axes. There is also an understanding of the role neurochemistry plays in the development and expression of lateralised functioning. There is a belief that although one hemisphere may predominate in a particular task, some of the processing load may be sent to the other hemisphere especially when the task is a higher level mental function.

The left side of the brain is considered to be the site of analytic, verbal cognition and the right side of the brain as the site of the holistic, affective and perceptual processes. Kitchens et al. (1991) stated:

> The left hemisphere is analytical and logical. It specializes in recognising the parts, it is linear and sequential, and it processes in a step-by-step manner. The right hemisphere is intuitive, creative, imaginative, and artistic, recognizing the whole as opposed to the parts. It is engaged in synthesis and seeks, recognizes, and constructs patterns and relationships. The right hemisphere is more efficient at image processing but is very limited in language capacity. It has been compared to a kaleidoscope, whereas the left hemisphere has been compared to a computer. Hatcher (1983) reports, “We know that the right brain cannot verbalize what it knows” and “the left brain ... is unable to create meaning or generate new ideas”(p. 9). This contrast suggests the need for whole brain thought if complete functioning is to occur. (p. 1)

The late nineties saw the rise of brain-based education which resulted from educators’ fascination with brain laterality research. To support their conclusions about the effects of left/right brain functions and their effects on learning they interpreted the data from neuroscientific research as proof for their theories on teaching and learning.

Not all believe that such support exists. However, very recent research on brain functioning using imaging techniques that allow researchers to “see” what part of the brain is active during cognitive tasks appears to provide the missing link between the psychological and biological basis of brain-based education theory.

Whilst the proof is not conclusive there is sufficient psychological and biological data to indicate that different areas of the brain are associated with different cognitive functions and that educators need to be familiar with the research and vary their teaching to cater for brain laterality in their students and themselves. According to Nunley and Van Tassell (2001), a recent study at Yale University with 3rd to 8th grade students showed that instruction involving analytical, creative and practical methods of instruction combined produced better results by students in performance-based and memory-based multiple choice tests than a traditional memory based approach to teaching. This result suggests using a variety of left-brain and right-brain teaching methods in a classroom and supports the following comment by Partridge (1983):

> If a child has a strong hemispheric preference, as determined by testing or through observation, introduce teaching activities in that mode, but later direct them to the other hemisphere for its appropriate development, as team work is essential for optimum performance. (p. 10)

and the comment in “Funderstanding” (2001):

> When educators take neuroscience into account, they organize a curriculum around real experiences and integrated, “whole” ideas. Plus, they focus on instruction that promotes complex thinking and the “growth” of the brain. (p. 1)

These two comments are also supported by German research (Fink, Marshall, Weiss, Shah, Toni & Halligan, 2000) in which it was found that people with right hemisphere brain damage cannot mark the centre of a horizontal line yet have no problems marking the centre of a square. The researchers used MRI to discover that line judgement uses the right cortex while finding the centre of a square uses the lingual gyrus in both brain hemispheres. They concluded that the more object-like gestalt you make a visual stimulus, the greater the brain regions used. Thus teaching simple abstract concepts should involve manipulatives and diagrams so that more of the brain is involved in the learning.

Conclusion

Whilst this chapter indicates a wealth of research on brain asymmetry and its application to teaching there appears to be no research on whether left-brain dominant teachers teach differently to right-brain dominant teachers and whether the difference, if any, affects their students' knowledge of geometry. Similarly, whilst spatial skills are important to the learning of geometry, there appears to be no research on whether left/right brain preference influences an individual's knowledge of geometry.

Whilst the first question is beyond the scope of this research the second question can be addressed. It is important, therefore, that the left/right brain preference of a preservice teacher be determined. This would allow an analysis of this preference and the relationship between it and gender, attitude and knowledge of geometry. Such data may help address the problem of teacher apprehension about geometry.

These conclusions generate the following research questions:

1. What is the left/right brain preference of preservice teachers?

2. Does the left/right brain preference of an individual affect their success in geometry?

3. Does the left/right brain preference of an individual affect their attitude to geometry?

4. Does attitude mediate the affect of the left/right brain preference of an individual on success in geometry (van Hiele level)?

Chapter 5

RESEARCH DESIGN

Nothing in life is to be feared, it is only to be understood. ... Marie Curie

The review of the literature in Chapters 1 to 4 together with the researcher's earlier work and his educational experiences with preservice teachers led to the formulation of several research questions. While these questions focus on seeing attitude as central to the learning of geometry it is understood that attitude is influenced by characteristics the student brings to the learning environment. In the present research left/right brain preference, age, gender and education represent these characteristics that the student brings to the learning environment. Due to the salience of brain-based teaching in the literature and in practice, research concerning left/right brain has been emphasised. However, to be consistent with the literature the remaining factors are researched as they are environmental factors considered in the literature to be important.

Attitude, it has been argued (see Chapter 3), can be understood as three analytically distinct factors: affective, cognitive and behavioural. Attitude, while a coherent whole, is malleable. Hence, in the present research there are relationships between the three factors *at a time* and *over time*. The present research focuses on *at a time*. Further research would be required to determine the relationships of these factors *over time*. The present research's concern is to establish empirical data in support of this theory of three distinct factors. Therefore, a survey method was adopted. Van Hiele's theory is prominent in the present research. The essence of this theory, for the present research, is that learning is a series of levels. In this instance four levels have been chosen because of the difficulty of measuring the fifth level. Due to the congruence between these levels and performance in geometry, the van Hiele levels have been chosen to represent the behavioural factor of the theory concerning attitude. Further research is necessary to evaluate the relationships of these three attitude factors with performance.

In the present research, the behavioural factor is evaluated from two perspectives. From the first perspective, the relationship between these three factors is determined by analysing the correlation matrix. This process determines whether there is empirical evidence in support of a three factor theory of attitude as it pertains to geometry. Noteworthy is the fact that the three attitude factors reside in a statistical model that includes the background factors. By simultaneously accounting for the statistical relationships of the background factors with the attitude factors, a more representative model of reality is explored.

From the second perspective, the model is used to not only determine the relationships of the background factors with the attitude factors, it is used to also determine the relationships of the two postulated attitude factors of cognitive and affective with the behavioural factor. Unlike the behavioural factor, the cognitive and affective factors are inferred rather than directly observed. Therefore, it seems relevant, that while simultaneously controlling for the effects of the background factors, the effects of the cognitive and affective factors of attitude on behaviour be determined.

There is much literature attesting that mental processes precede outcomes. It is the rare occasion when one acts instinctively. Hence, in the present research the cognitive and affective factors precede the behavioural factor. There is also much literature attesting that factors preceding an event influence the event. Generally, experience improves performance. Therefore, in the present research, the background factors precede the cognitive, affective and behavioural factors. Viewed this way, the cognitive and affective factors can be seen as intervening factors between the background factors and the behavioural factor.

The present research represents this model of attitude and background factors statistically to address the research questions reproduced below.

1. What is the van Hiele level of preservice teachers?

2. What is the attitude to geometry of preservice teachers?

3. What is the left/right brain preference of preservice teachers?

4. Does gender, age, education and left/right brain preference affect the van Hiele level of an individual?

5. Can the affective and cognitive factors of attitude be empirically differentiated, that is, do the Likert and Semantic Differential Scales measure the same construct?

6. Does gender, age, education and left/right brain preference affect attitude?

7. Does attitude affect success in geometry (van Hiele level)?

8. Does attitude mediate the effect of age, gender, education and left/right brain preference on success in geometry (van Hiele level)?

9. Do gender, age, education and left/right brain preference, preservice teachers' attitude to geometry and preservice teachers' van Hiele level of development in geometry *together* comprise a single coherent statistical model in which the relationships of the particular factors can be examined?

These questions focus on an empirical examination of the relationship of three broad areas:

1) preservice teachers' background factors (age, gender, education, left/right brain preference) as predictors of preservice teachers' attitude and success in geometry;
2) preservice teachers' attitude; and
3) preservice teachers' success in geometry

This chapter describes the method used to examine the relationship of these three areas which lead to the following research hypotheses:

1 Relationship of background factors and success in geometry.

1.1 age and success in geometry are positively correlated
1.2 gender and success in geometry are positively correlated
1.3 left/right brain preference and success in geometry are positively correlated
1.4 education and success in geometry are positively correlated

2 Relationship of attitude and success in geometry.

2.1 attitude and success in geometry are positively correlated

3 Relationship of background factors and attitude

3.1 age and attitude to geometry are positively correlated

3.2 gender and attitude are positively correlated

3.3 left/right brain preference and attitude are positively correlated

3.4 education and attitude are positively correlated

It is further hypothesised that:

(i) the effect of age on success in geometry is mediated by attitude.

(ii) the effect of gender on success in geometry is mediated by attitude.

(iii) the effect of left/right brain preference on success in geometry is mediated by attitude.

(iv) the effect of education on success in geometry is mediated by attitude.

This chapter emphasises the following key aspects and the hypotheses are tested in the following chapter.

- Background to the Research Design
- The Context of the Study
- Participants
- The Research Design
- Operationalisation of the Research Design

- The Development of the Instruments
- The Administration of the Instruments
- The Analysis of the Data.

The subsequent chapter presents the results and conclusions.

Background to the Research

The present research arose out of research that showed:

- a steady decline in success in geometry in Australian students (TIMSS-R, 1998);
- a lack of confidence in teachers when teaching geometry (TIMSS-R, 1998);
- an increase in brain-based education (Hart, 1983);
- the increasing percentage of female teachers (ABS 2002) and;
- earlier research by Brodie (1992) that focussed on NSW primary teachers.

TIMSS-R (1998) reported a continuing decline in success in geometry by Australian students and a lack of confidence in teaching geometry in teachers (see Chapter 1). Brain-based education started in the mid nineties and has grown in importance in America where curriculum is more and more based on left/right brain theory (see Chapter 4). Australia has seen a steady decline in the number of male teachers and hence a consequent increase in the number of female teachers. Indeed the education of primary school students is today largely in the hands of females (preschool and primary 79.1% female teachers, secondary 56.1% female teachers, ABS 2002). The Catholic School system in Australia has recently asked for exemption from sex discrimination laws so that they can launch a males-only teacher recruitment program (The Daily Telegraph, December 2002) and more recently the acceptance of primary school teaching scholarships by two males was reported in the Herald (Sydney Morning Herald, January 2004). If gender is found to be related to attitude to geometry or success in geometry then teacher education institutions may need to take this fact into consideration when devising courses.

Brodie's (1992) research involving a random sample of teachers (n = 131) from 228 primary schools investigated teacher attitude to geometry, their knowledge of research into the teaching of geometry and how they had introduced the space (geometry) section of the 1989 NSW K to 6 Mathematics Syllabus. He concluded that primary school teachers in general had a dislike for geometry and little knowledge of the research available on the teaching of geometry. This resulted in less time being devoted to geometry than was needed in the new syllabus. It is reasonable to assume that the teaching of geometry suffered because of this.

The present research extends the 1992 research project by the inclusion of a model of success in geometry, the van Hiele levels (see Chapter 2) and left/right brain preference (see Chapter 4) of preservice teachers as well as their attitude (see Chapter 3) to geometry. As well, the study includes the preservice teacher's age, gender and mathematics course studied at school. The previous research clearly demonstrated that attitude was significant not only to success in geometry but also to number and measurement. Whereas the previous research was concerned primarily with demonstrating that attitude was important to success, the present research shifts the focus to examine the relationship of other important factors found in the literature, such as, age and left/right brain preference to attitude and attitude to success in geometry.

The Context of the Study

The present research was carried out at the Penrith campus of the University of Western Sydney. The University of Western Sydney is one of the largest universities in Australia. It has over 30 000 students and campuses throughout Western Sydney at Bankstown, Blacktown, Campbelltown, Hawkesbury, Parramatta and Penrith. The University is the largest teacher education institution in New South Wales. A survey method was used to collect the data and the survey was administered to teacher preservice students of the University.

i) Participants

The students who participated in the research were first year (n = 167) and third year (n = 49) Bachelor of Teaching (Primary) students and fourth year (n = 10) Bachelor of Education students. All of the students in first year and all but two in third year accepted the invitation to be involved. Ten of the 163 fourth year students returned the completed survey (see The Research Design below). Of the 224 participants who completed the survey 181 were female, 34 were male and 9 did not specify. The students were grouped into age ranges; 15 - 19 years (n = 109), 20 - 24 years (n = 71), 25 - 29 years (n = 14), 30 - 34 years (n = 11), 35 - 39 years (n= 10), 40 - 45 years (n = 7) and > 45 years (n= 2). Data were also collected concerning the New South Wales Higher School Certificate (HSC) mathematics courses studied by the respondents (Mathematics in Practice (n = 8), Mathematics in Society (n = 97), 2 Unit mathematics (n = 85), 3 Unit mathematics (n = 13), 4 Unit mathematics (n = 1) and Other Courses (n = 20)). The other courses were courses completed in other states or non HSC Courses. These participants either had no degree (n = 210) or one degree (n = 14).

ii) The Research Design

Whilst Brodie used a Semantic Differential Scale to measure attitude in 1992, further research into the measurement of attitude (see Chapter 3) suggested that a Likert Scale might better measure attitude and may lead to the identification of attitude factors. In Chapter 3 it was suggested that it is possible that the Semantic Differential Scale may measure the affective factor of attitude whilst the Likert Scale may measure the cognitive factor of attitude. To determine the most appropriate strategy to use in the present research both a Semantic Differential Scale and a Likert Scale were used to measure attitude to geometry. However, the concepts of the Semantic Differential Scale were structured as a Likert Scale. This was done for two reasons. One was to overcome

Gardner’s concern (1975a) of reducing multi-dimensional attributes to a single score and the other was to allow the scales to be examined to determine whether it was appropriate to use one or both of the attitude scales in the research. The following briefly describes the process used to examine the question of one or two scales.

The question of one or two scales was addressed firstly by examining the unidimensionality of the attitude scales independently, secondly by collapsing the two scales into a single scale, and thirdly by examining the relationship of the two scales in a single model of student attitudes. The results of this (see Chapter 6) replicated the work of McCallum and Brown (1971), Schofield and Start (1978) and Visser (1983) in so far as the correlation between these two scales was 0.76. This replication is interesting when consideration is given to the fact that when the effects of other factors in the model are controlled for, it is only the Semantic Differential Scale (affective factor) that is significantly related to success in geometry. This could be due to the fact that the nature of the correlation may be due to another factor. This is discussed in Chapter 6.

Research (Pintrich, Marx & Boyle, 1993), posits that there is a relationship between students’ background factors that they bring to their study, for example, gender or beliefs they hold about learning and its personal value, and successful learning outcomes. The aim of the present study was to test empirically these posited relationships. To achieve this aim a correlation design (Gall, Borg & Gall, 1996) was employed and a survey (pencil and paper) was used to collect the data.

The investigation of these relationships involved the examination of the correlations between designated factors emphasising divergent and convergent validity of the constructs, and a test of the relations of the background factors on the outcome factors mediated by students' attitude to geometry. The results of the latter part of this investigation are presented in the second half of Chapter 6.

The Nature of a Mediator Variable

A variable may function as a mediator to the extent that it accounts, in part or the whole, for the relations between the independent variable or variables and the dependent variable (Baron & Kenny, 1986). The basic causal chain involved in mediation is as follows in Figure 5.1.

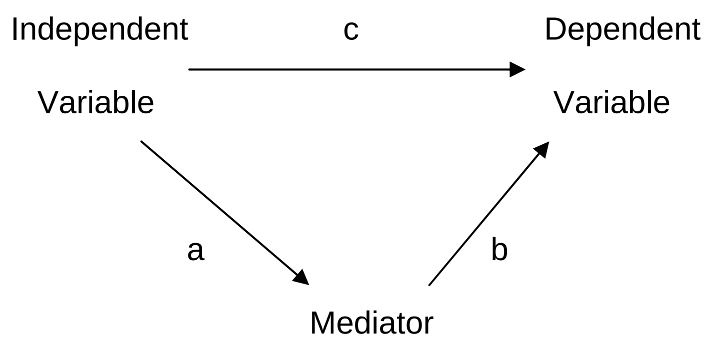

Figure 5.1: Causal chain involved in mediation.

According to Baron and Kenny (1986) a variable is a mediator when variations in levels of the independent variable significantly account for variations in the presumed mediator (path a), variations in the mediator significantly account for variations in the dependent variable (path b) and a previously significant relation between the independent and dependent variables is no longer significant when paths a and b are controlled. Such a result would constitute perfect mediation. However, a more likely outcome is that of partial mediation in which path c is significantly decreased rather than eliminated.

Operationalisation of the Research Design

Three pencil and paper instruments (CDSSAG, RUMEUS and Lawrie) and one set of interview items (Mayberry) were identified in the literature as having been used to assess an individual's van Hiele level in geometry.

Mayberry (1983) used seven geometric topics in her interviews, namely, square, right triangle, isosceles triangle, circle, parallel lines, congruency and similarity. The interview consisted of sixty-two items and required approximately two hours to complete. The questions in each geometric topic were designed to determine the van Hiele level at which the student was operating in that geometric topic. Mayberry chose the seven topics on the basis that they were in all elementary mathematics courses and students could be assumed to have studied them. Mayberry evaluated each student's interview results after the interview using a marking scale for her items which set the number of items that needed to be answered in each level of each topic before a student was considered to have achieved that particular level in the topic.

The CDASSG test was developed by the University Of Chicago in the Cognitive Development and Achievement in Secondary School Geometry project in 1982. This test was developed by Usiskin who wanted a test that retained the integrity of the van Hieles' original tests but could be administered and analysed using a large number of students over a short period of time. One of the simplest descriptions of the CDASSG Test is found in Wilson's reanalysis of the test. Wilson (1990) stated:

> The [thirty-five minute timed] CDASSG van Hiele Level Test was a 25-item multiple-choice test with five foils per item and five items per level. The test was graded according to the following rule: If a student met the criterion for passing each level up to and including level n and failed to meet the criterion for all levels above, then the student was assigned to level n; if the student could not be assigned to any level, then the student was said not to fit. There were two criteria for passing a level: 3 out of 5 items correct and 4 out of 5 items correct (p. 230).

Crowley (1990) analysed the data from the test and concluded that only the level 3 subtest met the minimum research criteria and that while the CDASSG test made a valuable contribution to research, further work needed to be done to obtain a multiple-choice test which would produce valid and reliable results. Crowley suggested that one way to do this would be to increase the number of items in each subtest as the kappa value would be influenced by this increase as it is highly sensitive to the number of items. (Cohen's kappa measures the consistency of the mastery/nonmastery decisions associated with the administration of a test. Its value ranges from 0, no agreement, to 1, perfect agreement).

Whilst "...the CDASSG test had the advantage of being shorter, and its multiple choice format made it more convenient and quicker to apply" (Smith, 1987 cited in Usiskin & Senk, 1990 p. 245), the test developed by the RUMEUS group at the University of Stellenbosch "outperformed the CDASSG test in virtually all aspects, most notably in regard to the placement of pupils in Van Hiele levels, its reliability and hierarchical structure" (Smith, 1987, cited in Usiskin & Senk, 1990, p. 245).

Lawrie (1998) changed the format of Mayberry's interview items to form a pencil and paper test and modified the American expressions in the items to ones that would be recognised by Australian students. She developed a marking scale which set the number of marks that needed to be gained before a student was considered to have achieved a particular van Hiele level in a particular topic. Lawrie calculated a most common van Hiele level for each student in four topics in order to make a meaningful comparison between the student's geometric understanding and their results.

Of the four tests identified only three were evaluated due to the University of Stellenbosch being unable to locate their RUMEUS test. The evaluation looked at the tests themselves, their ease of administration, collation of results and accuracy and the previous researchers' comments on the scales. Whilst the tests were similar in ease of administration and collation of results, given the concerns of Smith (1987) and Crowley (1990) about the CDASSG test, it was decided to use Lawrie's test as it was a modification of Mayberry's test, was suited to Australian students and had been shown to be accurate.

In addition to an investigation into available attitude tests the present research evaluated the left/right brain factor. Despite a vast amount of research on assessing an individual's left/right brain preference it was found that only one pencil and paper instrument existed. This was the 4-Mat test, developed by Lieberman in 1986, which consisted of thirty pairs of words. These pairs reflected themes that various authors had attributed to right or left hemisphere laterality and the individual is asked to mark a five point scale between each pair of words to indicate their degree of preference for one word over the other. The responses are scored using a -2 to +2 scale and the individual's overall score is calculated. If the score is negative the individual is said to have a left brain preference and if the score is positive the individual is said to have a right brain preference. The strength of the preference is determined by the value of the score.

Other than Lieberman's (1986) "The Hemispheric Mode Indicator Technical Notes" document which contains a study, using 2000 participants, to produce norms for the test there appears to be no further research on the validity of the test which is today available commercially in many countries. However, the comments by Scott (1994) in Chapter 4 on the 4MAT system which uses this test are reproduced below for the reader's assistance.

In the abstract on his research on the 4MAT system, Scott (1994) states:

> Legitimation of the model has come through academic discussion and widespread use of 4MAT concepts. … The professional literature indicates that the 4MAT model is capable of comprehensive use, for developing instructional units for discursive as well as non-discursive disciplines, for secondary as well as elementary education … (p. 1).

Hence four instruments were developed, that is, two attitude scales (see Chapter 3), one left/right brain preference test and one van Hiele level test.

The Development of the Instruments

The four instruments used in the present research are identified and described in this section.

i) The Semantic Differential Scale

The Semantic Differential Scale research instrument was developed using a list of twenty-three bi-polar pairs (see Table 3.1). According to research into the Semantic Differential Scale by Osgood, Suci and Tannenbaum (1957), these bi-polar pairs best represented the three factors of evaluation, potency and activity which were earlier identified by Osgood in his development of the Semantic Differential Scale. A Semantic Differential Scale includes bi-polar pairs from the evaluative (E), potency (P) and activity (A) lists and it is usual to use ten bi-polar pairs in the ratio E:P:A = 5:3:2. However, in the present research it was believed it would be better to use twelve pairs in the ratio E:P:A = 6:3:3 if analysis of the results was to be done using the measurement provided by the factors separately, as well as, together. This ratio maintained the E:P+A 50/50 split of the ten bi-polar pair scale.

ii) The Likert Scale

The Likert Scale research instrument was developed by studying a number of Likert Scales about attitudes, for example, the Test of Science-Related Attitudes (TOSRA) developed by Fraser (1978). Each item was then carefully worded and the scale checked by a qualified researcher. There was some difficulty in deciding how many items to use as the number varied widely in the samples studied. A twenty-five item test was finally developed to allow for factor analysis.

iii) Validity of the Scales

The Semantic Differential Scale and the twenty-five item Likert Scale were administered to thirty students and the results analysed. An alpha test on the Likert Scale (0.92) indicated that the internal validity of the scale would be improved if four of the twenty-five items (item14, item15, item17 and item20) were deleted from the scale. Consequently, a twenty-one item instrument was produced and used in the research (Alpha = 0.94). The Pearson correlation coefficient was calculated for the Likert and Semantic Differential Scales and the correlation between the data from the scales was found to be high (Pearson = 0.80).

The bi-polar pairs of the Semantic Differential Scale used in this research are listed in table 5.1 below and the twenty-one items of the Likert Scale used in this research are listed in table 5.2 below.

Table 5.1:
Bi-polar Pairs used in this Research

Bi-polar Pair	Type
Strong – Weak	Potency
Heavy - Light	Potency
Fast - Slow	Activity
Pleasant - Unpleasant	Evaluative
Honest - Dishonest	Evaluative
Valuable - Worthless	Evaluative
Clean - Dirty	Evaluative
Sharp - Dull	Activity
Sacred - Profane	Evaluative
Good - Bad	Evaluative
Hot - Cold	Activity
Large - Small	Potency

Table 5.2:

Items used in the Likert Scale

Likert Scale Item
I like to do lots of geometry.
If I had my way I would never do geometry.
I do geometry every chance I get.
I feel very comfortable when I do geometry.
Geometry is a waste of time.
I would like to spend more time doing geometry.
I try to get out of doing geometry whenever I can.
I look forward to doing geometry.
I am glad when I don’t have to do geometry.
I like talking about geometry.
I am fortunate to be able to do geometry.
I don’t do geometry well.
I like geometry best.
I never get tired of doing geometry.
Time goes quickly when I’m doing geometry.
I always like to do well in geometry.
I like some geometry.
I am glad when geometry is over.
I just pretend I’m doing geometry most of the time.
On the whole I enjoy geometry.
There is too much geometry in mathematics.

iv) The van Hiele Level Test

Lawrie modified the instrument developed by Mayberry to produce a pencil and paper van Hiele Test, and to make it more suitable to Australian education systems. Her research suggested that the van Hiele level of an individual could be assessed accurately up to level 4. Due to the time available to assess her students Lawrie developed two four-topic tests. One of Mayberry’s seven topics was used in both tests. After considering Mayberry’s seven topics the four chosen for this research were the square, parallel lines, congruence and isosceles triangles as each of these featured in all year 7 to 10 mathematics courses in NSW and the 2 and 3 unit senior courses. The test was printed using the same question numbers as Lawrie to allow for any cross referencing. Students were given an hour to complete it. However, as time was not a factor those who required more time were allowed to have it. A marking scale was produced in consultation with Lawrie and the results were recorded as levels in each topic. As was done by Lawrie a most common level for each student was determined. In 8% of the students the results were not consistent, that is, in one of the topics, but not more than one, the student achieved a level *n* understanding but not a level *n-1* understanding. It should be noted, however, that this anomaly changed the most common level across the four topics for only one student whose data were eliminated from the research.

v) The Hemispheric Mode Test

This test was purchased from 4Mat but the instructions were modified to make them easier to understand. The test consists of 30 pairs of descriptors which represent extremes of the hemispheric function continuum, for example, *Orderly .... Messy, How things look ... How things work.* There are five spaces between the words and the student is asked to place a cross nearer the word that best describes themselves. The proximity of the student's cross to the word indicates the strength of their attachment to that word. Each pair is allocated a mark from -2 to +2 and the student's total score is calculated. If the score is negative the student is said to be left-brain predisposed and if the score is positive the student is said to be right-brain predisposed. The larger the number the more left or right brained the student is said to be.

The Administration of the Instruments

The two instruments to measure attitude and the instruments to measure van Hiele level and left/right brain preference in their final form were then administered to the preservice teachers. The instruments were sealed in two envelopes which were given together to the students in class at the university. The first envelope contained the first questionnaire which asked for the student's age, gender, educational background and university year. It also contained the Semantic Differential Scale, the Likert Scale and the Hemispheric Mode Indicator test. The second envelope contained four sections of Lawrie's test, namely, the section on squares, isosceles triangles, parallel lines and congruence. The students were asked to complete the first questionnaire before starting on the contents of the second envelope. With the permission of the Ethics Committee (see Appendix E), the students were not told of the subject matter of the test in the second envelope. This was necessary for two reasons:

1. to avoid acquiescence and history invalidating the results of the measurement of their attitude to geometry in the first envelope.

2. earlier research by Brodie and others (see Chapter 3) had found a dislike for geometry among teachers and hence there may have been a reluctance to volunteer for the research had the specific topic been known.

If the students required extra time to complete the test they were given it. The fourth year students were given the tasks to do at home.

Ethics

For the reasons listed above informed consent was not sought from the participants. A clearance from the Ethics Committee of the University of Western Sydney Nepean was granted provided the researcher agreed to provide a debriefing for the participants and feedback to those who requested it at the end of the research. (see Appendix E)

The Analysis of the Data

The statistical package used to compile the descriptive statistics was SPSS V10.05 (Norusis/SPSS Inc., 1993) and Confirmatory Factor Analysis (CFA) and statistical inferences were based on LISREL 8.53 (Joreskog & Sorbom, 1996a) and Prelis 2.3 (Joreskog & Sorbom, 1996b).

i) An Introduction to Structural Equation Modeling (SEM)

SEM is a comprehensive statistical approach for testing hypotheses about the relationships among observed and latent variables (Hoyle, 1995). SEM, like correlation, multiple regression and ANOVA, is based on linear statistical models with the latter being special instances of the general structural equation model. According to Hoyle (1995) SEM has at least two advantages over other linear statistical models. Firstly, SEM offers no default model specifications like ANOVA and multiple regression analyses and therefore requires the researcher to specify relationships in the model. This characteristic is considered to be an advantage because it requires the researcher to think carefully about his/her data and venture hypotheses about each variable.

Secondly, SEM estimates and tests relations between latent variables whereas other linear models do not. SEM increases the probability of detecting associations between constructs and of obtaining parameter estimates close to their population values through isolating constructs from the uniqueness and unreliability of their indicators. The important difference between SEM and other methods of analysis such as multiple regression is that “SEM is the only analysis that allows complete and **simultaneous** (researcher’s emphasis) tests of all the relationships” (Tabachnick & Fidell, 2001, p. 656).

In the present research, SEM was used to allow the researcher to answer empirical questions about the nature of the relationship of background factors, attitudes and the success in geometry of preservice teachers. More specifically, SEM allows for the identification of any mediating effects that student’s attitude to geometry has for the background factors (for example, gender) on preservice teachers’ success in geometry.

ii) The Statistical Strategy

The statistical strategy (see Chapter 6) used in this research consists of two major sections. Section 1 deals with the measurement model in two parts, that is, the validation of the Semantic Differential and Likert Scales and the subsequent structural validation of all three major factors of the model (background factors, attitude and success in geometry) using Confirmatory Factor Analysis (CFA). Section 2 deals with the effect of the independent variables, *age, gender, education and left/right brain preference,* on the dependent variable, *success in geometry* mediated by the variable *attitude to geometry*. In the present research this is referred to as the path model.

Section 1 part 1 covers the psychometric properties of the Semantic Differential and Likert Scales used in the present research, namely, the two attitude scales (see Chapter 3). A number of measures, goodness of fit indices, (factor loadings, inter-item correlations and uniqueness) of items for the latent variable, face validity of the item, the researcher's alertness to the underlying meanings that may be attributed to the items, and common sense were used to establish unidemsionality of items for latent factors. A one-factor congeneric strategy and Cronbach's Alpha were used for this purpose. In SEM terms, this methodology together with the CFAs referred to below, is a model generating strategy (Joreskog & Sorbom, 1993) in that the fit indices resulting from different models containing modifications are compared.

The second part of section 1 is concerned with structural validity of the model of success in geometry. Byrne (1998), suggests that in conducting CFAs the researcher draws on knowledge of the theoretical structure of the variables, proposes a factor structure, and then statistically tests this hypothesised factor structure. In this research it was hypothesised that each measured variable would have a non-zero loading on the factor it was designed to measure and a zero loading on all other factors and that the error terms for each measurement variable would be uncorrelated. Byrne (1998) also suggests that for the fit of the data to be acceptable the data will not contain any negative variances, completely standardised factor loadings or factor correlations greater than one.

In section 2 the method recommended by Baron and Kenny (1986) is used to guide the research. It will be recalled that Baron and Kenny stated that an intervening variable may mediate the effects of the independent variable on the dependent variable as shown below in figure 5.2. In the present research the intervening variable is attitude and the dependent variable is success in geometry. Hence it is important to establish its relations with the background factors and success in geometry. In the second part of Chapter 6 this question of attitude as a mediator of the background factors on success in geometry is examined in detail.

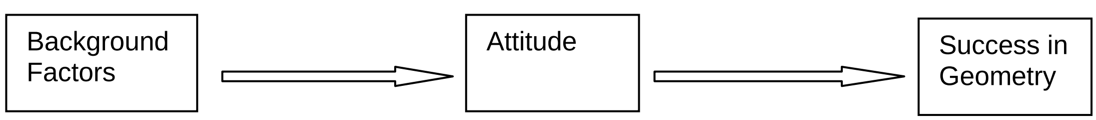

Figure 5.2: Mediation of the effects of the independent variable on the dependent variable.

LISREL 8.53 gives the researcher a number of different fit indices to determine the best model fit. Unfortunately there is no consensus among researchers as to which fit index is best to use (Marsh, Balla & Hau, 1996). However, it seems that the family of incremental fit indices is one of the most popular. Incremental fit indices suggest the degree of improvement in model fit by comparing the researcher's model to a nested baseline model. Typically, the baseline model is a null model in which all the observed variables are uncorrelated (Bentler & Bonett, 1980). In this research two qualitatively different but complementary incremental fit indices, the non-normed fit index (NNFI) which is also known as the Tucker Lewis index, and the normed relative comparative fit index (CFI) which is the normed version of the relative noncentrality index (RNI), were used to test the model fit. The distinction between these two fit indices is that the NNFI penalises model complexity. However, each of these fit indices is not biased by sample size. Basically the arbitrary and commonly accepted application of the 0.9 rule was applied to these indices to determine an acceptable fit for a model. Reported also is the Residual Mean Error of Approximation (RMSEA) to assess model fit. According to Steiger (1989) the RMSEA and NNFI are the least sensitive of the indexes to sample size. The RMSEA is a measure of the extent to which the model can be generalised to the population. Steiger (1989) suggests that an RMSEA value of less than 0.05 indicates a very good fit, a value of less than 0.10 indicates a reasonable fit and a value greater than 0.10 indicates some misfit. Brown and Cudeck (1993) suggest that an RMSEA value of less than 0.05 indicates close fit, a value between 0.05 and 0.08 indicates a fair fit and a value greater than 0.10 indicates a poor fit. MacCallum, Browne and Sugawara (1996) suggest that a value less than 0.05 indicates a good fit and a value between 0.08 and 0.10 indicates a mediocre fit. Hu and Bentler (1999) reviewed the fit indexes and suggested that a value less than 0.06 indicates an excellent fit and a value between 0.07 and 0.10 indicates an adequate fit.

In the present research the NNFI is emphasised. Whilst the statistical measures described above aid in determining the model of best fit, there is a degree of subjectivity and professional judgment in considering the statistical data and practical significance involved in selecting the best model (Marsh, Hau, Balla & Grayson, 1998).

Conclusion

This chapter outlines the model generating process and introduces Structural Equation Modelling as the means of analysing the data. The following chapter (Chapter 6) contains the results of the model generating process. It includes the validation of the Semantic Differential and Likert Scales and the subsequent structural validation of all three major factors of the model (background factors, attitude and success in geometry). It also contains a path model that is used to examine the structural relationships of the variables.

Chapter 6

RESULTS OF THE MODEL GENERATION PROCESS

It is the supreme art of the teacher to awaken joy in creative expression and knowledge *…* Albert Einstein

In this chapter a statistical model that depicts background factors believed to be predictors of success in geometry and measures of attitude about geometry, is developed and presented. The model is then used to address the research questions about the relations of these factors.

As discussed earlier (see Chapter 3) attitudes are important to success in geometry and the positive relation between the two has been emphasised in TIMSS-R (1998). Even after controlling for the background factors used in the current research the relation between attitude and success in geometry is strongly significant.

The chapter is in two parts. Part A: Confirmatory Factor Analysis, and Part B: The Model. Part A commences with an examination of the question as to whether the Semantic Differential and Likert Scales measure the same thing. While they are analytically distinct, the question remains as to whether they are empirically distinct. These steps are reported first. The chapter then turns to the model building process incorporating scales for all of the factors. Here the fit of a model comprising all the hypothesised factors is examined as well as the hypothesised correlations among the factors. Finally, in Part B, the research questions about the relations of the background factors, the cognitive and affective factors and the behavioural factor are examined using a path model of success in geometry.

Part A: Confirmatory Factor Analysis

1. Determination of One or Two Attitude Scales

As a result of studies of the literature (see Chapter 3), the conducting of Exploratory Factor Analysis and consultation with colleagues, a 10-item Likert Scale and a 9-item Semantic Differential Scale were developed (see Appendix B).

In the literature it is unclear whether the two scales measure the same thing or are distinct measures. Hence, advanced SEM methodology is used to determine the answer to this question. Addressing the question of whether the scales are interchangeable replicates the work of McCallum and Brown (1971) and Schofield and Start (1978). Both pairs of researchers used a Likert and a Semantic Differential Scale to measure attitude to Mathematics (not geometry). McCallum and Brown (1971) assessed the attitudes of 68 college students to mathematics and reported a high positive correlation (r = 0.90) between the results of the two scales. Schofield and Start

(1978) assessed 317 student teachers to determine their attitudes to mathematics. They reported a moderately high correlation (r =0.70) between the results of their two scales. From these results it appears that the scales are similar and perhaps interchangeable. In Chapters 3 and 5, however, it was noted that there was some question as to whether the Likert and Semantic Differential Scales do measure the same construct. Schibeci (1982) stated: “It seems that semantic differential and Likert data may not be used interchangeably as suggested by some authors” (p. 569).

This issue of one or two scales was at first addressed in the current research by examining and comparing the fit of each scale independently, by examining the relationship of the two scales in a single model of student attitudes, and finally by collapsing the two scales into a single scale (Marsh et al. 1996). The first step of this examination was to conduct a Confirmatory Factor Analysis (CFA) on each scale by constructing a congeneric model for each scale (Joreskog & Sorbom, 1996a). The second step was to conduct a CFA on a model that comprised both scales to test whether each scale was well defined and to examine the correlation between the two scales. The third step was to conduct a CFA in which both scales were collapsed as a single scale. Here the concern was to do two things; firstly, to compare the goodness of fit for each of the solutions in steps one to three and secondly, to examine the correlation between the two scales in step 2. As a basis of comparison the Non-Normed Fit Index (NNFI) is used.

These processes resulted in the first instance in an NNFI for the Semantic Differential Scale of 0.90 and an NNFI for the Likert Scale of 0.98. Clearly each scale performed well. In the second instance the model comprising the two scales resulted in an NNFI of 0.96. The model with the single collapsed scale resulted in an NNFI of 0.93. Table 6.1 presents the results of the tests.

Table 6.1:

Results of Confirmatory Factor Analysis on the Scales

	df	chi	RMSEA	NNFI	CFI
M1: Likert	35	87.31	0.08	0.98	0.98
M2: Semantic	27	168.83	0.15	0.90	0.93
M3:Two-independent	151	381.93	0.08	0.96	0.97
M4: Collapsed	152	827.37	0.14	0.93	0.94

The correlation between the two scales was $\underline{r} = 0.76$, which is similar to the result of Schofield and Start (1978). The correlation is high and this suggests that for the most part the scales may be measuring similar characteristics. The correlation is also of a magnitude that suggests that each scale is somewhat divergent. Consequently, the results are inconclusive in terms of whether to use one or two scales. However, given the NNFI of 0.96 realised for the two independent scales, the two scales were incorporated in the overall model comprising the 10 factors. The reasoning behind this decision was that while both scales perform well in all tested situations, it may be that when evaluated in the full model differences about their effect may be apparent. This was indeed the case as later reported.

In Chapter 3 it was reported that attitude consists of three parts and its measurement can involve three classes of response. According to Eagly and Chaiken (1993):

> Likert’s method is a general scaling technique that may be applied to any of the three classes of attitudinal responding. In contrast, the semantic differential does not apply across all three classes of indicators. It is instead based on the ratings of the attitude object on adjective scales that present generalized beliefs (e.g., good vs. bad) (p 51).

Hence, the Semantic Differential Scale only measures the affective response of attitude whereas the Likert Scale may measure the affective, cognitive and behavioural responses of attitude. That is to say the semantic differential measures the connotative meaning of the attitudinal object whereas the Likert Scale measures both the connotative and the denotative meaning of the attitudinal object (see Chapter 3).

This difference in the scales may account for the statistical findings reported above. The convergence of the scales may be due to them both measuring the connotative meanings of the items and the divergence of the scales may be due to the Likert Scale measuring the denotative meaning of the items as well. For example, the item from the Likert Scale *On the whole I enjoy geometry* can be responded to using an affective response where the word *geometry* is taken to have no denotative meaning and simply evokes emotion in the responder or it can be responded to using a cognitive response where *geometry* is taken by the responder to be a familiar body of knowledge that is part of the educational process. Importantly, the item could be responded to both affectively and cognitively at the same time.

Unlike the Semantic Differential Scale the cognitive response to attitude measurement in the Likert Scale can lead to acquiescence on the part of the student (Bryman, 2001). Student teachers would be aware of the importance of geometry in mathematics despite their personal feelings towards it and may respond accordingly. It is also possible that the items themselves may provide superficial clues and guide the answers of the students (Eagly & Chaiken, 1993).

Students may not use the same underlying processes when responding to the Likert and Semantic Differential Scales even though the attitude scores that are produced by them correlate highly. Completing the Likert Scale could involve students using a more elaborate and deeper cognitive process than they do when completing the Semantic Differential Scale in which answers are given using a stored general evaluation process. This is especially the case when, as in the present research, there is a large number of belief statements to consider.

The fact that the semantic differential cannot be applied across all classes of evaluative responding was seen by Osgood et al. (1957) and others (Tuckman, 1972; Kerlinger, 1973) to be a strength rather than a weakness as “it …limited the tendency to produce socially accepted responses” (Tuckman, 1972, p. 161). Unlike the Likert Scale in which a student’s attitude “must be inferred from the … endorsements of favourable or unfavourable beliefs, affects, or behaviours that have been selected for their relevance to a particular attitudinal object” (Eagly & Chaiken, 1993, p.57), the Semantic Differential Scale gives a direct measurement of the students’ stored evaluation process of an attitudinal object.

It would appear then, at least from a theoretical perspective, that it is appropriate to use the Semantic Differential Scale in this research. However, the empirical evidence concerning the two scales, at this stage, is inconclusive. Therefore, due to this and the discussion of the scales in Chapter 3, both scales continue to be examined for their appropriateness to the present research. Figure 3.2 is reproduced below for convenience.

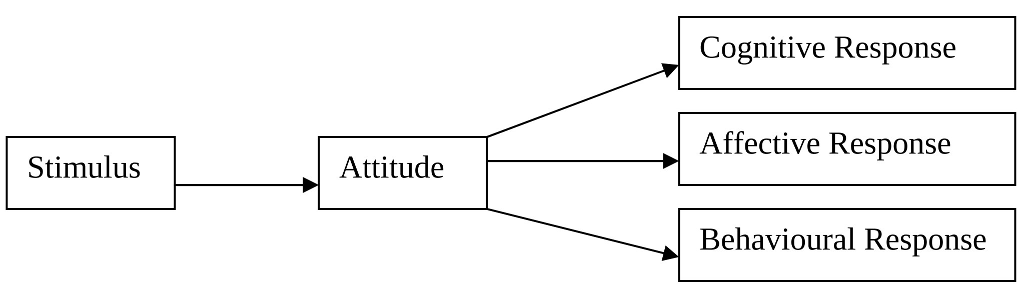

Figure 6.1: Figure 3.2: Attitude with evaluative responses divided into three classes.

2. The Hypothesised Factors and a Statistically Coherent Model

The correlations among the factors finally incorporated in the model are important to the present research because of the expected relationships among the factors. For example, it is expected that left/right brain preference will correlate positively with success in geometry and education will correlate positively with attitude. Hence, the question as to whether all these factors, *together,* comprise a single coherent statistical model in which the relationships of the particular factors can be examined is now addressed. Firstly, PRELIS 2.3 (Joreskog, K. & Sorbom, D. 1996b) was used to construct a 27 by 27 covariance matrix. This covariance matrix was used for all subsequent analysis. Table 6.3 (page 173) in the Summary of Results section of Part A, presents the correlation matrix for the 10-factor model of success in geometry.

Joreskog and Sorbom (1996a) recommend, when using scales such as those adopted in the present research, that the asymptotic covariance matrix should be used for estimation purposes given a large enough sample size. However, they point out that it is inadvisable to use the asymptotic covariance matrix with small sample sizes and they caution that to do so may cause more harm than good (see also Yuan & Bentler, 1999). They suggest that with small sample sizes the safest method to use for estimation purposes is Maximum Likelihood (ML). The present research uses the ML method of estimation.

For analysis the categorical variables, age and education, were changed to dichotomous variables. This is known as dummy coding. This was done to limit the relationship between the dichotomous variables and others to linear relationships.

i) Dummy Coding

In dummy coding, membership in a given category is assigned 1 and non-membership is assigned 0. For age the 24 years and under cohort was coded 0 while the 25 years and over cohort was coded 1. For gender, females were coded 0 and males 1. For education, Mathematics in Practice (MIP) and Mathematics in Society (MIS) were coded 0 as they are courses without a geometry component and 2U mathematics, 3U Mathematics, 4U Mathematics and other courses were coded 1 as they are courses with a geometry component.

ii) Solution to the Structural Validity of the Model

The initial tests were conducted with a 12 factor model comprising age, gender, left/right brain, education, course year, degree, Likert Scale, Semantic Differential Scale, van Hiele level squares, van Hiele level isosceles triangles, van Hiele level parallel lines and van Hiele level congruent triangles. However, the initial solutions during this model construction stage resulted in improper loadings and negative item residual variances. It was suspected that age, course year and degree factors were too similar causing multicollinearity in the model. A subsequent solution that retained age and excluded course year and degree was finally adopted. The basis for that decision was that, for the present research, the multicollinearity between these three factors meant that one factor could act as a proxy for the other two factors. This is not to say that the dimensions are not theoretically distinct. Rather it merely asserts that in this particular study they were not empirically distinguishable. This resulted in a 10-factor model comprising age, gender, left/right brain, education, Likert Scale, Semantic Differential Scale, van Hiele level squares, van Hiele level isosceles triangles, van Hiele level parallel lines and van Hiele level congruent triangles.

Table 6.2 below contains the goodness of fit indices for the 10-factor model reflecting the removal of course year and degree. The NNFI for the model was 0.94, indicating a statistically coherent model. This was a good basis on which to proceed with further analysis.

Table 6.2:

Goodness of Fit Indices for the 10-Factor Model

	df	chi	RSMEA	NNFI	CFI
10-Factor Model	287	610.07	0.075	0.94	0.95

The next section begins with a refocussing on the three broad areas covered by the research questions, continues with an examination of the relationship of the factors via research hypotheses, and then lists the correlation matrix and results of the examination. A summary of the results then follows.

3. The Relationship of the Factors

The focus in this section is on the relationship of the factors that are the subject of the present research. For example, it is expected that one's attitude changes with age and experience. Equally, a relationship between attitude and success in geometry would be expected. The more one likes geometry the more likely one would be to succeed in geometry. It is expected that there would be a relationship between gender and success in geometry given the results of the Australian Capital Territory Assessment Program (ACTAP, 2000 – 2002) on achievement in mathematics and despite the research of Frykholm (1994) and the report on the results of TIMSS-R (1998) by Zammit et al. (2002).

At the beginning of Chapter 5 it was stated that the research questions focus on the relationship of three broad areas. These areas are reproduced below for convenience.

1) background factors as predictors of preservice teacher success in geometry (age, gender, education, degree, left/right brain preference), teacher training (course year);

2) preservice teachers’ attitude; and

3) preservice teachers’ success in geometry.

Four sets of relationships are therefore addressed. These are:

1. The relationship between background factors (Independent Variables) and success in geometry (Dependent Variable).

2. The relationship between students’ attitude to geometry (Independent Variable) and success in geometry (Dependent Variable).

3. The relationship between background factors (Independent Variables) and attitude (Dependent Variable).

4. The relationship of the background factors with the success in geometry factors where attitude is an intervening variable.

i) Research Hypotheses

a) Relationship of background factors and success in geometry.

1. ***Age.*** Van Hiele posits that whilst an individual's level of understanding in geometry is not based on biological development an individual must have sufficient time to go through the necessary learning process. Frykholm (1994), when examining the effects of age in 14 to 18 year old high school students studying geometry on van Hiele level, found that age negatively correlated with the van Hiele level. ACTAP (2000 – 2002) suggests a positive correlation between age and success in geometry. Therefore, it is hypothesised that age and the respective van Hiele levels, as measured on four geometry topics, are positively correlated.

2. ***Gender.*** Gender and culture are of significant interest to the research and teaching communities. According to the ACER report by Zammit et al. (2002) on TIMSS-R (1998) there were no significant gender differences in any of the mathematical content areas and no gender differences in students' average achievement in mathematics. Frykholm (1994), when examining the effects of gender in 14 to 18 year old high school students studying geometry on van Hiele level, found that gender did not correlate. However, the results of testing year 3, 5, 7 and 9 students in Canberra (ACTAP, 2000 - 2002) indicate a significant difference between the achievement of males and females in all mathematics strands. Hence it is hypothesised that gender and the respective van Hiele levels, as measured on four geometry topics, are correlated.

3. ***Left/Right Brain.*** Brain-based education reinforces the need to cater for the left/right brain tendency of an individual (Partridge, 1983; Fink et al., 2000; Nunley & van Tassell, 2001). It indicates that geometry uses the creative right brain of the individual. Hence, it is hypothesised that left/right brain and the respective van Hiele levels, as measured on four geometry topics, are correlated.

4. ***Education.*** The course studied at school should be predictors of success in geometry due to their varying levels of difficulty and their geometry content (see Dummy Coding). Hence it is hypothesised that course studied at school and the respective van Hiele levels, as measured on four geometry topics, are correlated.

b) Relationship of attitude and success in geometry.

1. ***Attitude.*** There has been a wealth of studies that link attitude to mathematics and achievement in mathematics. After reviewing much of the research Ma and Kishor (1997) stated “The research literature, however, has failed to provide consistent findings regarding the relationship between attitude to mathematics and achievement in mathematics”. Due to different definitions of attitude and measuring instruments, however, these results are not surprising and should be treated with caution. Zammit et al. (2002), reviewing TIMSS-R (1998) concluded that “… in Australia, more positive attitudes were related to higher achievement scores” (p. 163). Hence it is hypothesised that attitude to geometry and the respective van Hiele levels, as measured on four geometry topics, are correlated.

c) Relationship of background factors and attitude.

1. ***Age and Attitude.*** Generally speaking, attitudes change with age. If there were not differing attitudes to concepts with age then generational differences in attitude would not be expected. However, the question here is whether age is related to attitude to *geometry*. It is hypothesised that age and attitude to geometry are correlated.

2. ***Gender and Attitude.*** Zammit et al. (2002), reported that "… significantly more males had high positive attitudes towards mathematics than females" (p. 163). Hence it is hypothesised that gender and attitude to geometry are correlated.

3. ***Left/Right Brain and Attitude.*** Brain based educators suggest that problem solving, artistic activity and creativity all reside in the right hemisphere of the brain (Wheatley et al., 1978; Kitchens et al., 1991; Schweiger, 2000). These are characteristics that assist in the learning of geometry. It could be expected that right brained individuals would have a positive attitude towards geometry. Hence, it is hypothesised that attitude to geometry and left/right brain preference are correlated.

4. ***Education and Attitude.*** Only some of the Higher School Certificate mathematics courses studied by the students contain a geometry component. What effect studying a non-geometry (Mathematics in Society, Mathematics in Practice) course or geometry course (2 Unit, 3 Unit, 4 Unit) has on attitude to geometry has not been researched. It is reasonable to assume, however, that studying a course containing a geometry component has the potential to influence in a positive or negative way, a student's attitude to geometry. Hence it is hypothesised that education and attitude to geometry are correlated.

Below in Table 6.3 is the Factor Correlation Matrix for the 10-Factor Model.

Table 6.3:
Factor Correlation Matrix for the 10-Factor Model

	Age	Gender	Education	Left/ Right Brain	Van Hiele Level Square	Van Hiele Level Isosceles Triangles	Van Hiele Level Parallel Lines	Van Hiele Level Congruent Triangles	Likert	Semantic Differential
Age	1.00									
Gender	-0.04	1.00								
Education	-0.61**	0.12	1.00							
Left/Right Brain	0.18**	0.08	-0.14*	1.00						
Van Hiele Level Square	0.07	-0.06	0.26**	0.01	1.00					
Van Hiele Level Isosceles Triangles	0.09	0.15*	0.20**	-0.03	0.51**	1.00				
Van Hiele Level Parallel Lines	0.01	0.05	0.42**	0.04	0.55**	0.58**	1.00			
Van Hiele Level Congruent Triangles	0.10	0.30**	0.37**	0.02	0.59**	0.46**	0.46**	1.00		
Likert	-0.02	0.27**	0.15*	-0.03	0.22**	0.23**	0.14	0.29**	1.00	
Semantic Differential	0.01	0.20**	0.14	-0.05	0.29**	0.31**	0.19**	0.39**	0.76**	1.00

Note ** = P < 0.01, * = P < .05

ii) Results

a) Relationship of background factors and success in geometry.

1. ***Age.*** The relationships between age and van Hiele level-squares (r =0.07), van Hiele level-isosceles triangles (r =0.09), van Hiele level-parallel lines (r =0.01) and van Hiele level-congruent triangles (r =0.10) were not significant.

Hence the hypothesis that age and the respective van Hiele levels are positively correlated is not supported.

2. ***Gender.*** The relationships between gender and van Hiele level-squares (r =-0.06) and van Hiele level-parallel lines (r =0.05) were not significant. However, the relationship between gender and van Hiele level-isosceles triangles was weakly significant (r =0.15, $p<0.05$) and between gender and van Hiele level-congruent triangles was moderately significant (r =0.30, $p< 0.01$).

There is no evidence to support the rejection of the hypothesis that gender and the respective van Hiele levels are correlated. Hence this hypothesis is supported.

3. ***Left/Right Brain.*** The relationships between left/right brain and van Hiele level-squares (r =0.01), van Hiele level-isosceles triangles (r =-0.03), van Hiele level-parallel lines (r =0.04), van Hiele level-congruent triangles (r =0.02) were not significant.

Hence the hypothesis that left/right brain and the respective van Hiele levels are correlated is not supported. Given the emphasis on brain-based teaching in schools this is an important result.

4. ***Education.*** The relationships between education and van Hiele level-squares (r =0.26, $p < 0.01$), van Hiele level-isosceles triangles (r =0.20, $p < 0.01$), van Hiele level-parallel lines (r =0.42, $p < 0.01$) and van Hiele level-congruent triangles (r =0.37. $p < 0.01$) were moderately significant.

There is no evidence to support the rejection of the hypothesis that education and the respective van Hiele levels are correlated. Hence this hypothesis is supported.

b) Relationship of attitude and success in geometry.

1. ***Attitude.*** The relationships between attitude (Semantic Differential Scale) and van Hiele level-squares (r =0.29, $p < 0.01$), van Hiele level-isosceles triangles (r =0.31, $p < 0.01$) and van Hiele level-congruent triangles (r=0.39, $p < 0.01$) were moderately significant and the relationship between attitude and van Hiele level-parallel lines (r =0.19, $p < 0.01$) was weakly significant. The relationships between attitude (Likert Scale) and van Hiele level-squares (r =0.22, $p < 0.01$), van Hiele level-isosceles triangles (r =0.23, $p < 0.01$) and van Hiele level-congruent triangles (r=0.29, $p < 0.01$) were moderately significant.

There is no evidence to support the rejection of the hypothesis that attitude to geometry and the respective van Hiele levels are correlated. Hence this hypothesis is supported.

c) Relationship of background factors and attitude.

1. ***Age and Attitude.*** The relationship between age and attitude (Likert: r =-0.02, SD: r =0.01) was not significant.

Hence, the hypothesis that age and attitude do correlate is not supported.

2. ***Gender and Attitude.*** The relationship between gender and attitude (Semantic Differential Scale) was moderately significant (r =0.20, $p < 0.01$) with males more likely to have a positive attitude to geometry than females. The relationship between gender and attitude (Likert Scale) is moderately significant (r =0.27, $p < 0.01$) with males more likely to have a positive attitude to geometry than females.

There is no evidence to support the rejection of the hypothesis that gender and attitude to geometry correlate. Hence this hypothesis is supported.

3. ***Left/Right Brain and Attitude.*** The relationship between Left/Right Brain and attitude (Likert: r =-0.03, SD: r =-0.05) was not significant.

Hence the hypothesis that attitude and left/right brain preference do correlate is not supported.

4. ***Education and Attitude.*** The relationship between education and attitude (Semantic Differential Scale) was not significant. The relationship between education and attitude (Likert Scale) is weakly significant ($r = 0.15$, $p < .05$).

Hence the hypothesis that attitude and education do correlate is not supported.

iii) Summary of Results

It is clear that there are significant relationships between two background variables (gender and education) and attitude (gender as measured on both scales and education as measured on the Likert Scale), between two of the background variables (gender and education), and success in geometry (van Hiele level) and between attitude (as measured on both scales) and success in geometry (van Hiele level). It is also clear that the hypothesised relationship between age and success in geometry (van Hiele level) was not supported. Van Hiele posited that age was important and Frykholm (1994) reported a negative correlation. It is possible, that relations with other variables have masked the effects of age. The hypothesised relationship between left/right brain and success in geometry was not supported.

There is little difference between the results of the relationships between attitude and the success in geometry factors as measured by the Semantic Differential and Likert Scales. Attitude (Semantic Differential Scale) correlates with van Hiele level parallel lines, nevertheless the correlation is weak ($r = 0.19$ $p < .05$). However, attitude (Likert Scale) does not correlate with van Hiele level parallel lines and the Semantic Differential Scale marginally outperforms the Likert Scale. Hence the question of whether there is empirical evidence in support of two factors is unresolved at this point.

The low, yet significant, correlations between the cognitive and affective factors and the van Hiele factors suggest that the factors are well defined. Whilst the correlations between the cognitive, affective and van Hiele factors do not provide firm evidence in favour of the three dimensional model of attitude, it is clear that there is no evidence here to disprove the theory. If the theory of a three dimensional model were not sound, then a weak or non-significant correlation would be expected. Given the dearth of empirical evidence in support of this concept, this is an important result.

Part B: The Path Model – The Direct and Indirect Affects of Background and Attitude Factors on Success in Geometry.

The research here is a correlation study. This is important, as it is usual to be cautious when interpreting the results of correlation research because the correlation between two factors may be due to the presence of other factors (Urdan & Maehr, 1995). For example, it could be hypothesised that being male is a better predictor of success in geometry because males have a better attitude to geometry or it could be postulated that studying the 2 unit mathematics course in the Higher School Certificate is a better predictor of success in geometry because 2 unit mathematics students may have a better attitude to geometry than students who complete non-geometry courses.

Hence, the question is whether the relations between the background factors and the van Hiele levels are, or are not, a consequence of other factors. Put another way, if other factors were controlled for, what would be the relationship between these factors? Therefore, an examination of the hypothesised direct and indirect effects of the background and attitude factors, on success in geometry, is now appropriate.

1. Introduction

A path model enables an examination of hypothesised relations among particular factors that comprise the model by controlling for the effects of other designated factors. Hence, having established the internal consistency, structural validity of the scales, and the structural validity of the 10-factor model of success in geometry, it is now appropriate to examine the hypothesised direct and indirect effects of the background and attitude factors, on success in geometry. In the present research it is hypothesised that attitude will mediate the effects of the background factors, age, gender, left/right brain and education on success in geometry. This is the same as saying that the effects of attitude on learning differ according to the background of the individual.

The nature of a path model is such that it can be constructed to control for the influence of various combinations of factors in the model thereby presenting a more accurate estimate of the direct and indirect influences of background and attitude factors on success in geometry. This process of controlling or partialling out the effects of the other factors on the measures of success in geometry is also referred to as decomposing factor correlations (Pedhazur, 1997). Figure 6.2 illustrates this decomposition which involves determining the direct effects (path c), indirect effects (path a and b) and the total effects (direct plus indirect effects), of an independent variable on a dependent variable.

A variable may function as a mediator to the extent that it accounts, in part or the whole, for the relation between the independent variable or variables and the dependent variable. That is, the mediator variable represents the generative mechanism through which the independent variable or variables is able to influence the dependent variable.

In Figure 5.1 (see Chapter 5), the basic causal chain involved in mediation was given. It is reproduced below for convenience.

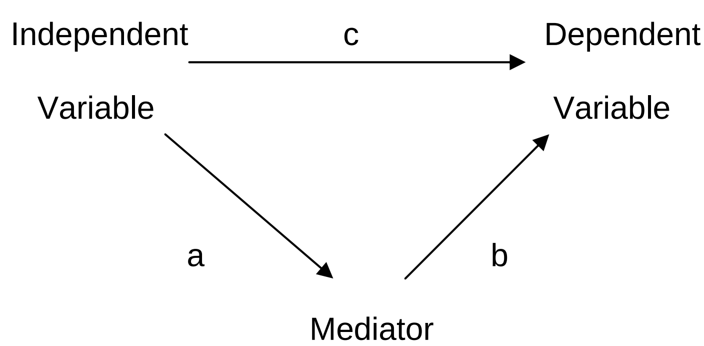

Figure 6.2: Figure 5.1: Causal chain involved in mediation.

The results of the correlation matrix (Table 6.3, page 173) suggest that the question of one or two attitude scales has not been resolved. They also indicate that attitude and education, which strongly correlate with success in geometry, and gender, which moderately correlates with success in geometry, are important factors. This is of importance, as whilst gender generally cannot be changed, attitude and education can be changed. The relationship between the background factors and attitude, and attitude and success in geometry, as indicated by the results of the correlation matrix is important because it suggests that attitude may mediate the effects of the background variables on success in geometry. Therefore, determining whether attitude mediates the effects of predispositional characteristics, such as gender, on success in geometry and acknowledging that suppressor variables may exist, suggests a way forward in improving on the current Australian success rate in geometry as indicated by the data in TIMSS-R (1998).

According to Baron and Kenny (1986), when multiple regression is used to estimate a mediational model two assumptions are made. One is that there is no measurement error in the mediator variable and the second is that the dependent variable does not cause the mediator (feedback). However, because the mediator is often a psychological variable, it is subject to error measurement. Error measurement in the mediator leads to an overestimation of the effect of the independent variable on the dependent variable and an underestimation of the effect of the mediating variable. Baron and Kenny also suggest that the usefulness of ANOVA is limited because not all paths are tested. To overcome these problems structural equation modeling is used in this research. The major advantages of using structural equation modelling to test the model, according to Baron and Kenny (1986), are:

> First, although these techniques were developed for the analysis of nonexperimental data (e.g., field-correlation studies), the experimental context actually strengthens the use of the techniques. Second, all the relevant paths are directly tested and none are omitted as in ANOVA. Third, complications of measurement error, correlated measurement error, and even feedback are incorporated directly into the model.

In the present research the independent variables in the causal chain are age, gender, left/right brain and education. The mediator is attitude (Likert and Semantic Differential) and the dependent variables are the four van Hiele level results.

To test whether attitude does mediate the effects of background variables on success in geometry as shown in figure 6.3, it is necessary to establish whether the following conditions apply (Baron & Kenny, 1986):

a) Significant total effects of the independent variable on the dependent variable.
b) Significant indirect effects of the independent variable on the dependent variable.
c) Significant direct effects of the independent variable on the mediating variable.
d) Significant direct effects of the mediating variable on the dependent variable.

In the present research it is hypothesised that students' attitudes to geometry mediate the effects of the background variables on success in geometry. Figure 6.3 presents a diagram of the 10-factor model of success in geometry showing the hypothesised mediator variable, attitude, as measured by a Likert Scale and a Semantic Differential Scale.

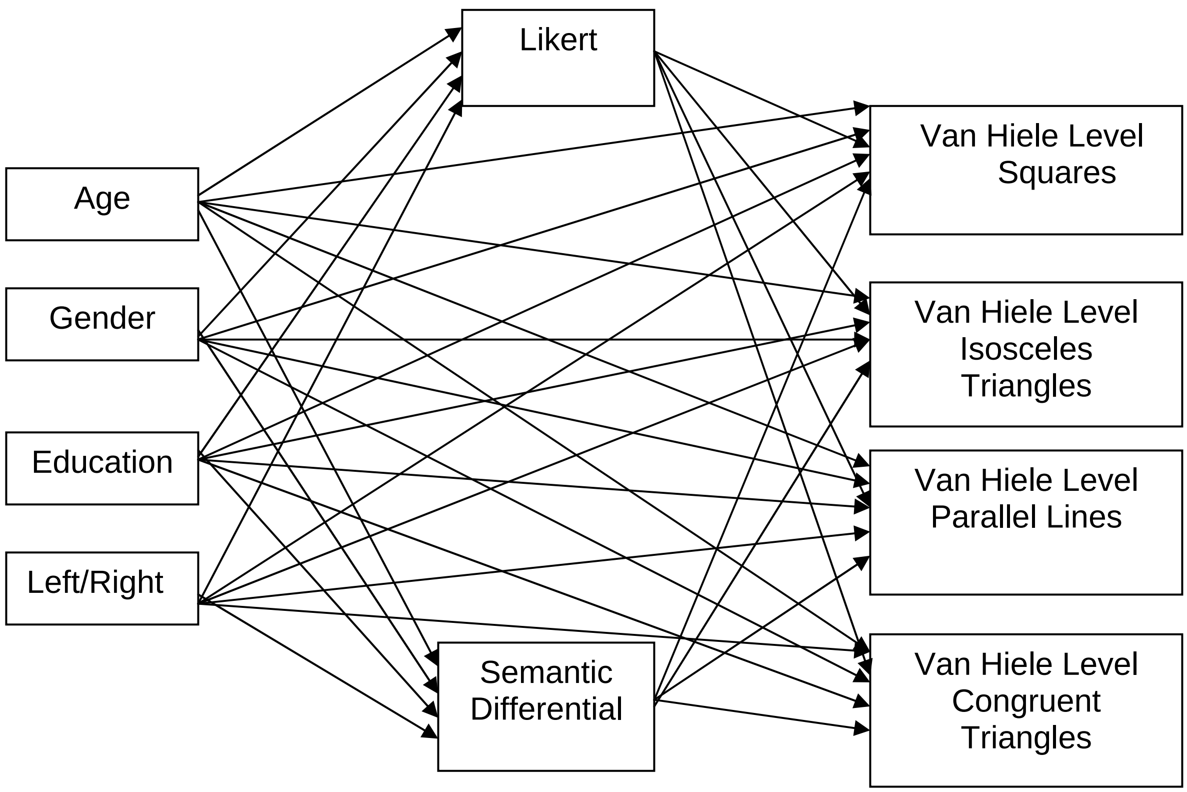

Figure 6.3: 10-Factor path model of success in geometry.

2. Research Mediation Hypotheses

a) Indirect Effects of Age on Success in Geometry Mediated by Attitude.

It is hypothesised that the effect of age on the respective van Hiele levels (4) is mediated by attitude.

b) Indirect Effects of Gender on Success in Geometry Mediated by Attitude.

It is hypothesised that the effect of gender on the respective van Hiele levels (4) is mediated by attitude.

c) Indirect Effects of Left/Right Brain Preference on Success in Geometry Mediated by Attitude.

It is hypothesised that the effects of left/right brain preference on the respective van Hiele levels (4) is mediated by attitude.

d) Indirect Effects of Education on Success in Geometry Mediated by Attitude.

It is hypothesised that the effect of education on the respective van Hiele levels (4) in geometry is mediated by attitude.

3. Results

Lisrel 8.3 reports standardised total, indirect and direct effects (Joreskog & Sorbom, 1996a). Therefore Lisrel 8.3, as suggested by Baron and Kenny (1986), is used here to examine the mediation effects of attitude. Using structural equation modeling methodology, and referring to figure 6.2 (page 181), there are three possible outcomes. Firstly, if paths "a" or "b" are non-significant, then there are no mediating effects. Secondly, if path "c" is non-significant and paths "a" and "b" are significant, there is a complete mediation effect. Thirdly, if paths "a", "b" and "c" are significant, there are partial mediation effects.

The results in tables 6.4 to 6.5 are for the hypothesised path model of success in geometry. Table 6.4 (page 188) shows the indirect effects and table 6.5 (page 189) the direct effects. From these tables it can be seen that there are:

1. Significant direct effects of age on van Hiele level squares, van Hiele level isosceles triangles, van Hiele level parallel lines and van Hiele level congruent triangles with path coefficients of 0.34, $p<0.01$, 0.31, $p<0.01$, 0.40, $p<0.01$ and 0.47, $p<0.01$ respectively (see Table 6.5).

2. Significant direct effects of gender on semantic differential, Likert, van Hiele level squares and van Hiele level congruent triangles with path coefficients of 0.19,

$p<0.01$, 0.25, $p<0.01$, –0.16, $p<0.05$ and 0.21, $p<0.01$ respectively (see Table 6.5).

3. Significant direct effects of education on semantic differential, Likert, van Hiele level squares, van Hiele level isosceles triangles, van Hiele level parallel lines and van Hiele level congruent triangles with path coefficients of 0.20, $p<0.05$, 0.18, $p<0.05$, 0.46, $p<0.01$, 0.35, $p<0.01$, 0.68, $p<0.01$ and 0.61, $p<0.01$ respectively (see Table 6.5).

4. Significant direct effects of semantic differential on van Hiele level squares, van Hiele level isosceles triangles and van Hiele level congruent triangles with path coefficients of 0.25, $p<0.05$, 0.29, $p<0.05$ and 0.33, $p<0.01$ respectively (see Table 6.5).

However, there are no indirect effects (Table 6.4). Hence attitude does not mediate the effects of the background variables, age, gender, left/right brain preference and education on success in geometry. Therefore the hypotheses that age, gender, left/right brain preference and education are mediated by attitude are not supported.

Table 6.4
Indirect Effects of the Background Variables on Success in Geometry

	Age	Gender	Education	Left/ Right Brain	Semantic Differential	Likert	Van Hiele Level Squares	Van HieleLevel Isosceles Triangles	Van Hiele Level Parallel Lines	Van Hiele Level Congruent Triangles
Age										
Gender										
Edu										
Left/Right Brain										
Semantic Differential										
Likert										
Van Hiele Level Squares	0.04	0.05	0.05	-0.02						
Van Hiele Level Isosceles Triangles	0.04	0.04	0.05	-0.02						
Van Hiele Level Parallel Lines	0.01	0.01	0.02	-0.01						
Van Hiele Level Congruent Triangles	0.04	0.04	0.05	-0.02						

Note ** = P < 0.01, * = P < .05

Table 6.5
Direct Effects of the Background Variables on Success in Geometry

	Age	Gender	Education	Left/ Right Brain	Semantic Differential	Likert	Van Hiele Level Squares	Van HieleLevel Isosceles Triangles	Van Hiele Level Parallel Lines	Van Hiele Level Congruent Triangles
Age										
Gender										
Edu										
Left/Right Brain										
Semantic Differential	0.15	0.19**	0.20*	-0.06						
Likert	0.11	0.25**	0.18*	-0.04						
Van Hiele Level Squares	0.34**	-0.16**	0.46**	0.04	0.25*	0.01				
Van Hiele Level Isosceles Triangles	0.31**	0.08	0.35**	-0.03	0.29*	-0.06				
Van Hiele Level Parallel Lines	0.40**	-0.04	0.68**	0.08	0.13	-0.05				
Van Hiele Level Congruent Triangles	0.47**	0.21**	0.61**	0.02	0.33**	-0.10				

Note ** = P < 0.01, * = P < .05

It is important to note that despite the fact attitude does not mediate the effects of age, gender, left/right brain preference and education on van Hiele level there is clear evidence that attitude, as measured by the Semantic Differential Scale, has direct effects on success in geometry. Attitude, as measured by the Likert Scale, has no direct effects on success in geometry. Therefore, the results of the decomposition of the correlations in the model appear to answer the question of one or two attitude scales by supporting the theoretical conclusion from the results of the confirmatory factor analysis referred to earlier, and the work of Eagly and Chaiken (1993), that the Semantic Differential Scale is the appropriate attitude scale to use. However, given that it is clear from the correlation matrix that the cognitive factor of attitude is important, the results may be indicating that the affective factor of attitude is more directly important than the cognitive factor which may have an indirect relationship with behaviour that is not apparent in the analysis.

4. Summary

The results presented in this chapter add to the literature on the measurement of attitude. The data suggest that the Semantic Differential and Likert Scales measure different facets of attitude to geometry. When answering the Likert Scale students depend on a different cognitive process to the cognitive process involved in answering the Semantic Differential Scale in which a stored general evaluation process is used. This difference had been suggested by Schibeci (1982) and is consistent with the work of Eagly and Chaiken (1993). Hence the hypothesis of McCallum and Brown (1971) and Schofield and Start (1978), that the Semantic Differential and Likert data are interchangeable, is not supported. The fact that the Semantic Differential Scale measures a stored general evaluative process about geometry has curriculum implications. These are discussed in Chapter 7.

The final model of success in geometry resulted from a number of tests that were carried out firstly on a 12-factor model and then a 10-factor model. The goodness of fit indices indicated that the 10-factor model is a statistically coherent and superior model. In the model the causal flow is unidirectional (recursive model), and no allowance is made for reciprocal causation between variables either directly or through a causal loop.

Three sets of relationships were addressed in this chapter. These are:

1. The relationship between background factors and success in geometry.

2. The relationship between students' attitude to geometry and success in geometry.

3. The relationship between background factors and attitude.

1. The results in this chapter add to the literature on background factors that predispose students to succeed in geometry. Several points are worth noting as a consequence of controlling for the effects of factors. When the effects of the factors in

the model on success in geometry are controlled for, the effect of gender on van Hiele level, the effect of education on van Hiele level and the effect of age on van Hiele level are all significant. Given that there is no correlation between age and van Hiele level, as indicated in the correlation matrix, the results of the path model suggest that other factors in the model may suppress the effects of age. The absence of any effect of left/right brain preference on van Hiele level is disappointing given the literature on brain-based education. These issues are further discussed in Chapter 7.

2. In addition, after controlling for other factors, the effect of attitude (as measured by the Semantic Differential Scale) on success in geometry is significant. This significant effect of attitude on van Hiele level supports the findings of TIMSS-R (1998) on attitude and success in mathematics, and has very important curriculum implications that are discussed in Chapter 7.

3. The findings concerning the effects of the background variables, after controlling for the effects of other factors on attitude are of interest and also add to the literature. The effects of gender on attitude and education on attitude are significant. These findings are important and have curriculum implications that are discussed in Chapter 7. The effects of age on attitude and left/right brain preference on attitude are not significant. Given the wealth of literature on brain-based education the absence of a relation between left/right brain and attitude is disappointing.

Despite the researcher's strongly held belief that attitude would mediate the effects of background variables on success in geometry, no mediation of the background variables by attitude was found. This result, which adds to the literature on the mediation of variables, is totally unexpected and has very important curriculum implications that are discussed in Chapter 7.

The significant paths and strengths of the relationships are shown in figure 6.4 below.

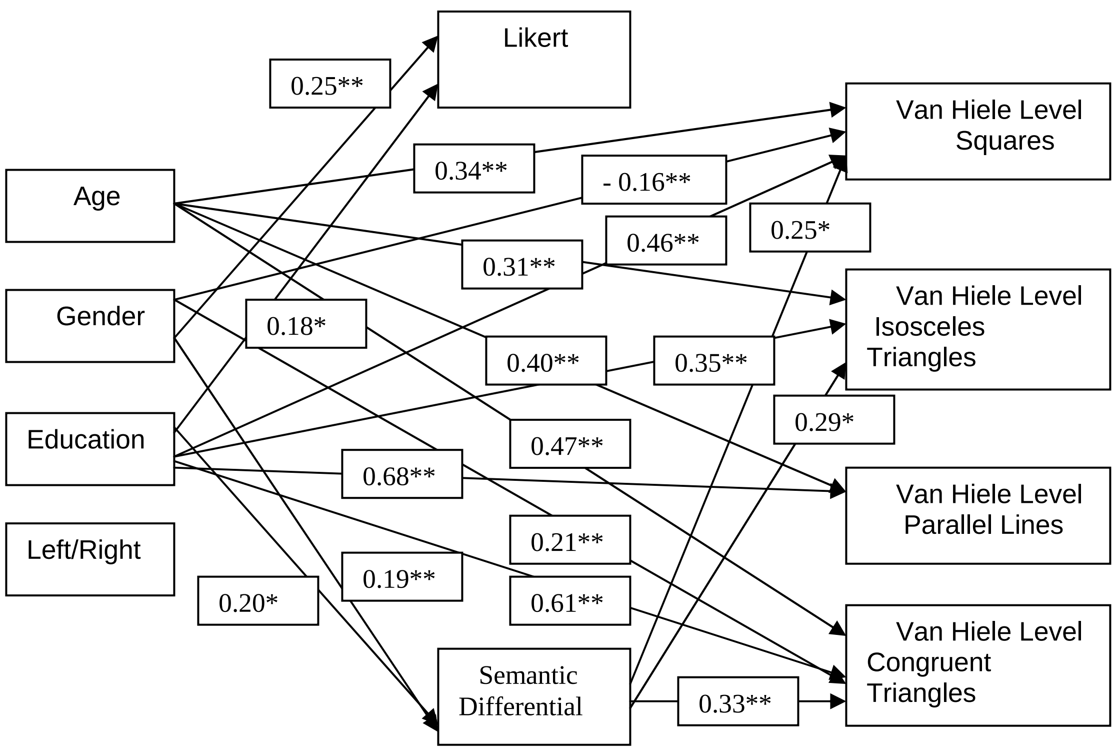

Figure 6.4: Significant paths of the model of success in geometry.

Chapter 7

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Your education is your life – guard it well … Proverbs 4:13

Introduction

The knowledge economy of a country is important to its survival and its place in the world. A country's knowledge economy is affected by many factors, not the least of which is the educational opportunities offered to its citizens. The quality of the educational opportunities that a country provides depends on the quality of its teachers. One important measure of the knowledge economy of a country is its relative world ranking in international studies such as the International Mathematics Studies of 1964 and 1978 and the International Mathematics and Science Study of 1994 (repeated in 1998).

Mathematics plays a key role in bolstering a country's knowledge economy. Research in Russia in 1960, and America in 1974 indicated the importance of geometry in the study of mathematics. Russian and then American educators (Teppo, 1991), having accepted the importance of geometry in the study of all mathematics, increased its prominence in all levels of mathematics study in schools (NCTM, 1989).

Factors that contribute to under-performance in aspects of the knowledge economy of a country should be addressed where possible. One aspect in which Australia under-performs in the knowledge economy is the achievement in geometry by Australian school students. The assertion in the present research is that a corollary of this underachievement in Australian school students in geometry is students' attitude to geometry. The present research investigates this issue of background factors and attitude and their relationship with students' success in geometry.

The problems of underachievement in geometry and lack of confidence in teaching geometry in Australia have been highlighted by TIMSS-R (1998), as has been the link between attitude and success. A dislike of geometry by both Jamaican students and teachers has been noted by Mitchelmore (1982) and a dislike of geometry by Australian teachers has been noted by Brodie (1992). A link between age of American college students and success in geometry and course studied and success in geometry was noted by Frykholm (1994) and, in addition, a significant lack of knowledge in geometry by Malaysian preservice teachers, and a link between gender and success in geometry, and course studied and success in geometry was noted by Ahuja (1996). However, it seems that little work has been done that brings these various factors together and empirically examines their relations. For example, little is known about the effects of the relations between age, education level, left/right brain preference and attitude on learning geometry.

Following an extensive literature review, discussion with researchers and teachers and reflection, the present researcher developed a theory of success in geometry that focussed on background variables and attitude. An important facet of this theory is the three dimensional concept of attitude comprising the affective, cognitive and behavioural factors. The theory is illustrated in figure 7.1 below. The essential hypothesis was that, irrespective of the factors that students bring to the study of geometry (e.g., education, left/right brain preference, gender), attitude could not be ignored as a contributor to outcomes. Clearly, factors such as enthusiasm play a major role in a student's success in geometry. Hence, the present research was undertaken to better understand the role of attitude in success in geometry and, in particular, attitude as a mediator of the factors that students bring to the school and the classroom.

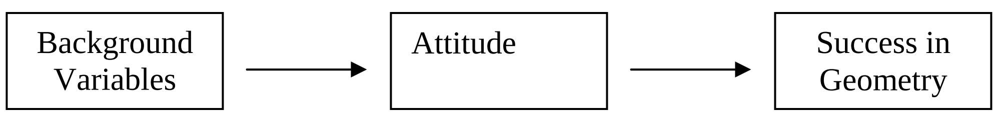

Figure 7.1: Theory of success in geometry.

A better understanding of the relationship of these factors with success in geometry involved determining four things:

- the background factors that may influence success in geometry;
- the effect of attitude on success in geometry;
- the relationship between background factors and attitude;
- the role of attitude as a mediator of the effects of the background factors on success in geometry.

To facilitate a better understanding and to systematically determine the relationships between the variables, a model of success in geometry was developed. The model emphasised attitude as a mediator of the background variables. Anecdotal and empirical evidence indicates that at some time in the lives of almost all individuals, a poor or superior performance has been attributed to attitude to the task. The model was designed to clarify the theory of success in geometry, as postulated earlier, and to assist in understanding the continuing decline in geometry standards in Australia. Indeed, a better understanding of the role of background variables and attitude, and their relationship to success in geometry may well lead not only to an improvement in geometry standards in particular and mathematics in general, but as well, contribute to an improvement in the knowledge economy of Australia.

The success or failure of individual students is a result of many factors. In the present research, to predict the success of individuals in geometry the van Hiele theory of levels of understanding in geometry was used. This theory has been shown to be significant in predicting the ability of students to deal with basic geometry through to advanced geometrical studies. In other words, a student’s van Hiele level is a proxy for their success in geometry. This use of van Hiele levels to predict success in geometry is in accordance with previous research, for example, Frykholm (1994) and Ahuja (1996). Due to this demonstrated congruence between van Hiele levels and performance, in the present research the success in geometry factors were used as a measure of behaviour.

Previous researchers have varied in the methods they used to explore the nature of success in geometry. For example, Ahuja (1996) mainly used t tests to produce his results and Frykholm (1994) used multivariate analysis to produce his. In the present research, Structural Equation Modelling (SEM) was used to analyse the data because it is believed to be superior to either t tests or multivariate ANOVA. This superiority is discussed in Chapter 5, part of which is reproduced below for convenience.

> According to Hoyle (1995) SEM has at least two advantages over other linear statistical models. Firstly, SEM offers no default model specifications like ANOVA and multiple regression analyses and therefore requires the researcher to specify relationships in the model. This characteristic is considered to be an advantage because it requires the researcher to think carefully about his/her data and venture hypotheses about each variable. Secondly, SEM estimates and tests relations between latent variables whereas other linear models do not. SEM increases the probability of detecting associations between constructs and of obtaining parameter estimates close to their population values through isolating constructs from

the uniqueness and unreliability of their indicators. The important difference between SEM and other methods of analysis such as multiple regression is that “SEM is the only analysis that allows complete and **simultaneous** (researcher’s emphasis) tests of all the relationships” (Tabachnick & Fidell, 2001, p. 656).

Of the variables contained in the theory of success in geometry, age and education had previously been the subject of research on success in geometry, and gender, left/right brain preference and attitude, were identified in the literature as important (Partridge, 1983; Frykholm, 1994; Ma & Kishnor, 1997; ACTAP, 2000 – 2002; Fink et al., 2000; Pargetter, 2003).

Age and Success in Geometry

Whilst a student’s age cannot be changed, it is an important variable. Unlike Piaget whose levels were linked to age, van Hiele believed that whilst age was important, his levels of understanding were not linked to a specific age. Research by Frykholm (1994), however, indicated a negative relationship between age and success in geometry, that is, the older a student was the less successful they were in geometry, and the Australian Capital Territory Assessment Program (ACTAP, 2000 – 2002), indicated a positive relationship between age and success in geometry. Clearly there is a need to clarify these divergent results and perhaps attitude to geometry may play a role here.

Education and Success in Geometry

Frykholm's (1994) research also indicated that a student's previous education influenced their success in geometry. As this is a variable that can be addressed by a change in curriculum it is an important variable.

Gender and Success in Geometry

Gender is another background factor and anecdotal evidence gathered by the researcher over many years of teaching indicates that females tend to distance themselves from geometry as much as possible. The ACTAP results show a relationship between gender and success in geometry with males being more successful than females. As the majority of teachers are female (preschool and primary 79.1%, secondary 56.1%, ABS 2002) this is an important variable given the influence of a teacher on a student's success in geometry.

Left/Right Brain Preference and Success in Geometry

The suggested link between left/right brain preference and gender and left/right brain preference and spatial visualisation, an important skill in geometry, indicated that left/right brain preference is an important background factor. Whilst left/right brain preference can be modified but not changed an awareness of its existence influences the methodology that teachers employ in the classroom.

Attitude and Success in Geometry

In their research conclusions, Ma and Kishor (1997) suggested that attitude may or may not influence success in mathematics. Also, there is a widely held belief that attitude mediates the effects of other factors on success in geometry. This belief influences the teaching methodologies used in classrooms today. Hence attitude is an important variable to consider.

Using the variables age, education, gender, left/right brain preference and attitude, has the advantage of allowing the results of the present research to be compared with other studies. In order to examine the theorised interrelations among the variables their causal relations were hypothesised (see Chapter 5), that is, it was hypothesised that success in geometry can be understood in terms of predictor variables with attitude mediating the effects of the background variables on success in geometry. Whilst the relationship between poor attitude towards geometry and lack of success in geometry has been identified in a number of studies, for example, TIMSS-R 1998, not a lot of research has been undertaken to determine the relationship between attitude, success and other variables. The present research addressed these shortcomings concerning their relationships by examining the following questions:

1. Which, if any, of the background variables influence success in geometry as measured by the van Hiele levels?

2. Does attitude influence success in geometry as measured by the van Hiele levels?

3. Is the influence of the background variables on success in geometry, as measured by the van Hiele levels, mediated by attitude?

To examine these questions a psychometric research methodology was adopted. The methodology reflected the literature related to a theory of learning geometry, the various methods used to measure attitude and the influence of brain-based education on learning. The research was operationalised by developing four instruments, that is, two attitude scales, one left/right brain test and one van Hiele level test.

Conclusions

1. The Relationship of Attitude and Success in Geometry

The findings in the present research, after controlling for other factors, show that attitude influences success in geometry and this is in accordance with the results of Neale et al. (1970), Enemark and Wise (1981), the Cockcroft report (1982) and the report on TIMSS-R (1998) in 2002 in which it is stated: “Across countries and in Australia, more positive attitudes were related to higher achievement scores, so the fostering of more positive attitudes towards mathematics … is to be encouraged” (p. 163).

For reasons stated in Chapter 3, which are reproduced below for convenience, this is a very important result with curriculum implications.

> Although it is certainly unfair to indict teachers too strongly as creators of negative student attitudes towards mathematics, the results of research have suggested that the teacher, perhaps even more than the parents, is an important determiner of student attitudes. (Suydam & Weaver 1975, p. 589)

Hence, if teachers do not have a positive attitude towards a subject, it is likely that this will influence the success of their students who will tune into the teacher’s non-positive attitude. In 1974 the Oregon Department of Education considered the fostering of positive attitudes toward learning so important that they legislatively mandated the fostering of positive attitudes towards learning in their minimum standards for public schools.

To foster positive attitudes to geometry, teachers need themselves to have a positive attitude towards geometry or the hidden curriculum will come through in their lessons. In the introduction to the 1989 NSW K-6 Mathematics Syllabus it states: “Students’ feelings are often strongly influenced by their teacher’s attitude towards mathematics. This is well documented in the case of girls”. (p. 18) It is very important, therefore, that teacher education institutions foster positive attitudes towards geometry, especially in females, in order to improve the teaching of geometry and arrest the identified falling standards in geometry in Australian school students. In order to foster these positive attitudes in preservice teachers the findings on the Likert (affective and cognitive components) and Semantic Differential (affective component) scales take on greater significance than has been indicated by previous research.

2. Different Measures of Attitude in the Present Research

The finding that the Likert and Semantic Differential Scales measure different facets of attitude to geometry is important and goes some way to explaining the divergent results reported by Ma and Kishor (1997) in various attitude to mathematics studies. What is clear is that the results from the Likert and Semantic Differential Scales are not interchangeable despite their high correlations, as the Likert Scale measures the affective and cognitive components of attitude whereas the Semantic Differential Scale measures only the affective component of attitude. In Chapter 6 it was pointed out that the participants in the present research used a stored general evaluative process to answer the Semantic Differential Scale. The present research shows that the preservice teachers' attitude to geometry, as measured by the Semantic Differential Scale, influences success in geometry. Therefore it is vitally important that a preservice teacher's stored evaluative process produces a positive attitude to geometry so that the preservice teachers can improve their success in geometry and hence improve their students' success in geometry by fostering positive attitudes and by being more competent in geometry. Changing this stored general evaluative process in a preservice teacher is a long-term project that needs to be addressed in every year of teacher education if teacher attitude to geometry, and hence student attitude to geometry, is to improve.

To break the bad-attitude bad-result cycle in school students, therefore, future teachers need to ensure that a positive attitude to geometry becomes part of the general evaluative process of their students. This can be achieved by teachers who have a positive attitude to geometry positively influencing their students throughout their schooling, especially in the first years of schooling.

These results indicate that improving the geometric comprehension of a preservice teacher (which would be indicated by a higher van Hiele level) is one part of the solution to the problem of falling standards in geometry of Australian school students and that preservice teacher attitude to geometry is another part of the solution.

3. Attitude as a Mediator

In the present thesis the hypothesis is that attitude will mediate the effects of the background variables on success in geometry. Put differently, despite various backgrounds, attitude may impede or enable performance in geometry. If evidence found supported this hypothesis, particularly if mediation were perfect as opposed to partial, then teachers could emphasise attitude in the classroom and be less concerned with the effects of the background variables.

However, the results of the present research suggest that attitude does not mediate the effects of background variables on success in geometry. This was despite the fact that both education and gender were significantly related to attitude and attitude was significantly related to success in geometry. Hence, attitude (affective factor) is independent of background factors. This finding is important as it shows that both background factors and attitude directly effect success in geometry. Therefore, teacher education institutions and classroom teachers need to focus on both background factors and attitude in classroom practice, rather than attitude or background factors alone, to improve the current level of success in geometry of Australian school students.

4. Background Factors

i) The Effect of Education on the van Hiele Levels

An analysis of the paths in the model of success in geometry (Figure 6. 4) indicates that the most significant *background factor* influence on an individual's success in geometry is education (course studied at school). This is to be expected. Those students who completed courses containing geometry had a better attitude to geometry and were more successful in geometry (as measured by the van Hiele levels) than the students who completed courses that did not contain geometry. This is a very important result that has implications for the curriculum of preservice teachers, as according to van Hiele (1955), Whitman (1994), The National Commission on Teaching and America's Future (NCTAF, 1996) and TIMSS-R (1998), in order to teach effectively a teacher needs to have a good understanding of the coursework. "What teachers know and can do is the most important influence on what students learn" (NCTAF, p. 10). If preservice teachers do not have an appropriate understanding of geometry they will not teach it effectively and the downward cycle of results in geometry will continue. Put succinctly, if preservice teachers study geometry their understanding of geometry should improve, their teaching of it should improve, and their students' results should improve. Van Hiele indicated that progress from one level to the next is a result of teaching. Hence it is of the utmost importance that the van Hiele level of student teachers entering teacher education be determined and that courses be developed to ensure that preservice teachers have an appropriate understanding of geometry before commencing teaching.

An appropriate understanding of geometry implies a van Hiele level of 3 or 4. Unfortunately, the data in figures 7.2 to 7.5 show that between 75% and 90% of the preservice teachers in the present research had a van Hiele level of 2, which is inadequate for effective teaching purposes. Of considerable concern is the result that 10% of the preservice teachers did not achieve van Hiele level 1 in isosceles triangles and congruent triangles. These students are represented in the figures 7.2 to 7.5 as No VHL. Students with a van Hiele Level of 1 are shown as VHL 1, students with a van Hiele Level of 2 are shown as VHL 2, students with a van Hiele Level of 3 are shown as VHL 3 and students with a van Hiele Level of 4 are shown as VHL 4.

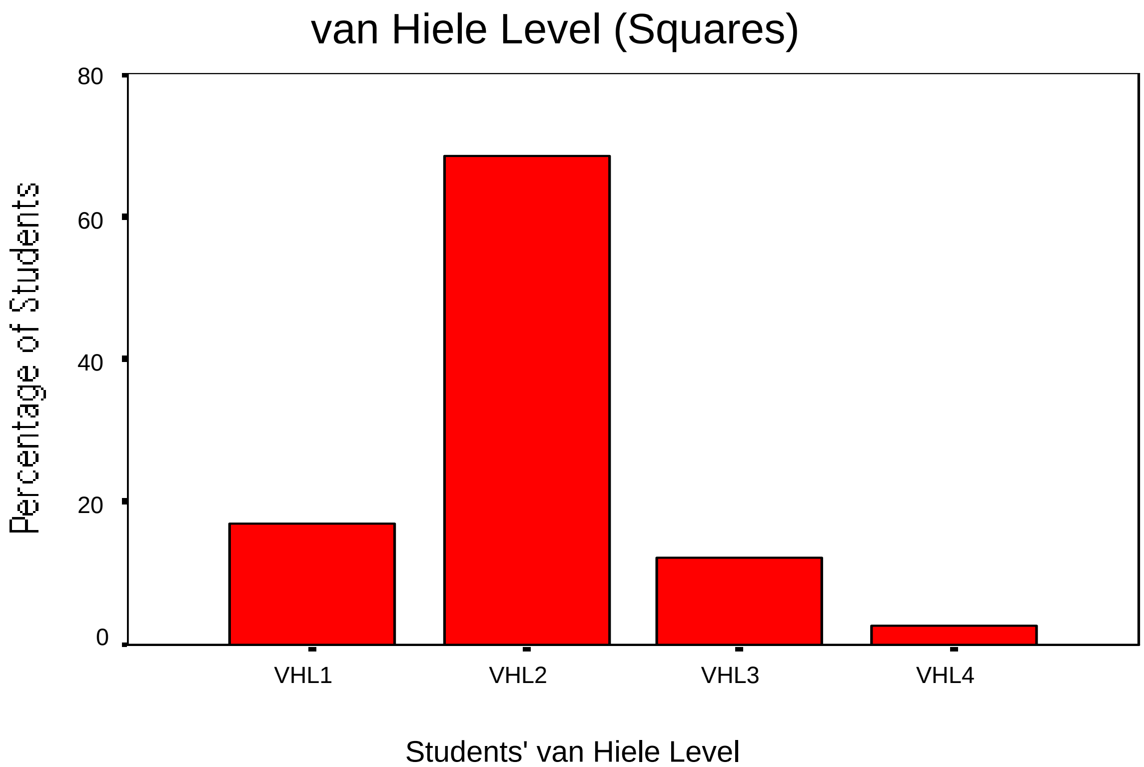

Figure 7.2: Students' van Hiele level (squares).

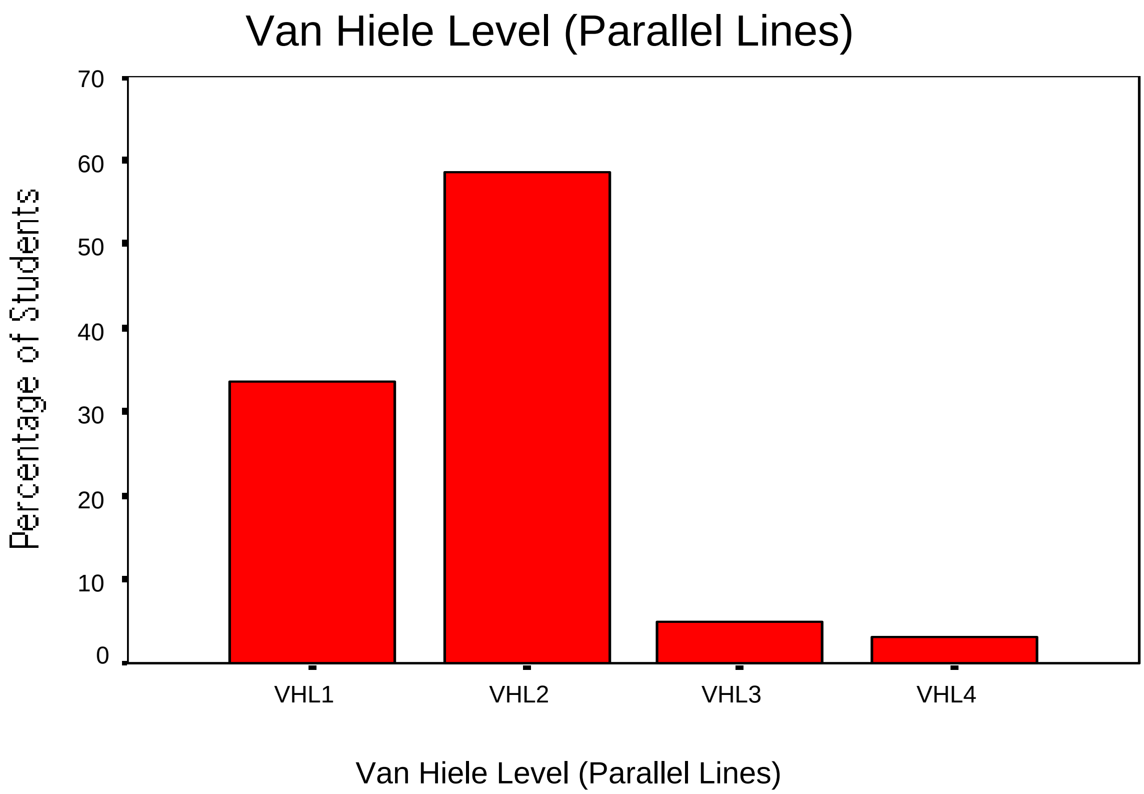

Figure 7.3: Students' van Hiele level (parallel lines).

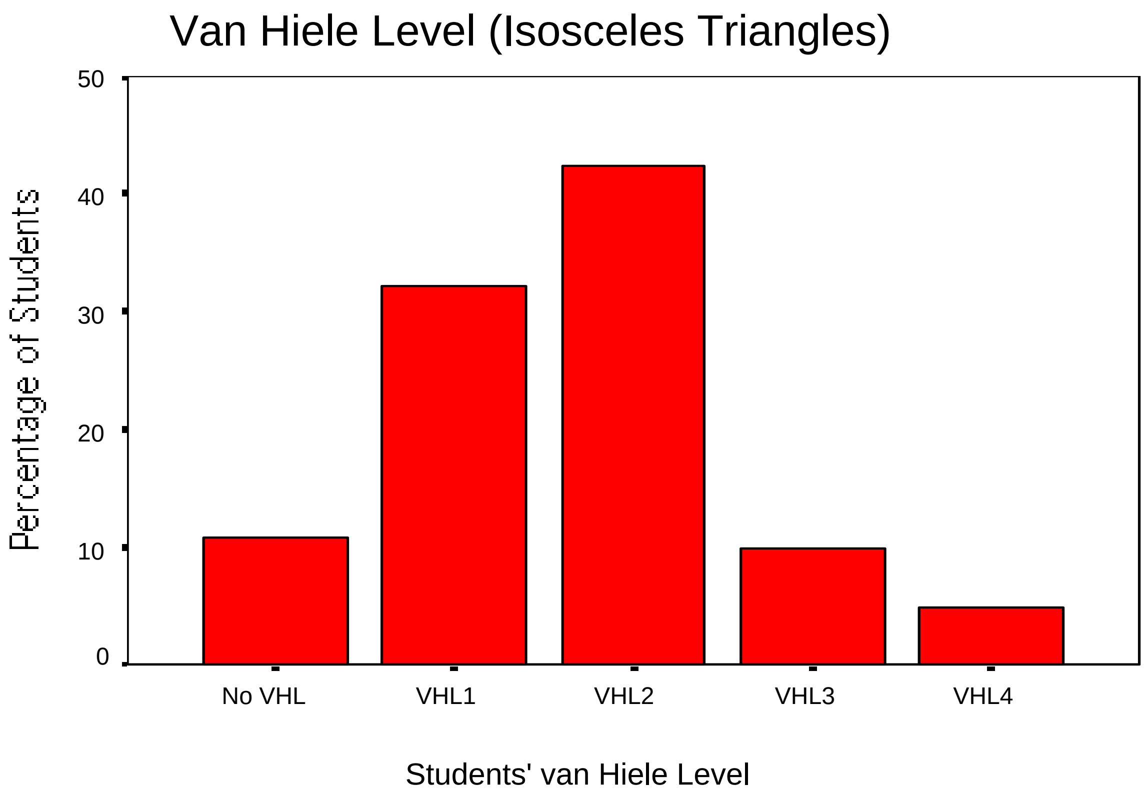

Figure 7.4: Students' van Hiele level (isosceles triangles).

Note: No VHL implies that the students did not achieve van Hiele level 1

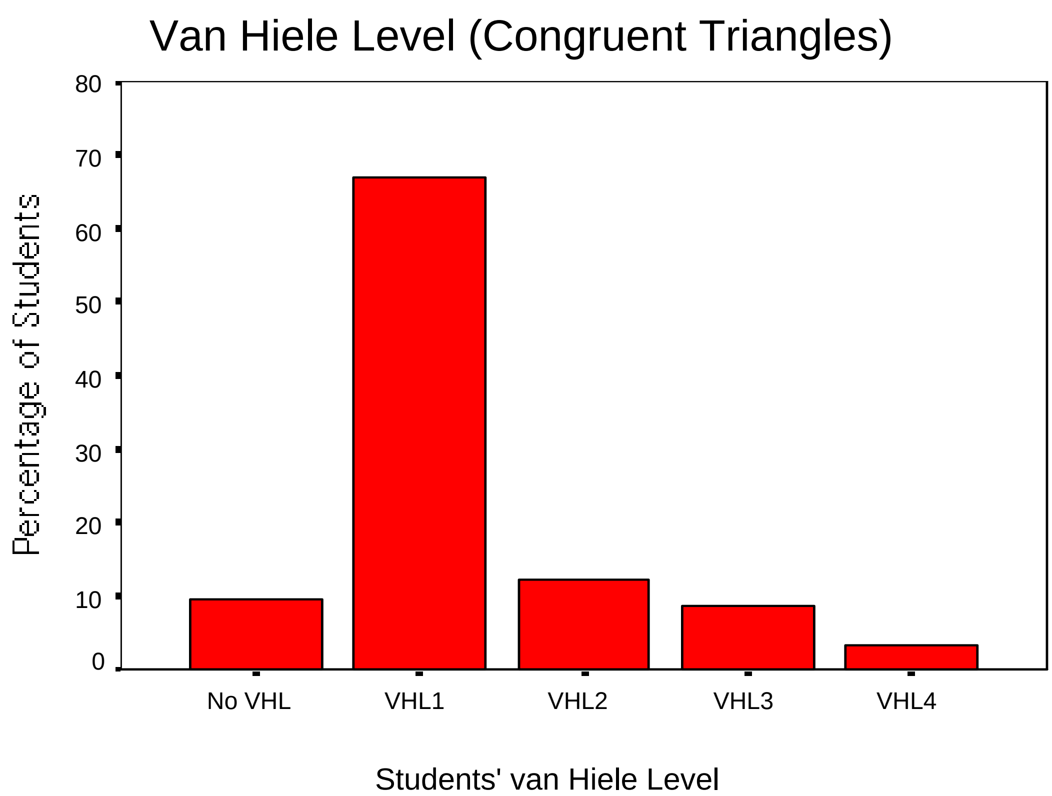

Figure 7.5: Students' van Hiele level (congruent triangles).

Note: No VHL implies that the students did not achieve van Hiele level 1

It is important to note that these van Hiele level results have significance for the curriculum of all preservice teachers, not just secondary preservice teachers, as kindergarten and primary school teachers need to have a good grasp of geometry and the van Hiele levels if they are to guide students through the early van Hiele levels effectively. According to Frykholm (1994), "… educators must continue to provide stimulating classroom opportunities for learners to come in contact with the basic principles of geometry **at young ages"** (researcher's emphasis). Also, Space and Geometry is one of the main strands in the NSW K-6 (2002) Mathematics Syllabus.

ii) The Effect of Age on the van Hiele Levels

The present research suggests that the next most significant background factor influence on a student's success in geometry is their age. This is an unexpected result but is similar to other research results. Frykholm (1994) suggested a negative relation between age and success in geometry and Canberra's Numeracy Assessment program, ACTAP 2000 – 2002, suggested a positive relation between age and success in geometry. After controlling for other factors in the model of success in geometry it was found that age varied positively with van Hiele level. This result agrees with the ACTAP results and is in accordance with the work of van Hiele who posited that the age of children is important to their level of understanding in geometry even though a particular level was not linked to a particular age. What is intriguing about this result is that prior to controlling for other factors in the model of success in geometry there was no relationship between age and van Hiele level. Is it possible then, that the effects of other factors, such as education, moderate, mediate or suppress the effects of age?

For example, in the case of a suppressor variable, it has long been held that if a variable which is correlated with an independent variable has a near zero correlation with a dependent variable then the non-correlated variable is a suppressor variable if after entering the variables into a multiple regression, the predictability of an independent variable becomes significant (Horst, 1941; Pedhazur, 1997). A suppressor variable is one that accounts for extraneous variance in the model. For example, the effect of a suppressor variable on higher scores than the mean on the cognitive and affective factors is to lower the scores and the effect on scores lower than the mean is to raise the scores.

In the present research, age is not correlated with any of the dependent variables. However, after decomposing the correlation matrix with the path model, age was a significant predictor of the four dependent variables. This suggests that the cognitive and affective factors of attitude are acting as suppressor variables. While the main findings of this research show that attitude is unlikely to act as a mediator variable, nevertheless, the present results suggest that the cognitive and affective factors play an important role in the relationship between age and success in geometry.

From a substantive viewpoint this is an interesting finding and suggests that attitude, while not mediating the effects of age on success in geometry, may be important in determining the outcome. For example, it may be that the older one becomes the less positive cognitive and affective thoughts and feelings are towards success in geometry. The converse may equally be true. Unfortunately, the present research has insufficient information to explore this issue and remains to be taken up at a later time in a longitudinal study.

iii) The Effect of Gender on the van Hiele Levels

The third background factor to influence success in geometry is gender. This result is in accordance with those of Ahuja (1996), and ACTAP (2000 – 2002). It also supports the following statement by Pargetter (2003):

> Gender is one factor that affects learning. The relationship is complex and can be swamped by a host of other factors, such as: intellectual abilities, cultural background, age and maturity. Nevertheless, the empirical research is beyond dispute that gender remains a significant factor, the impact of which varies from individual to individual and also changes as the individual develops biologically, socially and culturally (p. 26).

The influence of gender on success in geometry (as measured by the van Hiele levels) is not as strong as that of education and age but nevertheless, is significant. This has implications for teacher education as the majority of teachers in preschools and primary schools are female (79.1%, Schools Australia, 2002, ABS) and there are an increasing number of female teachers in secondary schools (56.1%, Schools Australia, 2002, ABS). The question, therefore, is should the number of male teachers be increased in primary schools or should programs that bring teachers to the required standard in geometry be developed. The latter should be the course of action taken to address this identified problem. Of note, however, is the fact that even though 57% of the female preservice teachers had completed geometry courses, gender was still identified as a factor in success in geometry. This needs further research.

iv) The Effect of Left/Right Brain Preference on the van Hiele Levels

The fact that left/right brain preference did not influence attitude or success in geometry is unexpected. Figure 7.6 shows the symmetrical spread of left/right brain preference among the students. Given the literature it was expected that this variable would have been more important.

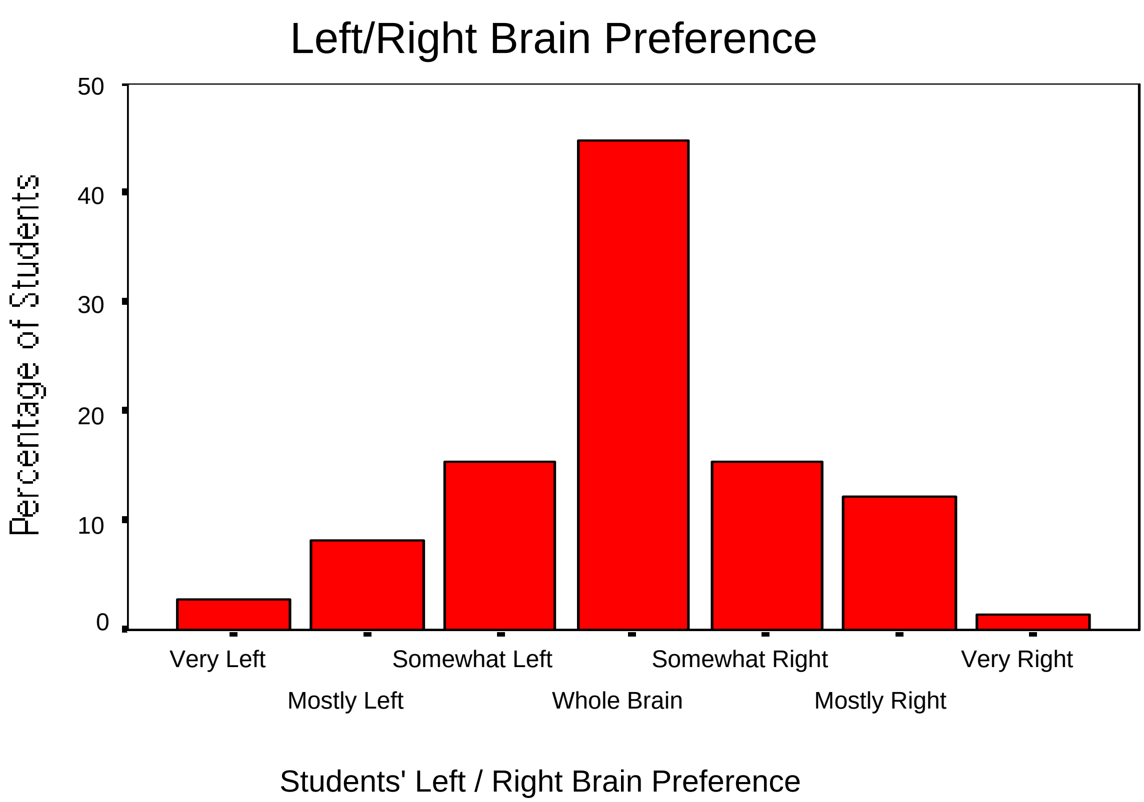

Figure 7.6: Students' left/right brain preference.

5. Age, Gender, Education and Success in Geometry

The present research suggests that there is a relationship between age, gender, and education, and success in geometry. However, the hypothesis that attitude mediated the effects of these factors on success in geometry was not supported. Hence it is important that future research focuses on systematically teasing out the nature of these relationships, especially given the ACTAP (2002) results that indicate females are as successful as males in geometry at a young age but are less successful as their age increases.

Summary

Mathematics plays a key role in bolstering a country's knowledge economy. Australia's knowledge economy is negatively affected by the underachievement of Australian school students in geometry. To address this issue a theory of success in geometry that focussed on background variables and attitude, was developed by this researcher. In the theory it was hypothesised that success in geometry can be understood in terms of predictor variables and that attitude mediates the effects of the variables on success in geometry. A model of success in geometry was developed to systematically determine the relationships of the variables.

Discussion

This thesis argues that attitude mediates the effects of background factors such as left/right brain preference, age, gender and education on success in geometry. These factors were chosen because of their prominence in the literature as affecting the learning of geometry. The question of mediation is important. If attitude positively mediates the effects of these factors, then it should be possible to develop programs that emphasise attitude to the advantage of students in learning situations in general, and geometry in particular. Despite the fact that attitude was found to correlate with all the background factors, except left/right brain preference, and the learning measures (van Hiele levels) of success in geometry, there was no evidence in the present research to support the mediation hypothesis. However, these correlation findings question the true relationship of attitude and background factors that are brought to the learning situation. It may be that attitude interacts with, or moderates, the effects of background factors brought to the learning situation. Future research should focus on the nature of this relationship.

Nevertheless, importantly, the evidence suggests that the hypothesis regarding the effects of attitude on success in geometry cannot be rejected. The evidence suggests that attitude is not only correlated with the measures of success in geometry (van Hiele levels) but that it may also be a predictor of success in geometry. Given these findings there is an urgent need to undertake further research using a longitudinal method with a larger sample to understand more thoroughly these effects over time. It is possible that a negative learning experience may adversely affect attitude in an individual despite them being older and better educated.

It was also hypothesised in the present research that attitude was composed of three analytically distinct factors (affect, cognitive and behavioural). The evidence in the present research suggests that this hypothesis cannot be rejected. This is an important finding as previous research has not been empirically able to distinguish these factors. Each of the hypothesised attitude factors were shown to be correlated. Importantly the affect factor was shown to be a predictor of success in geometry (behavioural factor). Clearly, attitude plays an important role in success in geometry. However, the findings also raise questions regarding the cognitive factor of learning, for example, does the cognitive factor interact with or modify the affect factor? Does feeling bad about geometry have an impact on an individual's cognitive ability in geometry?

The model of success in geometry developed in the present research clearly shows the complexity of success in geometry. Firstly, the model demonstrates that background factors, with the exception of left/right brain preference, brought to the learning situation are important and hence need to be accounted for in the classroom. These factors (age, gender and education) were shown to be predictors of success in geometry. In addition, the model demonstrates that the affect and cognitive factors of attitude have different relationships with the behavioural factor of attitude. The affect factor was shown to be a predictor of success in geometry while the cognitive factor was not. This, as has already been mentioned, was despite the fact that the cognitive factor was correlated with the background factors.

The fact that education, age and gender as well as attitude were all related to success in geometry suggests that classroom teachers need to concentrate on student's background factors as well as attitude, in order to improve their students' success in geometry. The present research suggests that all teachers need a good understanding of geometry and a positive attitude to geometry in order to teach geometry effectively and consequently raise their students' level of understanding in geometry and hence their students' success in geometry.

As well, teacher education institutions need to heed the support that the literature gives to:

1) the conclusions of van Hiele (1955), Whitman (1994), the National Commission on Teaching and America's Future (1996) and TIMSS-R (1998), that to teach geometry effectively teachers need to have a good understanding of the coursework, that is, a van Hiele level of 3 or 4.

2) the comment by Pargetter (2003) that gender is one factor that effects learning.

3) the conclusions of Brodie (1992) and Whitman (1994) that teachers with a knowledge of the van Hiele theory of learning geometry teach geometry more

effectively and therefore, that the van Hiele theory of learning geometry should be part of the *Theory of Learning* section of the preservice teachers' curriculum.

4) the conclusions of Haladyna et al. (1983) that teacher quality is consistently related to the attitude students have to mathematics.

5) Whitman's research (1994) that suggests if geometry lessons are planned using van Hiele's theory of learning geometry, then student success in geometry improves.

6) the recommendation of Malone and Haimes (2003) when commenting on the TIMSS-R (1998) study results, that there should be more emphasis on geometry in all secondary school curricula.

With a view to improving the performance of Australian school students in geometry, research is urgently needed to develop programs that strengthen preservice teachers' knowledge of, and attitude to, geometry. In addition, there is an urgent need for a research program to be developed that explores further the complex relationships between the various factors explored in the present research.

Recommendations

The ACER report by Zammit et al. (2002) and the analysis in *The Australian Senior Mathematics Journal* by Malone and Haimes (2003), on TIMSS-R (1998) indicate that Australian students continue to underachieve in geometry and that Australian teachers lack confidence in teaching geometry. These two problems are linked. A lack of confidence in geometry by Australian teachers leads to a lack of success in geometry by Australian school students.

It is clear that educational institutions that train teachers need to heed the findings of the present research concerning success in geometry. In order to improve the success of Australian school students in geometry and hence Australia's knowledge economy, the present research indicates that:

1) all preservice teachers should have their van Hiele level of geometry understanding determined.

2) appropriate geometry courses should be a mandatory part of the curriculum for all preservice teachers whose van Hiele level is less than three.

3) all preservice teachers should have a van Hiele level of three or four before they commence teaching.

4) appropriate changes to the curriculum of preservice teachers should be made so that their stored general evaluative process produces a positive attitude to geometry, especially in female students.

5) school students who intend to pursue a teaching career should complete mathematics courses with a geometry content.

Also, the present research suggests that further research is needed to determine:

1) the true nature of the relationship of attitude and background factors.

2) whether the cognitive factor of attitude interacts with or moderates the affect factor.

3) whether the effects of other factors such as education, moderate the effects of age on success in geometry.

4) why gender was identified as a factor in success in geometry despite nearly 60% of the female preservice teachers having completed geometry courses in secondary school.

5) The exact nature of the relationships between age, gender, education and success in geometry.

To assist the teacher education institutions to improve the teaching of geometry those who control school education in Australia need to heed the recommendation by Malone and Haimes (2003) and increase the emphasis on geometry in school mathematics courses. This increased emphasis on geometry should improve Australian students' success in geometry and contribute to improving Australia's knowledge economy.

Where to from Here?

Assumptions were made regarding the relations of the factors in the path model. The position adopted was that the background factors that students have influence their success in geometry. Others, for example, Frykholm (1994), hold this view. The merits or otherwise of a competing causal ordering that reflects a different theoretical perspective was not the concern of the present research which used cross-sectional (at time) data. A longitudinal (over time) study would now be appropriate to support and extend the conclusions of the current research and explore the moderating effects of attitude.

The method used allowed the systematic decomposition of the correlations among the hypothesised factors to better explain their relations. When the correlations of other factors in the model with the factors "a" and "b" are controlled for, the partial correlation between "a" and "b" is a resultant number. At the very least this is useful information for schools and teacher education institutions. Future research involving different decompositions and additional factors may extend the understanding of the role attitude plays.

Finally, acknowledging the discussions on the strengths and weaknesses of correlation methods (Johnson, 2001) on which the conclusions of the present research are based, the findings are too important not to be implemented in programs based on them in educational institutions.

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Positron Emission Tomography (PET) can be used to measure the rate at which radioactively labelled glucose is taken up by areas of the brain. The theory relies on the assumption that areas of the brain that are more active will require more energy and so will take up more glucose. PET provided three dimensional activation images with relatively high spatial resolution which allows for anatomical identification of the activated brain regions but with little or no temporal information. PET allows researchers to see which part of the brain is active during a cognitive task.

By applying nuclear magnetic resonance phenomena, ***Magnetic Resonance Imaging*** (MRI) can be used to create detailed images of the brain. The MRI technique uses a pulse of radio-frequency energy to excite the protons of hydrogen nuclei in the area of interest. Though MRI theory has been known since 1946 and was first used to produce an image in 1972, modern techniques in MRI take advantage of contrast between tissues to identify the location of structures emitting a specific MR signal. MRI can be used to generate additional information through ***Magnetic Resonance Spectroscopy*** (MRS). Using phosphorus (31P) NMR, MRS has been used to investigate brain metabolism, ischemia, and stroke. Rapid-scanning techniques which allow an MR image to be produced in 30 to 100 milliseconds have in the last two years been used to study human functional brain imaging. Localised changes in signal intensity in images of the brain during task-specific brain stimulation have been measured using this technique and should be able to be used to map the brain.

An emerging technology called ***Functional Magnetic Resonance Imaging*** (fMRI) relies on intrinsic contrast differences caused by oxygen metabolism, which produces different ratios of oxyhaemoglobin and deoxyhaemoglobin. These differences are the basis of intense interest in cognitive studies using fMRI. However, while fMRI is able to accurately localise activity, it suffers from the limitation of a suprasecond temporal resolution. This limitation requires multiple stimulus repetitions and hence produces training effects that may negate the data. Like PET, MRI and fMRI, enable researchers to “see” what part of the brain is active during a cognitive task.

The temporal resolution of **Evoked Potential** (EP) techniques, however, is in the range of milliseconds and thus eliminates any training effect on the brain. A relatively recent EP technique, ***Steady-State Probe Topography*** (SSPT), is a non-invasive brain electrical activity imaging technique. SSPT utilises the ***Steady-State Visually Evoked Potential*** (SSVEP) to examine changes in cortical activity occurring on a subsecond scale without the large number of repetitions required in standard evoked potential techniques and thus eliminates the training effects on the brain. SSPT provides activation images that give information about the temporal dynamics of the system and the linkages between the components in the system. The high temporal resolution provides insights into temporal dynamics of cognitive processes.

Harris, Silberstein, Pipingas and Pressing (1999) state

> The SSVEP technique involves stimulating a subject with a flickering light changing in luminance many times a second in a sinusoidal pattern. The cortical response to this type of stimulus, which may be recorded by an electrode on the scalp, has been demonstrated to consist of sinusoidal components at the stimulus frequency plus its harmonics. This information can be used to calculate the Fourier coefficients of the EEG signal at the stimulus frequency, averaged over sub-second time windows. The resulting analysis provides a description of the EEG signal in terms of the amplitude and latency at the stimulus frequency, with sufficiently fine-grained temporal resolution to capture cortical activity occurring on a subsecond scale. The SSVEP technique has most commonly been used to examine cognitive processing related to the visual modality, but has also been demonstrated to reflect task-related cognitive processing in the auditory modality (p. 1).

1. 10-Item Likert Scale

Item 1: I like to do lots of geometry

Item 3: I do geometry every chance I get

Item 4: I feel very comfortable when I do geometry

Item 6: I would like to spend more time doing geometry

Item 8: I kook forward to doing geometry

Item 10: I like talking about geometry

Item 13: I like geometry best

Item 14: I never get tired of doing geometry

Item 15: Time goes quickly when I’m doing geometry

Item 20: On the whole I enjoy geometry

2. 9-Item Semantic Differential Scale

Item 1: STRONG … WEAK

Item 3: FAST … SLOW

Item 4: PLEASANT … UNPLEASANT

Item 5: DISHONEST … HONEST

Item 6: VALUABLE … WORTHLESS

Item7: DIRTY … CLEAN

Item 8: SHARP … DULL

Item 10: BAD … GOOD

Item 12: LARGE … SMALL

DATE: 3/24/2003
TIME: 9:57

L I S R E L 8.53

BY

Karl G. J"reskog & Dag S"rbom

The following lines were read from file C:\Documents and Settings\default\My Documents\Students\JohnB\path_230303.ls8.Spl:

```
!This is the 10-factor model
!vhlsq vhlit vlhlpl vlhlct , Age, gender Edu lrcont likert, semantic
DA ni=30 no=201 ma=km
LA
age gender edu tert year
l1 l3 l4 l6 l8 l10 l13 l14 l15 l20
vhlsq vhlit vhlpl vhlct vhlo
lrcont
recg1 recg3 recg4 recg5 recg6 recg7 recg8 recg10 recg12
CM=dummy1.COV RE
MO ny=27 ne=10 ly=fu,fi ps=sy,fr be=fu,fi te=sy,fi
SE
age gender edu lrcont
l1 l3 l4 l6 l8 l10 l13 l14 l15 l20
recg1 recg3 recg4 recg5 recg6 recg7 recg8 recg10 recg12
vhlsq vhlit vhlpl vhlct/
pa ly
1 (1 0 0 0 0 0 0 0 0 0)
1 (0 1 0 0 0 0 0 0 0 0)
1 (0 0 1 0 0 0 0 0 0 0)
1 (0 0 0 1 0 0 0 0 0 0)
10(0 0 0 0 1 0 0 0 0 0)
9 (0 0 0 0 0 1 0 0 0 0)
1 (0 0 0 0 0 0 1 0 0 0)
1 (0 0 0 0 0 0 0 1 0 0)
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```

```
1 1 1
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1 1 1 1 0 0 0 0 0 0 !
1 1 1 1 0 0 0 0 0 0 !
1 1 1 1 1 1 0 0 0 0
1 1 1 1 1 1 0 0 0 0
1 1 1 1 1 1 0 0 0 0
1 1 1 1 1 1 0 0 0 0
st 1 ly 1 1 ly 2 2 ly 3 3 ly 4 4 ly 5 5 ly 15 6 ly 24 7 ly 25 8 ly 26 9 ly 27 10
fi   ly 1 1 ly 2 2 ly 3 3 ly 4 4 ly 5 5 ly 15 6 ly 24 7 ly 25 8 ly 26 9 ly 27 10
fr te 1 1 te 2 2 te 3 3 te 4 4 te 5 5 te 6 6 te 7 7 te 8 8 te 9 9 te 10 10
fr te 11 11 te 12 12 te 13 13 te 14 14 te 15 15 te 16 16 te 17 17 te 18 18 te 19 19
fr te 20 20 te 21 21 te 22 22 te 23 23 te 24 24 te 25 25 te 26 26 te 27 27
st 0 te 1 1 te 2 2 te 3 3 te 4 4  te 24 24 te 25 25 te 26 26 te 27 27
fi   te 1 1 te 2 2 te 3 3 te 4 4  te 24 24 te 25 25 te 26 26 te 27 27
pd
Le
Age Gender Edu lrcont Likert Semantic vhlsq vhlit vhlpl vhlct
OU EF SC AD=OFF

!This is the 10-factor model

                  Number of Input Variables 30
                  Number of Y - Variables   27
                  Number of X - Variables    0
                  Number of ETA - Variables 10
                  Number of KSI - Variables  0
                  Number of Observations   201

!This is the 10-factor model
```

Covariance Matrix

	age	gender	edu	lrcont	l1	l3
age	1.00					
gender	-0.04	1.00				
edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
l1	0.05	0.15	0.08	-0.04	1.00	
l3	-0.02	0.31	0.15	0.01	0.58	1.00
l4	0.00	0.36	0.16	0.01	0.60	0.50
l6	0.11	0.14	-0.03	-0.03	0.46	0.53
l8	-0.04	0.20	0.09	0.00	0.67	0.60
l10	-0.05	0.14	0.19	-0.12	0.46	0.47
l13	0.06	0.16	0.10	-0.01	0.58	0.54
l14	0.00	0.24	0.14	-0.02	0.50	0.52
l15	-0.10	0.25	0.14	-0.03	0.52	0.45
l20	-0.07	0.15	0.14	-0.01	0.74	0.55

recg1	0.05	0.22	0.21	-0.06	0.60	0.41
recg3	0.06	0.15	0.07	-0.10	0.56	0.39
recg4	-0.02	0.17	0.14	0.00	0.63	0.43
recg5	-0.07	0.22	0.00	-0.09	0.36	0.25
recg6	0.01	0.12	0.02	0.02	0.47	0.34
recg7	-0.14	-0.06	0.05	-0.10	0.31	0.24
recg8	0.06	0.11	0.11	-0.05	0.38	0.25
recg10	-0.02	0.12	0.07	0.04	0.50	0.31
recg12	-0.05	0.14	0.06	-0.10	0.25	0.15
vhlsq	0.07	-0.06	0.26	0.01	0.20	0.10
vhlit	0.09	0.15	0.20	-0.03	0.25	0.07
vhlpl	0.01	0.05	0.42	0.04	0.10	0.10
vhlct	0.10	0.30	0.37	0.02	0.19	0.15

Covariance Matrix

	l4	l6	l8	l10	l13	l14
l4	1.00					
l6	0.34	1.00				
l8	0.58	0.56	1.00			
l10	0.35	0.48	0.56	1.00		
l13	0.43	0.46	0.60	0.48	1.00	
l14	0.52	0.47	0.56	0.43	0.57	1.00
l15	0.46	0.47	0.55	0.47	0.49	0.52
l20	0.62	0.51	0.72	0.59	0.58	0.48
recg1	0.58	0.28	0.47	0.40	0.44	0.38
recg3	0.52	0.27	0.48	0.40	0.39	0.30
recg4	0.60	0.33	0.55	0.42	0.46	0.38
recg5	0.38	0.18	0.30	0.33	0.24	0.17
recg6	0.44	0.25	0.38	0.30	0.34	0.30
recg7	0.26	0.15	0.25	0.30	0.27	0.16
recg8	0.27	0.23	0.31	0.27	0.31	0.22
recg10	0.43	0.25	0.41	0.33	0.29	0.21
recg12	0.25	0.13	0.24	0.28	0.23	0.21
vhlsq	0.24	0.02	0.12	0.14	0.09	0.16
vhlit	0.28	0.05	0.14	0.10	0.14	0.19
vhlpl	0.12	0.02	0.02	0.09	0.16	0.15
vhlct	0.19	0.14	0.25	0.30	0.18	0.16

Covariance Matrix

	l15	l20	recg1	recg3	recg4	recg5
l15	1.00					
l20	0.60	1.00				
recg1	0.44	0.56	1.00			
recg3	0.40	0.53	0.71	1.00		
recg4	0.46	0.64	0.70	0.74	1.00	
recg5	0.25	0.31	0.36	0.39	0.44	1.00
recg6	0.32	0.45	0.50	0.47	0.59	0.46
recg7	0.22	0.36	0.34	0.43	0.44	0.50
recg8	0.31	0.37	0.55	0.46	0.50	0.29
recg10	0.33	0.50	0.48	0.50	0.60	0.56
recg12	0.20	0.21	0.27	0.37	0.29	0.35
vhlsq	0.21	0.25	0.30	0.17	0.24	0.17
vhlit	0.17	0.22	0.31	0.22	0.29	0.16
vhlpl	0.18	0.14	0.24	0.11	0.17	0.04
vhlct	0.24	0.30	0.42	0.29	0.33	0.16

Covariance Matrix

	recg6	recg7	recg8	recg10	recg12	vhlsq
recg6	1.00					
recg7	0.36	1.00				
recg8	0.47	0.30	1.00			
recg10	0.56	0.59	0.39	1.00		
recg12	0.24	0.18	0.23	0.35	1.00	
vhlsq	0.26	0.14	0.14	0.24	0.06	1.00
vhlit	0.14	0.15	0.26	0.18	0.07	0.51
vhlpl	0.13	0.05	0.17	0.07	0.02	0.55
vhlct	0.14	0.14	0.20	0.31	0.22	0.59

Covariance Matrix

	vhlit	vhlpl	vhlct
vhlit	1.00		
vhlpl	0.58	1.00	
vhlct	0.46	0.46	1.00

!This is the 10-factor model

Parameter Specifications

LAMBDA-Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	0	0	0	0	0	0
gender	0	0	0	0	0	0
edu	0	0	0	0	0	0
lrcont	0	0	0	0	0	0
l1	0	0	0	0	0	0
l3	0	0	0	0	1	0
l4	0	0	0	0	2	0
l6	0	0	0	0	3	0
l8	0	0	0	0	4	0
l10	0	0	0	0	5	0
l13	0	0	0	0	6	0
l14	0	0	0	0	7	0
l15	0	0	0	0	8	0
l20	0	0	0	0	9	0
recg1	0	0	0	0	0	0
recg3	0	0	0	0	0	10
recg4	0	0	0	0	0	11
recg5	0	0	0	0	0	12
recg6	0	0	0	0	0	13
recg7	0	0	0	0	0	14
recg8	0	0	0	0	0	15
recg10	0	0	0	0	0	16
recg12	0	0	0	0	0	17
vhlsq	0	0	0	0	0	0
vhlit	0	0	0	0	0	0
vhlpl	0	0	0	0	0	0
vhlct	0	0	0	0	0	0

LAMBDA-Y

	vhlsq	vhlit	vhlpl	vhlct
	--------	--------	--------	--------
age	0	0	0	0
gender	0	0	0	0
edu	0	0	0	0
lrcont	0	0	0	0
l1	0	0	0	0
l3	0	0	0	0
l4	0	0	0	0
l6	0	0	0	0
l8	0	0	0	0
l10	0	0	0	0
l13	0	0	0	0
l14	0	0	0	0
l15	0	0	0	0
l20	0	0	0	0
recg1	0	0	0	0
recg3	0	0	0	0
recg4	0	0	0	0
recg5	0	0	0	0
recg6	0	0	0	0
recg7	0	0	0	0
recg8	0	0	0	0
recg10	0	0	0	0
recg12	0	0	0	0
vhlsq	0	0	0	0
vhlit	0	0	0	0
vhlpl	0	0	0	0
vhlct	0	0	0	0

BETA

	Age	Gender	Edu	lrcont	Likert	Semantic
	--------	--------	--------	--------	--------	--------
Age	0	0	0	0	0	0
Gender	0	0	0	0	0	0
Edu	0	0	0	0	0	0
lrcont	0	0	0	0	0	0
Likert	18	19	20	21	0	0
Semantic	22	23	24	25	0	0
vhlsq	26	27	28	29	30	31
vhlit	32	33	34	35	36	37
vhlpl	38	39	40	41	42	43
vhlct	44	45	46	47	48	49

BETA

	vhlsq	vhlit	vhlpl	vhlct
	--------	--------	--------	--------
Age	0	0	0	0
Gender	0	0	0	0
Edu	0	0	0	0
lrcont	0	0	0	0
Likert	0	0	0	0
Semantic	0	0	0	0
vhlsq	0	0	0	0
vhlit	0	0	0	0
vhlpl	0	0	0	0
vhlct	0	0	0	0

PSI

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	50					
Gender	51	52				
Edu	53	54	55			
lrcont	56	57	58	59		
Likert	0	0	0	0	60	
Semantic	0	0	0	0	61	62
vhlsq	0	0	0	0	0	0
vhlit	0	0	0	0	0	0
vhlpl	0	0	0	0	0	0
vhlct	0	0	0	0	0	0

PSI

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	63			
vhlit	64	65		
vhlpl	66	67	68	
vhlct	69	70	71	72

THETA-EPS

age	gender	edu	lrcont	l1	l3
0	0	0	0	73	74

THETA-EPS

l4	l6	l8	l10	l13	l14
75	76	77	78	79	80

THETA-EPS

l15	l20	recg1	recg3	recg4	recg5
81	82	83	84	85	86

THETA-EPS

recg6	recg7	recg8	recg10	recg12	vhlsq
87	88	89	90	91	0

THETA-EPS

vhlit	vhlpl	vhlct
0	0	0

!This is the 10-factor model

Number of Iterations = 11

LISREL Estimates (Maximum Likelihood)

LAMBDA-Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	- -	- -	- -	- -	1.00	- -
l3	- -	- -	- -	- -	0.86 (0.08) 11.15	- -
l4	- -	- -	- -	- -	0.86 (0.08) 11.14	- -
l6	- -	- -	- -	- -	0.75 (0.08) 9.39	- -
l8	- -	- -	- -	- -	1.01 (0.07) 14.00	- -
l10	- -	- -	- -	- -	0.79 (0.08) 9.92	- -
l13	- -	- -	- -	- -	0.86 (0.08) 11.17	- -
l14	- -	- -	- -	- -	0.81 (0.08) 10.20	- -
l15	- -	- -	- -	- -	0.83 (0.08) 10.63	- -
l20	- -	- -	- -	- -	1.04 (0.07) 14.57	- -
recg1	- -	- -	- -	- -	- -	1.00
recg3	- -	- -	- -	- -	- -	1.02 (0.08) 12.78
recg4	- -	- -	- -	- -	- -	1.10

						(0.08) 14.14
recg5	- -	- -	- -	- -	- -	0.69 (0.09) 8.03
recg6	- -	- -	- -	- -	- -	0.83 (0.08) 9.93
recg7	- -	- -	- -	- -	- -	0.68 (0.09) 7.80
recg8	- -	- -	- -	- -	- -	0.74 (0.09) 8.65
recg10	- -	- -	- -	- -	- -	0.88 (0.08) 10.67
recg12	- -	- -	- -	- -	- -	0.49 (0.09) 5.53
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

LAMBDA-Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -

l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

BETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	0.09	0.21	0.15	-0.03	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.24	3.49	2.05	-0.54		
Semantic	0.12	0.15	0.16	-0.05	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.59	2.56	2.14	-0.85		
vhlsq	0.34	-0.16	0.46	0.04	0.01	0.32
	(0.08)	(0.07)	(0.08)	(0.06)	(0.14)	(0.14)
	4.22	-2.38	5.66	0.65	0.05	2.27
vhlit	0.31	0.08	0.35	-0.03	-0.07	0.36

	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	3.75	1.19	4.15	-0.48	-0.53	2.52
vhlpl	0.40	-0.04	0.68	0.08	-0.06	0.17
	(0.08)	(0.06)	(0.08)	(0.06)	(0.13)	(0.13)
	5.35	-0.60	8.87	1.28	-0.43	1.27
vhlct	0.47	0.21	0.61	0.02	-0.12	0.42
	(0.07)	(0.06)	(0.07)	(0.05)	(0.12)	(0.12)
	6.87	3.67	8.72	0.37	-1.01	3.40

BETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Covariance Matrix of ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	-0.02	0.22	0.13	-0.02	0.67	
Semantic	0.00	0.16	0.11	-0.04	0.50	0.64
vhlsq	0.07	-0.06	0.26	0.01	0.18	0.23
vhlit	0.09	0.15	0.20	-0.03	0.19	0.25
vhlpl	0.01	0.05	0.42	0.04	0.12	0.15
vhlct	0.10	0.30	0.37	0.02	0.24	0.31

Covariance Matrix of ETA

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	1.00			
vhlit	0.51	1.00		
vhlpl	0.55	0.58	1.00	
vhlct	0.59	0.46	0.46	1.00

PSI

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00 (0.10) 10.00					
Gender	-0.04 (0.07) -0.61	1.00 (0.10) 10.00				
Edu	-0.61 (0.08) -7.39	0.12 (0.07) 1.73	1.00 (0.10) 10.00			
lrcont	0.18 (0.07) 2.46	0.08 (0.07) 1.15	-0.14 (0.07) -2.03	1.00 (0.10) 10.00		
Likert	- -	- -	- -	- -	0.61 (0.09) 6.94	
Semantic	- -	- -	- -	- -	0.45 (0.06) 6.94	0.59 (0.09) 6.62
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

PSI

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	0.77 (0.08) 9.92			
vhlit	0.33 (0.06) 5.40	0.81 (0.08) 9.90		
vhlpl	0.31 (0.06) 5.56	0.38 (0.06) 6.41	0.69 (0.07) 9.97	
vhlct	0.34 (0.05) 6.30	0.19 (0.05) 3.66	0.14 (0.05) 3.12	0.56 (0.06) 9.80

Squared Multiple Correlations for Structural Equations

Age	Gender	Edu	lrcont	Likert	Semantic
- -	- -	- -	- -	0.09	0.07

Squared Multiple Correlations for Structural Equations

vhlsq	vhlit	vhlpl	vhlct
0.23	0.19	0.31	0.44

THETA-EPS

age	gender	edu	lrcont	l1	l3
- -	- -	- -	- -	0.33	0.50
				(0.04)	(0.05)
				8.54	9.29

THETA-EPS

l4	l6	l8	l10	l13	l14
0.50	0.62	0.31	0.58	0.50	0.56
(0.05)	(0.06)	(0.04)	(0.06)	(0.05)	(0.06)
9.29	9.56	8.40	9.49	9.29	9.45

THETA-EPS

l15	l20	recg1	recg3	recg4	recg5
0.53	0.27	0.36	0.34	0.23	0.69
(0.06)	(0.03)	(0.04)	(0.04)	(0.03)	(0.07)
9.39	8.07	8.47	8.33	7.15	9.62

THETA-EPS

recg6	recg7	recg8	recg10	recg12	vhlsq
0.56	0.71	0.65	0.50	0.84	- -
(0.06)	(0.07)	(0.07)	(0.06)	(0.09)	
9.32	9.65	9.54	9.15	9.84	

THETA-EPS

vhlit	vhlpl	vhlct
- -	- -	- -

Squared Multiple Correlations for Y - Variables

age	gender	edu	lrcont	l1	l3
1.00	1.00	1.00	1.00	0.67	0.50

Squared Multiple Correlations for Y - Variables

l4	l6	l8	l10	l13	l14
0.50	0.38	0.69	0.42	0.50	0.44

Squared Multiple Correlations for Y - Variables

l15	l20	recg1	recg3	recg4	recg5
0.47	0.73	0.64	0.66	0.77	0.31

Squared Multiple Correlations for Y - Variables

recg6	recg7	recg8	recg10	recg12	vhlsq
0.44	0.29	0.35	0.50	0.16	1.00

Squared Multiple Correlations for Y - Variables

vhlit	vhlpl	vhlct
1.00	1.00	1.00

Goodness of Fit Statistics

Degrees of Freedom = 287
Minimum Fit Function Chi-Square = 631.64 (P = 0.0)
Normal Theory Weighted Least Squares Chi-Square = 610.07 (P = 0.0)
Estimated Non-centrality Parameter (NCP) = 323.07
90 Percent Confidence Interval for NCP = (255.85 ; 398.03)

Minimum Fit Function Value = 3.16
Population Discrepancy Function Value (F0) = 1.62
90 Percent Confidence Interval for F0 = (1.28 ; 1.99)
Root Mean Square Error of Approximation (RMSEA) = 0.075
90 Percent Confidence Interval for RMSEA = (0.067 ; 0.083)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.00

Expected Cross-Validation Index (ECVI) = 3.96
90 Percent Confidence Interval for ECVI = (3.62 ; 4.34)
ECVI for Saturated Model = 3.78
ECVI for Independence Model = 39.50

Chi-Square for Independence Model with 351 Degrees of Freedom = 7846.91
Independence AIC = 7900.91
Model AIC = 792.07
Saturated AIC = 756.00
Independence CAIC = 8017.09
Model CAIC = 1183.67
Saturated CAIC = 2382.65

Normed Fit Index (NFI) = 0.92
Non-Normed Fit Index (NNFI) = 0.94
Parsimony Normed Fit Index (PNFI) = 0.75
Comparative Fit Index (CFI) = 0.95
Incremental Fit Index (IFI) = 0.95
Relative Fit Index (RFI) = 0.90

Critical N (CN) = 110.45

Root Mean Square Residual (RMR) = 0.056
Standardized RMR = 0.056
Goodness of Fit Index (GFI) = 0.82
Adjusted Goodness of Fit Index (AGFI) = 0.76
Parsimony Goodness of Fit Index (PGFI) = 0.62

!This is the 10-factor model

Standardized Solution

LAMBDA-Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	- -	- -	- -	- -	0.82	- -
l3	- -	- -	- -	- -	0.71	- -
l4	- -	- -	- -	- -	0.71	- -
l6	- -	- -	- -	- -	0.62	- -
l8	- -	- -	- -	- -	0.83	- -
l10	- -	- -	- -	- -	0.65	- -
l13	- -	- -	- -	- -	0.71	- -
l14	- -	- -	- -	- -	0.66	- -
l15	- -	- -	- -	- -	0.68	- -
l20	- -	- -	- -	- -	0.86	- -
recg1	- -	- -	- -	- -	- -	0.80
recg3	- -	- -	- -	- -	- -	0.81
recg4	- -	- -	- -	- -	- -	0.88
recg5	- -	- -	- -	- -	- -	0.55
recg6	- -	- -	- -	- -	- -	0.66
recg7	- -	- -	- -	- -	- -	0.54
recg8	- -	- -	- -	- -	- -	0.59
recg10	- -	- -	- -	- -	- -	0.70
recg12	- -	- -	- -	- -	- -	0.39
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

LAMBDA-Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -

l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

BETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	0.11	0.25	0.18	-0.04	- -	- -
Semantic	0.15	0.19	0.20	-0.06	- -	- -
vhlsq	0.34	-0.16	0.46	0.04	0.01	0.25
vhlit	0.31	0.08	0.35	-0.03	-0.06	0.29
vhlpl	0.40	-0.04	0.68	0.08	-0.05	0.13
vhlct	0.47	0.21	0.61	0.02	-0.10	0.33

BETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Correlation Matrix of ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	-0.02	0.27	0.15	-0.03	1.00	
Semantic	0.01	0.20	0.14	-0.05	0.76	1.00
vhlsq	0.07	-0.06	0.26	0.01	0.22	0.29
vhlit	0.09	0.15	0.20	-0.03	0.23	0.31
vhlpl	0.01	0.05	0.42	0.04	0.14	0.19

vhlct	0.10	0.30	0.37	0.02	0.29	0.39

Correlation Matrix of ETA

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	1.00			
vhlit	0.51	1.00		
vhlpl	0.55	0.58	1.00	
vhlct	0.59	0.46	0.46	1.00

PSI

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	- -	- -	- -	- -	0.91	
Semantic	- -	- -	- -	- -	0.68	0.93
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

PSI

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	0.77			
vhlit	0.33	0.81		
vhlpl	0.31	0.38	0.69	
vhlct	0.34	0.19	0.14	0.56

!This is the 10-factor model

Completely Standardized Solution

LAMBDA-Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	- -	- -	- -	- -	0.82	- -
l3	- -	- -	- -	- -	0.71	- -
l4	- -	- -	- -	- -	0.71	- -
l6	- -	- -	- -	- -	0.62	- -
l8	- -	- -	- -	- -	0.83	- -
l10	- -	- -	- -	- -	0.65	- -
l13	- -	- -	- -	- -	0.71	- -
l14	- -	- -	- -	- -	0.66	- -
l15	- -	- -	- -	- -	0.68	- -
l20	- -	- -	- -	- -	0.86	- -
recg1	- -	- -	- -	- -	- -	0.80
recg3	- -	- -	- -	- -	- -	0.81
recg4	- -	- -	- -	- -	- -	0.88

recg5	- -	- -	- -	- -	- -	0.55
recg6	- -	- -	- -	- -	- -	0.66
recg7	- -	- -	- -	- -	- -	0.54
recg8	- -	- -	- -	- -	- -	0.59
recg10	- -	- -	- -	- -	- -	0.70
recg12	- -	- -	- -	- -	- -	0.39
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

LAMBDA-Y

	vhlsq	vhlit	vhlpl	vhlct
	--------	--------	--------	--------
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

BETA

	Age	Gender	Edu	lrcont	Likert	Semantic
	--------	--------	--------	--------	--------	--------
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	0.11	0.25	0.18	-0.04	- -	- -
Semantic	0.15	0.19	0.20	-0.06	- -	- -
vhlsq	0.34	-0.16	0.46	0.04	0.01	0.25
vhlit	0.31	0.08	0.35	-0.03	-0.06	0.29
vhlpl	0.40	-0.04	0.68	0.08	-0.05	0.13
vhlct	0.47	0.21	0.61	0.02	-0.10	0.33

BETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Correlation Matrix of ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	-0.02	0.27	0.15	-0.03	1.00	
Semantic	0.01	0.20	0.14	-0.05	0.76	1.00
vhlsq	0.07	-0.06	0.26	0.01	0.22	0.29
vhlit	0.09	0.15	0.20	-0.03	0.23	0.31
vhlpl	0.01	0.05	0.42	0.04	0.14	0.19
vhlct	0.10	0.30	0.37	0.02	0.29	0.39

Correlation Matrix of ETA

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	1.00			
vhlit	0.51	1.00		
vhlpl	0.55	0.58	1.00	
vhlct	0.59	0.46	0.46	1.00

PSI

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	- -	- -	- -	- -	0.91	
Semantic	- -	- -	- -	- -	0.68	0.93
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

PSI

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	0.77			
vhlit	0.33	0.81		
vhlpl	0.31	0.38	0.69	
vhlct	0.34	0.19	0.14	0.56

THETA-EPS

age	gender	edu	lrcont	l1	l3
- -	- -	- -	- -	0.33	0.50

THETA-EPS

l4	l6	l8	l10	l13	l14
0.50	0.62	0.31	0.58	0.50	0.56

THETA-EPS

l15	l20	recg1	recg3	recg4	recg5
0.53	0.27	0.36	0.34	0.23	0.69

THETA-EPS

recg6	recg7	recg8	recg10	recg12	vhlsq
0.56	0.71	0.65	0.50	0.84	- -

THETA-EPS

vhlit	vhlpl	vhlct
- -	- -	- -

!This is the 10-factor model

Total and Indirect Effects

Total Effects of ETA on ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	0.09	0.21	0.15	-0.03	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.24	3.49	2.05	-0.54		
Semantic	0.12	0.15	0.16	-0.05	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.59	2.56	2.14	-0.85		
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.32
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	4.57	-1.63	6.16	0.39	0.05	2.27
vhlit	0.34	0.12	0.39	-0.05	-0.07	0.36

```
              (0.08)     (0.07)   (0.08)    (0.07)    (0.14)     (0.14)
                4.10       1.78       4.64      -0.70      -0.53       2.52

   vhlpl       0.42      -0.02       0.69      0.07      -0.06       0.17
              (0.08)     (0.06)     (0.08)     (0.06)    (0.13)     (0.13)
                5.55      -0.39       9.19       1.16      -0.43       1.27

   vhlct       0.51       0.25       0.65      0.00      -0.12       0.42
              (0.07)     (0.06)     (0.07)    (0.06)    (0.12)   (0.12)
                 7.13       4.30       9.11       0.06      -1.01       3.40
```

Total Effects of ETA on ETA

```
             vhlsq      vhlit      vhlpl      vhlct
            --------   --------   --------   --------
    Age         - -        - -        - -        - -

  Gender        - -        - -        - -        - -

    Edu         - -        - -        - -        - -

  lrcont        - -        - -        - -        - -

  Likert        - -        - -        - -        - -

Semantic        - -        - -        - -        - -

   vhlsq        - -        - -        - -        - -

   vhlit        - -        - -        - -        - -

   vhlpl        - -        - -        - -        - -

   vhlct        - -        - -        - -        - -
```

Largest Eigenvalue of B*B' (Stability Index) is   2.211

Indirect Effects of ETA on ETA

```
               Age     Gender       Edu     lrcont     Likert   Semantic
            --------   --------   --------   --------   --------   --------
    Age         - -        - -        - -        - -        - -        - -

  Gender        - -        - -        - -        - -        - -        - -

    Edu         - -        - -        - -        - -        - -        - -

  lrcont        - -        - -        - -        - -        - -        - -

  Likert        - -        - -        - -        - -        - -        - -

Semantic        - -        - -        - -        - -        - -        - -

   vhlsq       0.04       0.05       0.05      -0.02        - -        - -
              (0.03)     (0.03)     (0.03)     (0.02)
                1.47       1.94       1.87      -0.82

   vhlit       0.04       0.04       0.05      -0.02        - -        - -
```

	(0.03)	(0.03)	(0.03)	(0.02)		
	1.40	1.54	1.69	-0.82		
vhlpl	0.01	0.01	0.02	-0.01	- -	- -
	(0.01)	(0.02)	(0.02)	(0.01)		
	1.06	0.76	1.10	-0.73		
vhlct	0.04	0.04	0.05	-0.02	- -	- -
	(0.03)	(0.02)	(0.03)	(0.02)		
	1.40	1.52	1.70	-0.82		

Indirect Effects of ETA on ETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Total Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	0.09	0.21	0.15	-0.03	1.00	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.24	3.49	2.05	-0.54		
l3	0.08	0.18	0.13	-0.03	0.86	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.43	2.04	-0.54	11.15	
l4	0.08	0.18	0.13	-0.03	0.86	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.43	2.04	-0.54	11.14	

l6	0.07	0.16	0.11	-0.02	0.75	- -
	(0.06)	(0.05)	(0.06)	(0.04)	(0.08)	
	1.24	3.37	2.02	-0.54	9.39	
l8	0.09	0.21	0.15	-0.03	1.01	- -
	(0.07)	(0.06)	(0.07)	(0.06)	(0.07)	
	1.24	3.50	2.05	-0.54	14.00	
l10	0.07	0.16	0.12	-0.02	0.79	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.39	2.03	-0.54	9.92	
l13	0.08	0.18	0.13	-0.03	0.86	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.44	2.04	-0.54	11.17	
l14	0.07	0.17	0.12	-0.03	0.81	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.40	2.03	-0.54	10.20	
l15	0.08	0.17	0.13	-0.03	0.83	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.42	2.03	-0.54	10.63	
l20	0.10	0.22	0.16	-0.03	1.04	- -
	(0.08)	(0.06)	(0.08)	(0.06)	(0.07)	
	1.24	3.50	2.05	-0.54	14.57	
recg1	0.12	0.15	0.16	-0.05	- -	1.00
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.59	2.56	2.14	-0.85		
recg3	0.12	0.15	0.16	-0.05	- -	1.02
	(0.07)	(0.06)	(0.07)	(0.06)		(0.08)
	1.59	2.57	2.14	-0.85		12.78
recg4	0.13	0.16	0.17	-0.05	- -	1.10
	(0.08)	(0.06)	(0.08)	(0.06)		(0.08)
	1.59	2.58	2.14	-0.85		14.14
recg5	0.08	0.10	0.11	-0.03	- -	0.69
	(0.05)	(0.04)	(0.05)	(0.04)		(0.09)
	1.57	2.49	2.09	-0.84		8.03
recg6	0.10	0.12	0.13	-0.04	- -	0.83
	(0.06)	(0.05)	(0.06)	(0.05)		(0.08)
	1.58	2.53	2.12	-0.84		9.93
recg7	0.08	0.10	0.11	-0.03	- -	0.68
	(0.05)	(0.04)	(0.05)	(0.04)		(0.09)
	1.57	2.48	2.09	-0.84		7.80
recg8	0.09	0.11	0.12	-0.04	- -	0.74
	(0.05)	(0.04)	(0.06)	(0.04)		(0.09)
	1.57	2.51	2.10	-0.84		8.65
recg10	0.10	0.13	0.14	-0.04	- -	0.88
	(0.06)	(0.05)	(0.07)	(0.05)		(0.08)
	1.58	2.54	2.12	-0.84		10.67

```
recg12     0.06     0.07     0.08    -0.02      - -      0.49
          (0.04)   (0.03)   (0.04)   (0.03)            (0.09)
           1.54     2.37     2.02    -0.84              5.53

 vhlsq     0.38    -0.11     0.51     0.03     0.01     0.32
          (0.08)   (0.07)   (0.08)   (0.07)   (0.14)   (0.14)
           4.57    -1.63     6.16     0.39     0.05     2.27

 vhlit     0.34     0.12     0.39    -0.05    -0.07     0.36
          (0.08)   (0.07)   (0.08)   (0.07)   (0.14)   (0.14)
           4.10     1.78     4.64    -0.70    -0.53     2.52

 vhlpl     0.42    -0.02     0.69     0.07    -0.06     0.17
          (0.08)   (0.06)   (0.08)   (0.06)   (0.13)   (0.13)
           5.55    -0.39     9.19     1.16    -0.43     1.27

 vhlct     0.51     0.25     0.65     0.00    -0.12     0.42
          (0.07)   (0.06)   (0.07)   (0.06)   (0.12)   (0.12)
           7.13     4.30     9.11     0.06    -1.01     3.40
```

```
    Total Effects of ETA on Y

         vhlsq    vhlit    vhlpl    vhlct
        -------- -------- -------- --------
   age     - -      - -      - -      - -

gender     - -      - -      - -      - -

   edu     - -      - -      - -      - -

lrcont     - -      - -      - -      - -

    l1     - -      - -      - -      - -

    l3     - -      - -      - -      - -

    l4     - -      - -      - -      - -

    l6     - -      - -      - -      - -

    l8     - -      - -      - -      - -

   l10     - -      - -      - -      - -

   l13     - -      - -      - -      - -

   l14     - -      - -      - -      - -

   l15     - -      - -      - -      - -

   l20     - -      - -      - -      - -

 recg1     - -      - -      - -      - -

 recg3     - -      - -      - -      - -

 recg4     - -      - -      - -      - -
```

recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

Indirect Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	- -	- -	- -	- -	- -	- -
gender	- -	- -	- -	- -	- -	- -
edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
l1	0.09	0.21	0.15	-0.03	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.24	3.49	2.05	-0.54		
l3	0.08	0.18	0.13	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.43	2.04	-0.54		
l4	0.08	0.18	0.13	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.43	2.04	-0.54		
l6	0.07	0.16	0.11	-0.02	- -	- -
	(0.06)	(0.05)	(0.06)	(0.04)		
	1.24	3.37	2.02	-0.54		
l8	0.09	0.21	0.15	-0.03	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.24	3.50	2.05	-0.54		
l10	0.07	0.16	0.12	-0.02	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.39	2.03	-0.54		
l13	0.08	0.18	0.13	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.44	2.04	-0.54		

l14	0.07	0.17	0.12	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.40	2.03	-0.54		
l15	0.08	0.17	0.13	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.42	2.03	-0.54		
l20	0.10	0.22	0.16	-0.03	- -	- -
	(0.08)	(0.06)	(0.08)	(0.06)		
	1.24	3.50	2.05	-0.54		
recg1	0.12	0.15	0.16	-0.05	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.59	2.56	2.14	-0.85		
recg3	0.12	0.15	0.16	-0.05	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.59	2.57	2.14	-0.85		
recg4	0.13	0.16	0.17	-0.05	- -	- -
	(0.08)	(0.06)	(0.08)	(0.06)		
	1.59	2.58	2.14	-0.85		
recg5	0.08	0.10	0.11	-0.03	- -	- -
	(0.05)	(0.04)	(0.05)	(0.04)		
	1.57	2.49	2.09	-0.84		
recg6	0.10	0.12	0.13	-0.04	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.58	2.53	2.12	-0.84		
recg7	0.08	0.10	0.11	-0.03	- -	- -
	(0.05)	(0.04)	(0.05)	(0.04)		
	1.57	2.48	2.09	-0.84		
recg8	0.09	0.11	0.12	-0.04	- -	- -
	(0.05)	(0.04)	(0.06)	(0.04)		
	1.57	2.51	2.10	-0.84		
recg10	0.10	0.13	0.14	-0.04	- -	- -
	(0.06)	(0.05)	(0.07)	(0.05)		
	1.58	2.54	2.12	-0.84		
recg12	0.06	0.07	0.08	-0.02	- -	- -
	(0.04)	(0.03)	(0.04)	(0.03)		
	1.54	2.37	2.02	-0.84		
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.32
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	4.57	-1.63	6.16	0.39	0.05	2.27
vhlit	0.34	0.12	0.39	-0.05	-0.07	0.36
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	4.10	1.78	4.64	-0.70	-0.53	2.52
vhlpl	0.42	-0.02	0.69	0.07	-0.06	0.17
	(0.08)	(0.06)	(0.08)	(0.06)	(0.13)	(0.13)
	5.55	-0.39	9.19	1.16	-0.43	1.27

vhlct	0.51	0.25	0.65	0.00	-0.12	0.42
	(0.07)	(0.06)	(0.07)	(0.06)	(0.12)	(0.12)
	7.13	4.30	9.11	0.06	-1.01	3.40

Indirect Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -

vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

!This is the 10-factor model

Standardized Total and Indirect Effects

Standardized Total Effects of ETA on ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	0.11	0.25	0.18	-0.04	- -	- -
Semantic	0.15	0.19	0.20	-0.06	- -	- -
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25
vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Standardized Total Effects of ETA on ETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Standardized Indirect Effects of ETA on ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	- -	- -	- -	- -	- -	- -
Semantic	- -	- -	- -	- -	- -	- -
vhlsq	0.04	0.05	0.05	-0.02	- -	- -
vhlit	0.04	0.04	0.05	-0.02	- -	- -
vhlpl	0.01	0.01	0.02	-0.01	- -	- -
vhlct	0.04	0.04	0.05	-0.02	- -	- -

Standardized Indirect Effects of ETA on ETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -

Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Standardized Total Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	0.09	0.21	0.15	-0.03	0.82	- -
l3	0.08	0.18	0.13	-0.03	0.71	- -
l4	0.08	0.18	0.13	-0.03	0.71	- -
l6	0.07	0.16	0.11	-0.02	0.62	- -
l8	0.09	0.21	0.15	-0.03	0.83	- -
l10	0.07	0.16	0.12	-0.02	0.65	- -
l13	0.08	0.18	0.13	-0.03	0.71	- -
l14	0.07	0.17	0.12	-0.03	0.66	- -
l15	0.08	0.17	0.13	-0.03	0.68	- -
l20	0.10	0.22	0.16	-0.03	0.86	- -
recg1	0.12	0.15	0.16	-0.05	- -	0.80
recg3	0.12	0.15	0.16	-0.05	- -	0.81
recg4	0.13	0.16	0.17	-0.05	- -	0.88
recg5	0.08	0.10	0.11	-0.03	- -	0.55
recg6	0.10	0.12	0.13	-0.04	- -	0.66
recg7	0.08	0.10	0.11	-0.03	- -	0.54
recg8	0.09	0.11	0.12	-0.04	- -	0.59
recg10	0.10	0.13	0.14	-0.04	- -	0.70
recg12	0.06	0.07	0.08	-0.02	- -	0.39
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25
vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Standardized Total Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -

recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

Completely Standardized Total Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	0.09	0.21	0.15	-0.03	0.82	- -
l3	0.08	0.18	0.13	-0.03	0.71	- -
l4	0.08	0.18	0.13	-0.03	0.71	- -
l6	0.07	0.16	0.11	-0.02	0.62	- -
l8	0.09	0.21	0.15	-0.03	0.83	- -
l10	0.07	0.16	0.12	-0.02	0.65	- -
l13	0.08	0.18	0.13	-0.03	0.71	- -
l14	0.07	0.17	0.12	-0.03	0.66	- -
l15	0.08	0.17	0.13	-0.03	0.68	- -
l20	0.10	0.22	0.16	-0.03	0.86	- -
recg1	0.12	0.15	0.16	-0.05	- -	0.80
recg3	0.12	0.15	0.16	-0.05	- -	0.81
recg4	0.13	0.16	0.17	-0.05	- -	0.88
recg5	0.08	0.10	0.11	-0.03	- -	0.55
recg6	0.10	0.12	0.13	-0.04	- -	0.66
recg7	0.08	0.10	0.11	-0.03	- -	0.54
recg8	0.09	0.11	0.12	-0.04	- -	0.59
recg10	0.10	0.13	0.14	-0.04	- -	0.70
recg12	0.06	0.07	0.08	-0.02	- -	0.39
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25
vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Completely Standardized Total Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -

l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

Standardized Indirect Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	- -	- -	- -	- -	- -	- -
gender	- -	- -	- -	- -	- -	- -
edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
l1	0.09	0.21	0.15	-0.03	- -	- -
l3	0.08	0.18	0.13	-0.03	- -	- -
l4	0.08	0.18	0.13	-0.03	- -	- -
l6	0.07	0.16	0.11	-0.02	- -	- -
l8	0.09	0.21	0.15	-0.03	- -	- -
l10	0.07	0.16	0.12	-0.02	- -	- -
l13	0.08	0.18	0.13	-0.03	- -	- -
l14	0.07	0.17	0.12	-0.03	- -	- -
l15	0.08	0.17	0.13	-0.03	- -	- -
l20	0.10	0.22	0.16	-0.03	- -	- -
recg1	0.12	0.15	0.16	-0.05	- -	- -
recg3	0.12	0.15	0.16	-0.05	- -	- -
recg4	0.13	0.16	0.17	-0.05	- -	- -
recg5	0.08	0.10	0.11	-0.03	- -	- -
recg6	0.10	0.12	0.13	-0.04	- -	- -
recg7	0.08	0.10	0.11	-0.03	- -	- -
recg8	0.09	0.11	0.12	-0.04	- -	- -
recg10	0.10	0.13	0.14	-0.04	- -	- -
recg12	0.06	0.07	0.08	-0.02	- -	- -
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25
vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Standardized Indirect Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -

l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Completely Standardized Indirect Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
	--------	--------	--------	--------	--------	--------
age	- -	- -	- -	- -	- -	- -
gender	- -	- -	- -	- -	- -	- -
edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
l1	0.09	0.21	0.15	-0.03	- -	- -
l3	0.08	0.18	0.13	-0.03	- -	- -
l4	0.08	0.18	0.13	-0.03	- -	- -
l6	0.07	0.16	0.11	-0.02	- -	- -
l8	0.09	0.21	0.15	-0.03	- -	- -
l10	0.07	0.16	0.12	-0.02	- -	- -
l13	0.08	0.18	0.13	-0.03	- -	- -
l14	0.07	0.17	0.12	-0.03	- -	- -
l15	0.08	0.17	0.13	-0.03	- -	- -
l20	0.10	0.22	0.16	-0.03	- -	- -
recg1	0.12	0.15	0.16	-0.05	- -	- -
recg3	0.12	0.15	0.16	-0.05	- -	- -
recg4	0.13	0.16	0.17	-0.05	- -	- -
recg5	0.08	0.10	0.11	-0.03	- -	- -
recg6	0.10	0.12	0.13	-0.04	- -	- -
recg7	0.08	0.10	0.11	-0.03	- -	- -
recg8	0.09	0.11	0.12	-0.04	- -	- -
recg10	0.10	0.13	0.14	-0.04	- -	- -
recg12	0.06	0.07	0.08	-0.02	- -	- -
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25
vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Completely Standardized Indirect Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
	--------	--------	--------	--------
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -

lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Time used: 1.031 Seconds

DATE: 3/24/2003
TIME: 9:57

L I S R E L 8.53

BY

Karl G. J"reskog & Dag S"rbom

The following lines were read from file C:\Documents and Settings\default\My Documents\Students\JohnB\path_230303.ls8.Spl:

```
!This is the 10-factor model
!vhlsq vhlit vlhlpl vlhlct , Age, gender Edu lrcont likert, semantic
DA ni=30 no=201 ma=km
LA
age gender edu tert year
l1 l3 l4 l6 l8 l10 l13 l14 l15 l20
vhlsq vhlit vhlpl vhlct vhlo
lrcont
recg1 recg3 recg4 recg5 recg6 recg7 recg8 recg10 recg12
CM=dummy1.COV RE
MO ny=27 ne=10 ly=fu,fi ps=sy,fr be=fu,fi te=sy,fi
SE
age gender edu lrcont
l1 l3 l4 l6 l8 l10 l13 l14 l15 l20
recg1 recg3 recg4 recg5 recg6 recg7 recg8 recg10 recg12
vhlsq vhlit vhlpl vhlct/
pa ly
1 (1 0 0 0 0 0 0 0 0 0)
1 (0 1 0 0 0 0 0 0 0 0)
1 (0 0 1 0 0 0 0 0 0 0)
1 (0 0 0 1 0 0 0 0 0 0)
10(0 0 0 0 1 0 0 0 0 0)
9 (0 0 0 0 0 1 0 0 0 0)
1 (0 0 0 0 0 0 1 0 0 0)
1 (0 0 0 0 0 0 0 1 0 0)
1 (0 0 0 0 0 0 0 0 1 0)
1 (0 0 0 0 0 0 0 0 0 1)
pa ps
1
1 1
1 1 1
1 1 1 1
0 0 0 0 1
0 0 0 0 1 1
```

```
0 0 0 0 0 0 1
0 0 0 0 0 0 1 1
0 0 0 0 0 0 1 1 1
0 0 0 0 0 0 1 1 1 1
pa be
0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0
1 1 1 1 0 0 0 0 0 0 !
1 1 1 1 0 0 0 0 0 0 !
1 1 1 1 1 1 0 0 0 0
1 1 1 1 1 1 0 0 0 0
1 1 1 1 1 1 0 0 0 0
1 1 1 1 1 1 0 0 0 0
st 1 ly 1 1 ly 2 2 ly 3 3 ly 4 4 ly 5 5 ly 15 6 ly 24 7 ly 25 8 ly 26 9 ly 27 10
fi   ly 1 1 ly 2 2 ly 3 3 ly 4 4 ly 5 5 ly 15 6 ly 24 7 ly 25 8 ly 26 9 ly 27 10
fr te 1 1 te 2 2 te 3 3 te 4 4 te 5 5 te 6 6 te 7 7 te 8 8 te 9 9 te 10 10
fr te 11 11 te 12 12 te 13 13 te 14 14 te 15 15 te 16 16 te 17 17 te 18 18 te 19 19
fr te 20 20 te 21 21 te 22 22 te 23 23 te 24 24 te 25 25 te 26 26 te 27 27
st 0 te 1 1 te 2 2 te 3 3 te 4 4  te 24 24 te 25 25 te 26 26 te 27 27
fi   te 1 1 te 2 2 te 3 3 te 4 4  te 24 24 te 25 25 te 26 26 te 27 27
pd
Le
Age Gender Edu lrcont Likert Semantic vhlsq vhlit vhlpl vhlct
OU EF SC AD=OFF

!This is the 10-factor model

                    Number of Input Variables 30
                    Number of Y - Variables   27
                    Number of X - Variables    0
                    Number of ETA - Variables 10
                    Number of KSI - Variables  0
                    Number of Observations   201

!This is the 10-factor model
```

Covariance Matrix

	age	gender	edu	lrcont	l1	l3
age	1.00					
gender	-0.04	1.00				
edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
l1	0.05	0.15	0.08	-0.04	1.00	
l3	-0.02	0.31	0.15	0.01	0.58	1.00
l4	0.00	0.36	0.16	0.01	0.60	0.50
l6	0.11	0.14	-0.03	-0.03	0.46	0.53
l8	-0.04	0.20	0.09	0.00	0.67	0.60
l10	-0.05	0.14	0.19	-0.12	0.46	0.47
l13	0.06	0.16	0.10	-0.01	0.58	0.54
l14	0.00	0.24	0.14	-0.02	0.50	0.52
l15	-0.10	0.25	0.14	-0.03	0.52	0.45
l20	-0.07	0.15	0.14	-0.01	0.74	0.55
recg1	0.05	0.22	0.21	-0.06	0.60	0.41
recg3	0.06	0.15	0.07	-0.10	0.56	0.39
recg4	-0.02	0.17	0.14	0.00	0.63	0.43

recg5	-0.07	0.22	0.00	-0.09	0.36	0.25
recg6	0.01	0.12	0.02	0.02	0.47	0.34
recg7	-0.14	-0.06	0.05	-0.10	0.31	0.24
recg8	0.06	0.11	0.11	-0.05	0.38	0.25
recg10	-0.02	0.12	0.07	0.04	0.50	0.31
recg12	-0.05	0.14	0.06	-0.10	0.25	0.15
vhlsq	0.07	-0.06	0.26	0.01	0.20	0.10
vhlit	0.09	0.15	0.20	-0.03	0.25	0.07
vhlpl	0.01	0.05	0.42	0.04	0.10	0.10
vhlct	0.10	0.30	0.37	0.02	0.19	0.15

Covariance Matrix

	l4	l6	l8	l10	l13	l14
	--------	--------	--------	--------	--------	--------
l4	1.00					
l6	0.34	1.00				
l8	0.58	0.56	1.00			
l10	0.35	0.48	0.56	1.00		
l13	0.43	0.46	0.60	0.48	1.00	
l14	0.52	0.47	0.56	0.43	0.57	1.00
l15	0.46	0.47	0.55	0.47	0.49	0.52
l20	0.62	0.51	0.72	0.59	0.58	0.48
recg1	0.58	0.28	0.47	0.40	0.44	0.38
recg3	0.52	0.27	0.48	0.40	0.39	0.30
recg4	0.60	0.33	0.55	0.42	0.46	0.38
recg5	0.38	0.18	0.30	0.33	0.24	0.17
recg6	0.44	0.25	0.38	0.30	0.34	0.30
recg7	0.26	0.15	0.25	0.30	0.27	0.16
recg8	0.27	0.23	0.31	0.27	0.31	0.22
recg10	0.43	0.25	0.41	0.33	0.29	0.21
recg12	0.25	0.13	0.24	0.28	0.23	0.21
vhlsq	0.24	0.02	0.12	0.14	0.09	0.16
vhlit	0.28	0.05	0.14	0.10	0.14	0.19
vhlpl	0.12	0.02	0.02	0.09	0.16	0.15
vhlct	0.19	0.14	0.25	0.30	0.18	0.16

Covariance Matrix

	l15	l20	recg1	recg3	recg4	recg5
	--------	--------	--------	--------	--------	--------
l15	1.00					
l20	0.60	1.00				
recg1	0.44	0.56	1.00			
recg3	0.40	0.53	0.71	1.00		
recg4	0.46	0.64	0.70	0.74	1.00	
recg5	0.25	0.31	0.36	0.39	0.44	1.00
recg6	0.32	0.45	0.50	0.47	0.59	0.46
recg7	0.22	0.36	0.34	0.43	0.44	0.50
recg8	0.31	0.37	0.55	0.46	0.50	0.29
recg10	0.33	0.50	0.48	0.50	0.60	0.56
recg12	0.20	0.21	0.27	0.37	0.29	0.35
vhlsq	0.21	0.25	0.30	0.17	0.24	0.17
vhlit	0.17	0.22	0.31	0.22	0.29	0.16
vhlpl	0.18	0.14	0.24	0.11	0.17	0.04
vhlct	0.24	0.30	0.42	0.29	0.33	0.16

Covariance Matrix

	recg6	recg7	recg8	recg10	recg12	vhlsq
	--------	--------	--------	--------	--------	--------
recg6	1.00					
recg7	0.36	1.00				
recg8	0.47	0.30	1.00			
recg10	0.56	0.59	0.39	1.00		
recg12	0.24	0.18	0.23	0.35	1.00	
vhlsq	0.26	0.14	0.14	0.24	0.06	1.00
vhlit	0.14	0.15	0.26	0.18	0.07	0.51
vhlpl	0.13	0.05	0.17	0.07	0.02	0.55
vhlct	0.14	0.14	0.20	0.31	0.22	0.59

Covariance Matrix

	vhlit	vhlpl	vhlct
	--------	--------	--------
vhlit	1.00		
vhlpl	0.58	1.00	
vhlct	0.46	0.46	1.00

!This is the 10-factor model

Parameter Specifications

LAMBDA-Y

	Age	Gender	Edu	lrcont	Likert	Semantic
	--------	--------	--------	--------	--------	--------
age	0	0	0	0	0	0
gender	0	0	0	0	0	0
edu	0	0	0	0	0	0
lrcont	0	0	0	0	0	0
l1	0	0	0	0	0	0
l3	0	0	0	0	1	0
l4	0	0	0	0	2	0
l6	0	0	0	0	3	0
l8	0	0	0	0	4	0
l10	0	0	0	0	5	0
l13	0	0	0	0	6	0
l14	0	0	0	0	7	0
l15	0	0	0	0	8	0
l20	0	0	0	0	9	0
recg1	0	0	0	0	0	0
recg3	0	0	0	0	0	10
recg4	0	0	0	0	0	11
recg5	0	0	0	0	0	12
recg6	0	0	0	0	0	13
recg7	0	0	0	0	0	14
recg8	0	0	0	0	0	15
recg10	0	0	0	0	0	16
recg12	0	0	0	0	0	17
vhlsq	0	0	0	0	0	0
vhlit	0	0	0	0	0	0
vhlpl	0	0	0	0	0	0
vhlct	0	0	0	0	0	0

LAMBDA-Y

	vhlsq	vhlit	vhlpl	vhlct
	--------	--------	--------	--------
age	0	0	0	0
gender	0	0	0	0
edu	0	0	0	0
lrcont	0	0	0	0
l1	0	0	0	0
l3	0	0	0	0
l4	0	0	0	0
l6	0	0	0	0
l8	0	0	0	0
l10	0	0	0	0
l13	0	0	0	0
l14	0	0	0	0
l15	0	0	0	0
l20	0	0	0	0
recg1	0	0	0	0
recg3	0	0	0	0
recg4	0	0	0	0
recg5	0	0	0	0
recg6	0	0	0	0
recg7	0	0	0	0
recg8	0	0	0	0
recg10	0	0	0	0
recg12	0	0	0	0
vhlsq	0	0	0	0
vhlit	0	0	0	0
vhlpl	0	0	0	0
vhlct	0	0	0	0

BETA

	Age	Gender	Edu	lrcont	Likert	Semantic
	--------	--------	--------	--------	--------	--------
Age	0	0	0	0	0	0
Gender	0	0	0	0	0	0
Edu	0	0	0	0	0	0
lrcont	0	0	0	0	0	0
Likert	18	19	20	21	0	0
Semantic	22	23	24	25	0	0
vhlsq	26	27	28	29	30	31
vhlit	32	33	34	35	36	37
vhlpl	38	39	40	41	42	43
vhlct	44	45	46	47	48	49

BETA

	vhlsq	vhlit	vhlpl	vhlct
	--------	--------	--------	--------
Age	0	0	0	0
Gender	0	0	0	0
Edu	0	0	0	0
lrcont	0	0	0	0
Likert	0	0	0	0
Semantic	0	0	0	0
vhlsq	0	0	0	0
vhlit	0	0	0	0
vhlpl	0	0	0	0
vhlct	0	0	0	0

PSI

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	50					
Gender	51	52				
Edu	53	54	55			
lrcont	56	57	58	59		
Likert	0	0	0	0	60	
Semantic	0	0	0	0	61	62
vhlsq	0	0	0	0	0	0
vhlit	0	0	0	0	0	0
vhlpl	0	0	0	0	0	0
vhlct	0	0	0	0	0	0

PSI

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	63			
vhlit	64	65		
vhlpl	66	67	68	
vhlct	69	70	71	72

THETA-EPS

age	gender	edu	lrcont	l1	l3
0	0	0	0	73	74

THETA-EPS

l4	l6	l8	l10	l13	l14
75	76	77	78	79	80

THETA-EPS

l15	l20	recg1	recg3	recg4	recg5
81	82	83	84	85	86

THETA-EPS

recg6	recg7	recg8	recg10	recg12	vhlsq
87	88	89	90	91	0

THETA-EPS

vhlit	vhlpl	vhlct
0	0	0

!This is the 10-factor model

Number of Iterations = 11

LISREL Estimates (Maximum Likelihood)

LAMBDA-Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	- -	- -	- -	- -	1.00	- -
l3	- -	- -	- -	- -	0.86 (0.08) 11.15	- -
l4	- -	- -	- -	- -	0.86 (0.08) 11.14	- -
l6	- -	- -	- -	- -	0.75 (0.08) 9.39	- -
l8	- -	- -	- -	- -	1.01 (0.07) 14.00	- -
l10	- -	- -	- -	- -	0.79 (0.08) 9.92	- -
l13	- -	- -	- -	- -	0.86 (0.08) 11.17	- -
l14	- -	- -	- -	- -	0.81 (0.08) 10.20	- -
l15	- -	- -	- -	- -	0.83 (0.08) 10.63	- -
l20	- -	- -	- -	- -	1.04 (0.07) 14.57	- -
recg1	- -	- -	- -	- -	- -	1.00
recg3	- -	- -	- -	- -	- -	1.02 (0.08) 12.78

recg4	- -	- -	- -	- -	- -	1.10
						(0.08)
						14.14
recg5	- -	- -	- -	- -	- -	0.69
						(0.09)
						8.03
recg6	- -	- -	- -	- -	- -	0.83
						(0.08)
						9.93
recg7	- -	- -	- -	- -	- -	0.68
						(0.09)
						7.80
recg8	- -	- -	- -	- -	- -	0.74
						(0.09)
						8.65
recg10	- -	- -	- -	- -	- -	0.88
						(0.08)
						10.67
recg12	- -	- -	- -	- -	- -	0.49
						(0.09)
						5.53
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

LAMBDA-Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -

l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

BETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	0.09 (0.07) 1.24	0.21 (0.06) 3.49	0.15 (0.07) 2.05	-0.03 (0.06) -0.54	- -	- -
Semantic	0.12 (0.07) 1.59	0.15 (0.06) 2.56	0.16 (0.07) 2.14	-0.05 (0.06) -0.85	- -	- -
vhlsq	0.34	-0.16	0.46	0.04	0.01	0.32

	(0.08)	(0.07)	(0.08)	(0.06)	(0.14)	(0.14)
	4.22	-2.38	5.66	0.65	0.05	2.27
vhlit	0.31	0.08	0.35	-0.03	-0.07	0.36
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	3.75	1.19	4.15	-0.48	-0.53	2.52
vhlpl	0.40	-0.04	0.68	0.08	-0.06	0.17
	(0.08)	(0.06)	(0.08)	(0.06)	(0.13)	(0.13)
	5.35	-0.60	8.87	1.28	-0.43	1.27
vhlct	0.47	0.21	0.61	0.02	-0.12	0.42
	(0.07)	(0.06)	(0.07)	(0.05)	(0.12)	(0.12)
	6.87	3.67	8.72	0.37	-1.01	3.40

BETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Covariance Matrix of ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	-0.02	0.22	0.13	-0.02	0.67	
Semantic	0.00	0.16	0.11	-0.04	0.50	0.64
vhlsq	0.07	-0.06	0.26	0.01	0.18	0.23
vhlit	0.09	0.15	0.20	-0.03	0.19	0.25
vhlpl	0.01	0.05	0.42	0.04	0.12	0.15
vhlct	0.10	0.30	0.37	0.02	0.24	0.31

Covariance Matrix of ETA

vhlsq vhlit vhlpl vhlct

vhlsq	1.00			
vhlit	0.51	1.00		
vhlpl	0.55	0.58	1.00	
vhlct	0.59	0.46	0.46	1.00

PSI

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00 (0.10) 10.00					
Gender	-0.04 (0.07) -0.61	1.00 (0.10) 10.00				
Edu	-0.61 (0.08) -7.39	0.12 (0.07) 1.73	1.00 (0.10) 10.00			
lrcont	0.18 (0.07) 2.46	0.08 (0.07) 1.15	-0.14 (0.07) -2.03	1.00 (0.10) 10.00		
Likert	- -	- -	- -	- -	0.61 (0.09) 6.94	
Semantic	- -	- -	- -	- -	0.45 (0.06) 6.94	0.59 (0.09) 6.62
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

PSI

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	0.77 (0.08) 9.92			
vhlit	0.33 (0.06) 5.40	0.81 (0.08) 9.90		
vhlpl	0.31 (0.06) 5.56	0.38 (0.06) 6.41	0.69 (0.07) 9.97	

vhlct	0.34	0.19	0.14	0.56
	(0.05)	(0.05)	(0.05)	(0.06)
	6.30	3.66	3.12	9.80

Squared Multiple Correlations for Structural Equations

Age	Gender	Edu	lrcont	Likert	Semantic
- -	- -	- -	- -	0.09	0.07

Squared Multiple Correlations for Structural Equations

vhlsq	vhlit	vhlpl	vhlct
0.23	0.19	0.31	0.44

THETA-EPS

age	gender	edu	lrcont	l1	l3
- -	- -	- -	- -	0.33	0.50
				(0.04)	(0.05)
				8.54	9.29

THETA-EPS

l4	l6	l8	l10	l13	l14
0.50	0.62	0.31	0.58	0.50	0.56
(0.05)	(0.06)	(0.04)	(0.06)	(0.05)	(0.06)
9.29	9.56	8.40	9.49	9.29	9.45

THETA-EPS

l15	l20	recg1	recg3	recg4	recg5
0.53	0.27	0.36	0.34	0.23	0.69
(0.06)	(0.03)	(0.04)	(0.04)	(0.03)	(0.07)
9.39	8.07	8.47	8.33	7.15	9.62

THETA-EPS

recg6	recg7	recg8	recg10	recg12	vhlsq
0.56	0.71	0.65	0.50	0.84	- -
(0.06)	(0.07)	(0.07)	(0.06)	(0.09)	
9.32	9.65	9.54	9.15	9.84	

THETA-EPS

vhlit	vhlpl	vhlct
- -	- -	- -

Squared Multiple Correlations for Y - Variables

age	gender	edu	lrcont	l1	l3
1.00	1.00	1.00	1.00	0.67	0.50

Squared Multiple Correlations for Y - Variables

l4	l6	l8	l10	l13	l14
0.50	0.38	0.69	0.42	0.50	0.44

Squared Multiple Correlations for Y - Variables

l15	l20	recg1	recg3	recg4	recg5
0.47	0.73	0.64	0.66	0.77	0.31

Squared Multiple Correlations for Y - Variables

recg6	recg7	recg8	recg10	recg12	vhlsq
0.44	0.29	0.35	0.50	0.16	1.00

Squared Multiple Correlations for Y - Variables

vhlit	vhlpl	vhlct
1.00	1.00	1.00

Goodness of Fit Statistics

Degrees of Freedom = 287
Minimum Fit Function Chi-Square = 631.64 (P = 0.0)
Normal Theory Weighted Least Squares Chi-Square = 610.07 (P = 0.0)
Estimated Non-centrality Parameter (NCP) = 323.07
90 Percent Confidence Interval for NCP = (255.85 ; 398.03)

Minimum Fit Function Value = 3.16
Population Discrepancy Function Value (F0) = 1.62
90 Percent Confidence Interval for F0 = (1.28 ; 1.99)
Root Mean Square Error of Approximation (RMSEA) = 0.075
90 Percent Confidence Interval for RMSEA = (0.067 ; 0.083)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.00

Expected Cross-Validation Index (ECVI) = 3.96
90 Percent Confidence Interval for ECVI = (3.62 ; 4.34)
ECVI for Saturated Model = 3.78
ECVI for Independence Model = 39.50

Chi-Square for Independence Model with 351 Degrees of Freedom = 7846.91
Independence AIC = 7900.91
Model AIC = 792.07
Saturated AIC = 756.00
Independence CAIC = 8017.09
Model CAIC = 1183.67
Saturated CAIC = 2382.65

Normed Fit Index (NFI) = 0.92
Non-Normed Fit Index (NNFI) = 0.94
Parsimony Normed Fit Index (PNFI) = 0.75
Comparative Fit Index (CFI) = 0.95
Incremental Fit Index (IFI) = 0.95
Relative Fit Index (RFI) = 0.90

Critical N (CN) = 110.45

Root Mean Square Residual (RMR) = 0.056
Standardized RMR = 0.056
Goodness of Fit Index (GFI) = 0.82
Adjusted Goodness of Fit Index (AGFI) = 0.76
Parsimony Goodness of Fit Index (PGFI) = 0.62

!This is the 10-factor model

Standardized Solution

LAMBDA-Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	- -	- -	- -	- -	0.82	- -
l3	- -	- -	- -	- -	0.71	- -
l4	- -	- -	- -	- -	0.71	- -
l6	- -	- -	- -	- -	0.62	- -
l8	- -	- -	- -	- -	0.83	- -
l10	- -	- -	- -	- -	0.65	- -
l13	- -	- -	- -	- -	0.71	- -
l14	- -	- -	- -	- -	0.66	- -
l15	- -	- -	- -	- -	0.68	- -
l20	- -	- -	- -	- -	0.86	- -
recg1	- -	- -	- -	- -	- -	0.80
recg3	- -	- -	- -	- -	- -	0.81
recg4	- -	- -	- -	- -	- -	0.88
recg5	- -	- -	- -	- -	- -	0.55
recg6	- -	- -	- -	- -	- -	0.66
recg7	- -	- -	- -	- -	- -	0.54
recg8	- -	- -	- -	- -	- -	0.59
recg10	- -	- -	- -	- -	- -	0.70
recg12	- -	- -	- -	- -	- -	0.39
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

LAMBDA-Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -

edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

BETA

	Age	Gender	Edu	lrcont	Likert	Semantic
	--------	--------	--------	--------	--------	--------
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	0.11	0.25	0.18	-0.04	- -	- -
Semantic	0.15	0.19	0.20	-0.06	- -	- -
vhlsq	0.34	-0.16	0.46	0.04	0.01	0.25
vhlit	0.31	0.08	0.35	-0.03	-0.06	0.29
vhlpl	0.40	-0.04	0.68	0.08	-0.05	0.13
vhlct	0.47	0.21	0.61	0.02	-0.10	0.33

BETA

	vhlsq	vhlit	vhlpl	vhlct
	--------	--------	--------	--------
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Correlation Matrix of ETA

	Age	Gender	Edu	lrcont	Likert	Semantic

Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	-0.02	0.27	0.15	-0.03	1.00	
Semantic	0.01	0.20	0.14	-0.05	0.76	1.00
vhlsq	0.07	-0.06	0.26	0.01	0.22	0.29
vhlit	0.09	0.15	0.20	-0.03	0.23	0.31
vhlpl	0.01	0.05	0.42	0.04	0.14	0.19
vhlct	0.10	0.30	0.37	0.02	0.29	0.39

Correlation Matrix of ETA

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	1.00			
vhlit	0.51	1.00		
vhlpl	0.55	0.58	1.00	
vhlct	0.59	0.46	0.46	1.00

PSI

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	- -	- -	- -	- -	0.91	
Semantic	- -	- -	- -	- -	0.68	0.93
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

PSI

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	0.77			
vhlit	0.33	0.81		
vhlpl	0.31	0.38	0.69	
vhlct	0.34	0.19	0.14	0.56

!This is the 10-factor model

Completely Standardized Solution

LAMBDA-Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	- -	- -	- -	- -	0.82	- -
l3	- -	- -	- -	- -	0.71	- -

l4	- -	- -	- -	- -	0.71	- -
l6	- -	- -	- -	- -	0.62	- -
l8	- -	- -	- -	- -	0.83	- -
l10	- -	- -	- -	- -	0.65	- -
l13	- -	- -	- -	- -	0.71	- -
l14	- -	- -	- -	- -	0.66	- -
l15	- -	- -	- -	- -	0.68	- -
l20	- -	- -	- -	- -	0.86	- -
recg1	- -	- -	- -	- -	- -	0.80
recg3	- -	- -	- -	- -	- -	0.81
recg4	- -	- -	- -	- -	- -	0.88
recg5	- -	- -	- -	- -	- -	0.55
recg6	- -	- -	- -	- -	- -	0.66
recg7	- -	- -	- -	- -	- -	0.54
recg8	- -	- -	- -	- -	- -	0.59
recg10	- -	- -	- -	- -	- -	0.70
recg12	- -	- -	- -	- -	- -	0.39
vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

LAMBDA-Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

BETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -

Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	0.11	0.25	0.18	-0.04	- -	- -
Semantic	0.15	0.19	0.20	-0.06	- -	- -
vhlsq	0.34	-0.16	0.46	0.04	0.01	0.25
vhlit	0.31	0.08	0.35	-0.03	-0.06	0.29
vhlpl	0.40	-0.04	0.68	0.08	-0.05	0.13
vhlct	0.47	0.21	0.61	0.02	-0.10	0.33

BETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Correlation Matrix of ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	-0.02	0.27	0.15	-0.03	1.00	
Semantic	0.01	0.20	0.14	-0.05	0.76	1.00
vhlsq	0.07	-0.06	0.26	0.01	0.22	0.29
vhlit	0.09	0.15	0.20	-0.03	0.23	0.31
vhlpl	0.01	0.05	0.42	0.04	0.14	0.19
vhlct	0.10	0.30	0.37	0.02	0.29	0.39

Correlation Matrix of ETA

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	1.00			
vhlit	0.51	1.00		
vhlpl	0.55	0.58	1.00	
vhlct	0.59	0.46	0.46	1.00

PSI

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	1.00					
Gender	-0.04	1.00				
Edu	-0.61	0.12	1.00			
lrcont	0.18	0.08	-0.14	1.00		
Likert	- -	- -	- -	- -	0.91	
Semantic	- -	- -	- -	- -	0.68	0.93

vhlsq	- -	- -	- -	- -	- -	- -
vhlit	- -	- -	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -	- -	- -
vhlct	- -	- -	- -	- -	- -	- -

PSI

	vhlsq	vhlit	vhlpl	vhlct
vhlsq	0.77			
vhlit	0.33	0.81		
vhlpl	0.31	0.38	0.69	
vhlct	0.34	0.19	0.14	0.56

THETA-EPS

age	gender	edu	lrcont	l1	l3
- -	- -	- -	- -	0.33	0.50

THETA-EPS

l4	l6	l8	l10	l13	l14
0.50	0.62	0.31	0.58	0.50	0.56

THETA-EPS

l15	l20	recg1	recg3	recg4	recg5
0.53	0.27	0.36	0.34	0.23	0.69

THETA-EPS

recg6	recg7	recg8	recg10	recg12	vhlsq
0.56	0.71	0.65	0.50	0.84	- -

THETA-EPS

vhlit	vhlpl	vhlct
- -	- -	- -

!This is the 10-factor model

Total and Indirect Effects

Total Effects of ETA on ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -

Likert	0.09	0.21	0.15	-0.03	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.24	3.49	2.05	-0.54		
Semantic	0.12	0.15	0.16	-0.05	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.59	2.56	2.14	-0.85		
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.32
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	4.57	-1.63	6.16	0.39	0.05	2.27
vhlit	0.34	0.12	0.39	-0.05	-0.07	0.36
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	4.10	1.78	4.64	-0.70	-0.53	2.52
vhlpl	0.42	-0.02	0.69	0.07	-0.06	0.17
	(0.08)	(0.06)	(0.08)	(0.06)	0.13)	(0.13)
	5.55	-0.39	9.19	1.16	-0.43	1.27
vhlct	0.51	0.25	0.65	0.00	-0.12	0.42
	(0.07)	(0.06)	(0.07)	(0.06)	(0.12)	(0.12)
	7.13	4.30	9.11	0.06	-1.01	3.40

Total Effects of ETA on ETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Largest Eigenvalue of B*B' (Stability Index) is 2.211

Indirect Effects of ETA on ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -

Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	- -	- -	- -	- -	- -	- -
Semantic	- -	- -	- -	- -	- -	- -
vhlsq	0.04	0.05	0.05	-0.02	- -	- -
	(0.03)	(0.03)	(0.03)	(0.02)		
	1.47	1.94	1.87	-0.82		
vhlit	0.04	0.04	0.05	-0.02	- -	- -
	(0.03)	(0.03)	(0.03)	(0.02)		
	1.40	1.54	1.69	-0.82		
vhlpl	0.01	0.01	0.02	-0.01	- -	- -
	(0.01)	(0.02)	(0.02)	(0.01)		
	1.06	0.76	1.10	-0.73		
vhlct	0.04	0.04	0.05	-0.02	- -	- -
	(0.03)	(0.02)	(0.03)	(0.02)		
	1.40	1.52	1.70	-0.82		

Indirect Effects of ETA on ETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Total Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -

edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	0.09	0.21	0.15	-0.03	1.00	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.24	3.49	2.05	-0.54		
l3	0.08	0.18	0.13	-0.03	0.86	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.43	2.04	-0.54	11.15	
l4	0.08	0.18	0.13	-0.03	0.86	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.43	2.04	-0.54	11.14	
l6	0.07	0.16	0.11	-0.02	0.75	- -
	(0.06)	(0.05)	(0.06)	(0.04)	(0.08)	
	1.24	3.37	2.02	-0.54	9.39	
l8	0.09	0.21	0.15	-0.03	1.01	- -
	(0.07)	(0.06)	(0.07)	(0.06)	(0.07)	
	1.24	3.50	2.05	-0.54	14.00	
l10	0.07	0.16	0.12	-0.02	0.79	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.39	2.03	-0.54	9.92	
l13	0.08	0.18	0.13	-0.03	0.86	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.44	2.04	-0.54	11.17	
l14	0.07	0.17	0.12	-0.03	0.81	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.40	2.03	-0.54	10.20	
l15	0.08	0.17	0.13	-0.03	0.83	- -
	(0.06)	(0.05)	(0.06)	(0.05)	(0.08)	
	1.24	3.42	2.03	-0.54	10.63	
l20	0.10	0.22	0.16	-0.03	1.04	- -
	(0.08)	(0.06)	(0.08)	(0.06)	(0.07)	
	1.24	3.50	2.05	-0.54	14.57	
recg1	0.12	0.15	0.16	-0.05	- -	1.00
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.59	2.56	2.14	-0.85		
recg3	0.12	0.15	0.16	-0.05	- -	1.02
	(0.07)	(0.06)	(0.07)	(0.06)		(0.08)
	1.59	2.57	2.14	-0.85		12.78
recg4	0.13	0.16	0.17	-0.05	- -	1.10
	(0.08)	(0.06)	(0.08)	(0.06)		(0.08)
	1.59	2.58	2.14	-0.85		14.14
recg5	0.08	0.10	0.11	-0.03	- -	0.69
	(0.05)	(0.04)	(0.05)	(0.04)		(0.09)

	1.57	2.49	2.09	-0.84		8.03
recg6	0.10	0.12	0.13	-0.04	- -	0.83
	(0.06)	(0.05)	(0.06)	(0.05)		(0.08)
	1.58	2.53	2.12	-0.84		9.93
recg7	0.08	0.10	0.11	-0.03	- -	0.68
	(0.05)	(0.04)	(0.05)	(0.04)		(0.09)
	1.57	2.48	2.09	-0.84		7.80
recg8	0.09	0.11	0.12	-0.04	- -	0.74
	(0.05)	(0.04)	(0.06)	(0.04)		(0.09)
	1.57	2.51	2.10	-0.84		8.65
recg10	0.10	0.13	0.14	-0.04	- -	0.88
	(0.06)	(0.05)	(0.07)	(0.05)		(0.08)
	1.58	2.54	2.12	-0.84		10.67
recg12	0.06	0.07	0.08	-0.02	- -	0.49
	(0.04)	(0.03)	(0.04)	(0.03)		(0.09)
	1.54	2.37	2.02	-0.84		5.53
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.32
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	4.57	-1.63	6.16	0.39	0.05	2.27
vhlit	0.34	0.12	0.39	-0.05	-0.07	0.36
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	4.10	1.78	4.64	-0.70	-0.53	2.52
vhlpl	0.42	-0.02	0.69	0.07	-0.06	0.17
	(0.08)	(0.06)	(0.08)	(0.06)	(0.13)	(0.13)
	5.55	-0.39	9.19	1.16	-0.43	1.27
vhlct	0.51	0.25	0.65	0.00	-0.12	0.42
	(0.07)	(0.06)	(0.07)	(0.06)	(0.12)	(0.12)
	7.13	4.30	9.11	0.06	-1.01	3.40

Total Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
	--------	--------	--------	--------
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -

l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

Indirect Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	- -	- -	- -	- -	- -	- -
gender	- -	- -	- -	- -	- -	- -
edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
l1	0.09	0.21	0.15	-0.03	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.24	3.49	2.05	-0.54		
l3	0.08	0.18	0.13	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.43	2.04	-0.54		

l4	0.08	0.18	0.13	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.43	2.04	-0.54		
l6	0.07	0.16	0.11	-0.02	- -	- -
	(0.06)	(0.05)	(0.06)	(0.04)		
	1.24	3.37	2.02	-0.54		
l8	0.09	0.21	0.15	-0.03	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.24	3.50	2.05	-0.54		
l10	0.07	0.16	0.12	-0.02	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.39	2.03	-0.54		
l13	0.08	0.18	0.13	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.44	2.04	-0.54		
l14	0.07	0.17	0.12	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.40	2.03	-0.54		
l15	0.08	0.17	0.13	-0.03	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.24	3.42	2.03	-0.54		
l20	0.10	0.22	0.16	-0.03	- -	- -
	(0.08)	(0.06)	(0.08)	(0.06)		
	1.24	3.50	2.05	-0.54		
recg1	0.12	0.15	0.16	-0.05	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.59	2.56	2.14	-0.85		
recg3	0.12	0.15	0.16	-0.05	- -	- -
	(0.07)	(0.06)	(0.07)	(0.06)		
	1.59	2.57	2.14	-0.85		
recg4	0.13	0.16	0.17	-0.05	- -	- -
	(0.08)	(0.06)	(0.08)	(0.06)		
	1.59	2.58	2.14	-0.85		
recg5	0.08	0.10	0.11	-0.03	- -	- -
	(0.05)	(0.04)	(0.05)	(0.04)		
	1.57	2.49	2.09	-0.84		
recg6	0.10	0.12	0.13	-0.04	- -	- -
	(0.06)	(0.05)	(0.06)	(0.05)		
	1.58	2.53	2.12	-0.84		
recg7	0.08	0.10	0.11	-0.03	- -	- -
	(0.05)	(0.04)	(0.05)	(0.04)		
	1.57	2.48	2.09	-0.84		
recg8	0.09	0.11	0.12	-0.04	- -	- -
	(0.05)	(0.04)	(0.06)	(0.04)		
	1.57	2.51	2.10	-0.84		

recg10	0.10	0.13	0.14	-0.04	- -	- -
	(0.06)	(0.05)	(0.07)	(0.05)		
	1.58	2.54	2.12	-0.84		
recg12	0.06	0.07	0.08	-0.02	- -	- -
	(0.04)	(0.03)	(0.04)	(0.03)		
	1.54	2.37	2.02	-0.84		
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.32
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	4.57	-1.63	6.16	0.39	0.05	2.27
vhlit	0.34	0.12	0.39	-0.05	-0.07	0.36
	(0.08)	(0.07)	(0.08)	(0.07)	(0.14)	(0.14)
	4.10	1.78	4.64	-0.70	-0.53	2.52
vhlpl	0.42	-0.02	0.69	0.07	-0.06	0.17
	(0.08)	(0.06)	(0.08)	(0.06)	(0.13)	(0.13)
	5.55	-0.39	9.19	1.16	-0.43	1.27
vhlct	0.51	0.25	0.65	0.00	-0.12	0.42
	(0.07)	(0.06)	(0.07)	(0.06)	(0.12)	(0.12)
	7.13	4.30	9.11	0.06	-1.01	3.40

Indirect Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
	--------	--------	--------	--------
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -

recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

!This is the 10-factor model

Standardized Total and Indirect Effects

Standardized Total Effects of ETA on ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	0.11	0.25	0.18	-0.04	- -	- -
Semantic	0.15	0.19	0.20	-0.06	- -	- -
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25
vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Standardized Total Effects of ETA on ETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Standardized Indirect Effects of ETA on ETA

	Age	Gender	Edu	lrcont	Likert	Semantic
Age	- -	- -	- -	- -	- -	- -
Gender	- -	- -	- -	- -	- -	- -
Edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
Likert	- -	- -	- -	- -	- -	- -
Semantic	- -	- -	- -	- -	- -	- -
vhlsq	0.04	0.05	0.05	-0.02	- -	- -
vhlit	0.04	0.04	0.05	-0.02	- -	- -
vhlpl	0.01	0.01	0.02	-0.01	- -	- -
vhlct	0.04	0.04	0.05	-0.02	- -	- -

Standardized Indirect Effects of ETA on ETA

	vhlsq	vhlit	vhlpl	vhlct
Age	- -	- -	- -	- -
Gender	- -	- -	- -	- -
Edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
Likert	- -	- -	- -	- -
Semantic	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Standardized Total Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	0.09	0.21	0.15	-0.03	0.82	- -
l3	0.08	0.18	0.13	-0.03	0.71	- -
l4	0.08	0.18	0.13	-0.03	0.71	- -
l6	0.07	0.16	0.11	-0.02	0.62	- -
l8	0.09	0.21	0.15	-0.03	0.83	- -
l10	0.07	0.16	0.12	-0.02	0.65	- -
l13	0.08	0.18	0.13	-0.03	0.71	- -
l14	0.07	0.17	0.12	-0.03	0.66	- -
l15	0.08	0.17	0.13	-0.03	0.68	- -
l20	0.10	0.22	0.16	-0.03	0.86	- -
recg1	0.12	0.15	0.16	-0.05	- -	0.80
recg3	0.12	0.15	0.16	-0.05	- -	0.81
recg4	0.13	0.16	0.17	-0.05	- -	0.88
recg5	0.08	0.10	0.11	-0.03	- -	0.55
recg6	0.10	0.12	0.13	-0.04	- -	0.66
recg7	0.08	0.10	0.11	-0.03	- -	0.54
recg8	0.09	0.11	0.12	-0.04	- -	0.59
recg10	0.10	0.13	0.14	-0.04	- -	0.70
recg12	0.06	0.07	0.08	-0.02	- -	0.39
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25

vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Standardized Total Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

Completely Standardized Total Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	1.00	- -	- -	- -	- -	- -
gender	- -	1.00	- -	- -	- -	- -
edu	- -	- -	1.00	- -	- -	- -
lrcont	- -	- -	- -	1.00	- -	- -
l1	0.09	0.21	0.15	-0.03	0.82	- -
l3	0.08	0.18	0.13	-0.03	0.71	- -
l4	0.08	0.18	0.13	-0.03	0.71	- -
l6	0.07	0.16	0.11	-0.02	0.62	- -
l8	0.09	0.21	0.15	-0.03	0.83	- -
l10	0.07	0.16	0.12	-0.02	0.65	- -
l13	0.08	0.18	0.13	-0.03	0.71	- -
l14	0.07	0.17	0.12	-0.03	0.66	- -
l15	0.08	0.17	0.13	-0.03	0.68	- -
l20	0.10	0.22	0.16	-0.03	0.86	- -
recg1	0.12	0.15	0.16	-0.05	- -	0.80
recg3	0.12	0.15	0.16	-0.05	- -	0.81
recg4	0.13	0.16	0.17	-0.05	- -	0.88
recg5	0.08	0.10	0.11	-0.03	- -	0.55
recg6	0.10	0.12	0.13	-0.04	- -	0.66

recg7	0.08	0.10	0.11	-0.03	- -	0.54
recg8	0.09	0.11	0.12	-0.04	- -	0.59
recg10	0.10	0.13	0.14	-0.04	- -	0.70
recg12	0.06	0.07	0.08	-0.02	- -	0.39
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25
vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Completely Standardized Total Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	1.00	- -	- -	- -
vhlit	- -	1.00	- -	- -
vhlpl	- -	- -	1.00	- -
vhlct	- -	- -	- -	1.00

Standardized Indirect Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	- -	- -	- -	- -	- -	- -
gender	- -	- -	- -	- -	- -	- -
edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
l1	0.09	0.21	0.15	-0.03	- -	- -
l3	0.08	0.18	0.13	-0.03	- -	- -
l4	0.08	0.18	0.13	-0.03	- -	- -
l6	0.07	0.16	0.11	-0.02	- -	- -
l8	0.09	0.21	0.15	-0.03	- -	- -
l10	0.07	0.16	0.12	-0.02	- -	- -
l13	0.08	0.18	0.13	-0.03	- -	- -
l14	0.07	0.17	0.12	-0.03	- -	- -
l15	0.08	0.17	0.13	-0.03	- -	- -
l20	0.10	0.22	0.16	-0.03	- -	- -

recg1	0.12	0.15	0.16	-0.05	- -	- -
recg3	0.12	0.15	0.16	-0.05	- -	- -
recg4	0.13	0.16	0.17	-0.05	- -	- -
recg5	0.08	0.10	0.11	-0.03	- -	- -
recg6	0.10	0.12	0.13	-0.04	- -	- -
recg7	0.08	0.10	0.11	-0.03	- -	- -
recg8	0.09	0.11	0.12	-0.04	- -	- -
recg10	0.10	0.13	0.14	-0.04	- -	- -
recg12	0.06	0.07	0.08	-0.02	- -	- -
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25
vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Standardized Indirect Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Completely Standardized Indirect Effects of ETA on Y

	Age	Gender	Edu	lrcont	Likert	Semantic
age	- -	- -	- -	- -	- -	- -
gender	- -	- -	- -	- -	- -	- -
edu	- -	- -	- -	- -	- -	- -
lrcont	- -	- -	- -	- -	- -	- -
l1	0.09	0.21	0.15	-0.03	- -	- -
l3	0.08	0.18	0.13	-0.03	- -	- -
l4	0.08	0.18	0.13	-0.03	- -	- -
l6	0.07	0.16	0.11	-0.02	- -	- -
l8	0.09	0.21	0.15	-0.03	- -	- -

l10	0.07	0.16	0.12	-0.02	- -	- -
l13	0.08	0.18	0.13	-0.03	- -	- -
l14	0.07	0.17	0.12	-0.03	- -	- -
l15	0.08	0.17	0.13	-0.03	- -	- -
l20	0.10	0.22	0.16	-0.03	- -	- -
recg1	0.12	0.15	0.16	-0.05	- -	- -
recg3	0.12	0.15	0.16	-0.05	- -	- -
recg4	0.13	0.16	0.17	-0.05	- -	- -
recg5	0.08	0.10	0.11	-0.03	- -	- -
recg6	0.10	0.12	0.13	-0.04	- -	- -
recg7	0.08	0.10	0.11	-0.03	- -	- -
recg8	0.09	0.11	0.12	-0.04	- -	- -
recg10	0.10	0.13	0.14	-0.04	- -	- -
recg12	0.06	0.07	0.08	-0.02	- -	- -
vhlsq	0.38	-0.11	0.51	0.03	0.01	0.25
vhlit	0.34	0.12	0.39	-0.05	-0.06	0.29
vhlpl	0.42	-0.02	0.69	0.07	-0.05	0.13
vhlct	0.51	0.25	0.65	0.00	-0.10	0.33

Completely Standardized Indirect Effects of ETA on Y

	vhlsq	vhlit	vhlpl	vhlct
age	- -	- -	- -	- -
gender	- -	- -	- -	- -
edu	- -	- -	- -	- -
lrcont	- -	- -	- -	- -
l1	- -	- -	- -	- -
l3	- -	- -	- -	- -
l4	- -	- -	- -	- -
l6	- -	- -	- -	- -
l8	- -	- -	- -	- -
l10	- -	- -	- -	- -
l13	- -	- -	- -	- -
l14	- -	- -	- -	- -
l15	- -	- -	- -	- -
l20	- -	- -	- -	- -
recg1	- -	- -	- -	- -
recg3	- -	- -	- -	- -
recg4	- -	- -	- -	- -
recg5	- -	- -	- -	- -
recg6	- -	- -	- -	- -
recg7	- -	- -	- -	- -
recg8	- -	- -	- -	- -
recg10	- -	- -	- -	- -
recg12	- -	- -	- -	- -
vhlsq	- -	- -	- -	- -
vhlit	- -	- -	- -	- -
vhlpl	- -	- -	- -	- -
vhlct	- -	- -	- -	- -

Time used: 1.031 Seconds

UNIVERSITY OF WESTERN SYDNEY

Nepean

HUMAN ETHICS REVIEW COMMITTEE

HERC PROTOCOL REPORT

ATTACHMENT 1

HERC PROTOCOL NO.

HE99/028

CHIEF INVESTIGATOR

Brodie, John H

PROJECT TITLE

The Relationship between Background Factors and Success in Geometry in Trainee Teachers

APPROVAL DATE

April 23 1999

EXPIRY DATE

October 30 2000

CONDITIONS OF APPROVAL (if applicable)

Please advise the Research Ethics Officer if your records differ from the above Protocol