UNIVERSITY OF SOUTHERN QUEENSLAND AUSTRALIA

MEASURING PREFERENCES FOR VISUAL-SPATIAL LEARNING

A thesis submitted by

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Abstract

This dissertation is a report on the validation of an instrument, Visual-Spatial Learning Questionnaire (VSLQ), developed to measure preferences for visual-spatial learning in secondary school students. A reliable and valid comprehensive instrument for measuring preferences for visual-spatial learning would allow secondary school teachers to effectively cater for the individual learning needs of students with a preference for this learning style. During Study 1 an Exploratory Factor Analysis (EFA) was conducted to remove redundant items and identify the factors underlying the 70-item instrument. The EFA was conducted on 2006 archival data collected using the VSLQ. As a result of the EFA, the instrument was reduced from 70 items to 15. Reducing the number of items removed extraneous underlying factors that did not measure preferences for visual-spatial learning and made the questionnaire more useful for classroom teachers. Completing 70 items is a significant time imposition for both students and teachers, and takes away a lot of time from a lesson. A smaller number of items will allow the classroom teacher to quickly identify a student's learning preference and use pedagogical strategies that have been shown to be successful with students who have a preference for visual-spatial learning. Four factors emerged in analysis, each with acceptable internal consistency: organisation (disorganisation), spatial awareness, object-visualisation, and spatial-visualisation. Six items loaded onto the factor of organisation (disorganisation), five onto spatial awareness, two onto object-visualisation, and two loaded onto spatial visualisation. The EFA also began the process of providing evidence that the VSLQ has internal reliability and construct validity (*KMO* = .60, BTS = .00).

During Study 2 a Confirmatory Factor Analysis (CFA) was conducted on the 15-item version of the VSLQ. A re-examination of the eigenvalues, Scree plot and total variance from Study 1 suggested that the 4 underlying factors should be merged to form 2 factors - organisation (disorganisation) and spatial awareness. Object-visualisation, spatial awareness, and spatial-visualisation have interrelated characteristics and were grouped together under the heading of spatial awareness. The CFA further reduced the instrument to 8-items and provided evidence of its internal consistency (NC = 2.64 [X^2 = 52.98/ df = 20], $p < .001$, $RMSEA$ = 0.05, CFI = .91, TLI = .84, NFI = .86, IFI = .91). During Study 3, the results of the revised 8-item version of the VSLQ were compared against the results of two other instruments designed to measure visual-spatial learning and visual-spatial ability – Silverman's (2000) Visual-Spatial Identifier (VSI), and Newton and Bristoll's (2009) Spatial Ability Test (SAT). To date, Silverman's (2000) VSI is the most widely used questionnaire to identify visual-spatial learners (VSL). Correlations between the underlying factors on the three instruments provided evidence of the convergent validity of the VSLQ.

The results of the three studies demonstrated that the revised 8-item version of the VSLQ has both reliability, in the form of internal consistency, and construct validity. The implications of a short and reliable instrument for measuring preferences for visual-spatial learning will also be discussed. Unlike Silverman's (2000) VSI, the revised 8-item version of the VSLQ has demonstrated reliability and validity. As such, classroom teachers in secondary schools who use the instrument can trust that a student identified as having a preference for visual-spatial learning will most likely achieve success if visual-spatial teaching methods are used within the classroom. The revised 8-item version of the VSLQ is half the length of Silverman's (2000) VSI. As such, it is quicker to use for classroom

teachers. Rather than spending significant periods of time having students complete the questionnaire and analysing the results, it allows classroom teachers to quickly identify the learning preferences of their students and cater for their individual learning needs. By identifying students' individual learning needs, teachers can use teaching strategies that will hopefully lead to educational success.

Keywords:

VSLQ, EFA, CFA, reliability, construct validity

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List of Abbreviations and Glossary of Terms

Abbreviation/Symbol	Definition
ASD	Autism Spectrum Disorder
ASL	Auditory-Sequential Learner
BTS	Bartlett’s Test of Sphericity
CFA	Confirmatory Factor Analysis
CFI	Comparative fit index
df	Degrees of Freedom
EFA	Exploratory Factor Analysis
ES	Effect Size
G&T	Gifted and Talented
IFI	Incremental fit index
KMO	Kaiser-Mayer-Olkin
n	Number of cases
NC	Normed chi square
NFI	Normed fit index
OSIVQ	Object-Spatial Imagery and Verbal Questionnaire
p	Probability
PCA	Principal Component Analysis
r	Estimate of the Pearson product-moment correlation coefficient
RMSEA	Root mean square error of approximation
SAT	Spatial Ability Test
TLI	Tucker Lewis index
VSI	Visual-Spatial Identifier
VSL	Visual-Spatial Identifier
VSLQ	Visual-Spatial Learning Questionnaire
VVQ	Visualizer-Verbalizer Questionnaire
X^2	The chi-square distribution

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Certification of Thesis

I certify that the ideas, results, analyses, and conclusions reported in this thesis are entirely my work, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

_____________________________ 08/03/2016

Matt Capp Date

Endorsement

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Signature of Supervisors Date

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Hopefully the psychometric instrument that I developed during this research project is useful for classroom teachers when working with students who have a preference for visual-spatial learning. Unfortunately the needs of many students with preferences for visual-spatial learning (e.g. students with autism spectrum disorder, and gifted and talented students) are not catered for within the classroom context. By identifying the individual learning needs of these students, teachers can use visual-spatial teaching and assessment strategies that research has shown to be effective with students who have a preference for visual-spatial learning.

Chapter 1: Introduction

> It is rather surprising that systematic studies of human abilities were not undertaken until the second half of the last century…An accurate method was available for measuring the circumference of the earth 2000 years before the first systematic measures of human ability were developed (Nunnally, 1967).

The current study is a quantitative study based on psychometric principles and specifically aims to validate a questionnaire developed to identify secondary school students with a preference for visual-spatial learning. The aim of the current research project is to develop a new psychometric instrument that measures preferences for visual-spatial learning, the VSLQ.

This research project builds on instruments for measuring visual-spatial ability. Yet, it diverges from them in terms of its practical purpose. Unlike current psychometric instruments developed to measure visual-spatial ability, the VSLQ was constructed to identify secondary school students who demonstrate a preference for learning through visual-spatial methods**.** Success in both primary and secondary school generally occurs when there is a correlation between the teaching strategies used by a classroom teacher and the learning preferences of a student (Hattie, 2008). The current research project aims to demonstrate the reliability and construct validity of the newly developed VSLQ. A pre-existing instrument that measures preferences for visual-spatial learning lacks both reliability and validity, and the current measure is intended to fill this gap in the literature.

Objective of Research Project

Whilst there are a number of reliable and valid instruments for measuring visual-spatial ability, a review of the literature has identified the lack of a psychometrically sound instrument for measuring preferences for visual-spatial learning. For example, Silverman's (2000) VSI has questionable internal consistency, no published data on construct validity, and a Likert scale that may bias the responses of participants. Although many psychometrically sound instruments for measuring visual-spatial ability exist, the underlying factors associated with visual-spatial learning are much broader than those associated with visual-spatial ability. Visual-spatial ability is the ability to mentally manipulate two-dimensional and three-dimensional figures (Weckbacher, 2007). It also involves "the ability to mentally rotate or fold objects in two or three dimensions and to imagine the changing configurations of objects that would result from such manipulations" (Mayer & Simms, 1994, p. 392). Visual-spatial learning, in contrast, is a preference for using images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005). As such, instruments for measuring visual-spatial ability are not reliable at identifying students who have a preference for visual-spatial learning. The development of an instrument for measuring preferences for visual-spatial learning in secondary school students will help teachers to identify students who display these preferences within their classroom. Those students who display visual-spatial preferences require individual teaching strategies to promote educational success. This is supported by the claims of a number of researchers (Griggs & Dunn, 1984; Smith & Renzulli, 1984; Charkins, O'Toole, & Wetzel, 1985) who argue that the narrower the gap between teaching style and learning style the greater the chance of achieving desired learning outcomes. By identifying students with a preference for visual-spatial learning within their classrooms, secondary school teachers will be able to use visual-spatial teaching strategies to ensure that they achieve educational success. This research project aims to:

1. Develop a reliable and valid instrument for measuring preferences for visual-spatial learning in secondary school students.
2. Compare the newly developed measure's potential against a pre-existing instrument and discuss the practical implications for the student learner.

Dissertation Outline

Chapter 2: Theoretical Frameworks for Measuring Preferences for Visual-Spatial Learning. The second chapter explores the literature on measuring visual-spatial ability and preferences for visual-spatial learning, and its application within the classroom context. It outlines how developments in the fields of science, psychology, and education have influenced the concept of the VSL. The differences between visual-spatial learning and other styles of learning are examined. The arguments for developing an instrument for measuring preferences for visual-spatial learning are proposed. Why an instrument needs to demonstrate the psychometric principles of reliability and validity will also be discussed. The limitations of the current psychometric instrument available for measuring preferences for visual-spatial learning – Silverman's (2000) VSI – will be examined.

Chapter 3: Study 1. The third chapter discusses the methodology and results of the EFA on 125 completed VSLQs. During this study, archival data collected in 2006 was re-examined.

Chapter 4: Study 2. The fourth chapter examines the methodology and results of the CFA on 227 completed VSLQs (15-item version).

Chapter 5: Study 3. The fifth chapter outlines the methodology and results when the VSLQ (8-item version) was compared with Silverman's (2000) VSI and Newton and Bristoll's (2009) SAT. A correlational analysis was conducted on the results of 300 completed VSLQs, VSIs, and SATs.

Chapter 6: General Discussion. The final chapter of the dissertation presents a general discussion of the key findings in relation to the reliability and construct validity of the revised 8-item version of the VSLQ. The practical and theoretical implications of this instrument for measuring preferences for visual-spatial learning will also be discussed.

Chapter 2:

Theoretical Frameworks for Measuring Preferences for Visual-Spatial Learning

> I think in pictures. Words are like a second language to me. I translate both spoken and written words into full-colour movies, complete with sound, which run like a DVD in my head. When somebody speaks to me, the words are instantly translated into pictures (Grandin, 2006).

A review of the literature has identified the lack of a reliable and valid instrument for measuring preferences for visual-spatial learning in secondary school students. Currently there is only one instrument available – Silverman's (2000) VSI – to measure visual-spatial learning in the primary school student community. However, the reliability and validity of this instrument is questionable. Silverman (2000) stated that α = .71, a measure of the internal reliability of a psychometric instrument, was acceptable. However, this was achieved by commingling data from parent, teacher, and student reports and no reliability data for students alone was reported (Mann, 2005). Through a follow up study Mann (2005) obtained α = .46, which indicates an unacceptable level of internal consistency. Silverman (2000) also does not provide any evidence of the construct validity of this instrument. In terms of a psychometric instrument, validity is more important than internal consistency. If Silverman (2000) had provided evidence of the construct validity of the VSI, α = .46 may have been considered acceptable, and undermined its validity coefficients. Despite the unacceptable level of internal consistency and lack of evidence of construct validity, this widely used psychometric instrument provided a foundation for the development of the 70-item version of the VSLQ. Many classroom teachers use questionnaires that have no evidence of meeting criteria for reliability and validity. Silverman's (2000) VSI is a commonly used instrument for identifying VSL in the primary school years. Silverman (2000) has also provided some evidence to support the claim that the questionnaire has construct validity. As such, it is a more useful instrument to underpin the development of the VSLQ than other instruments that have not be subjected to any form of psychometric analysis or are not commonly used by teaching professionals.

Preferences for Visual-Spatial Learning in the Educational Context

Students who display preferences for visual-spatial learning require appropriate teaching strategies (Gilakjani, 2012; Hattie, 2008; Silverman, 2005, 2013). Mann (2006) asserts that students who have spatial strengths and weak verbal skills often struggle in the traditional classroom. This is because the traditional educational system focuses primarily on using verbal and writing based teaching strategies rather than teaching strategies using images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005). A preference for visual-spatial learning is not the same as visual-spatial ability. Visual-spatial ability is the ability to mentally manipulate two-dimensional and three-dimensional figures (Weckbacher, 2007). Visual-spatial learning is a preference for the way an individual learns to organise and communicate ideas and concepts (Silverman, 2005). A preference for visual-spatial learning is identified through instruments that measure typical performance, whereas visual-spatial ability is generally identified through measures of maximal performance (Cronbach, 1960; Klehe & Latham, 2008). Typical performance instruments measure a respondent’s motivation rather than his/her ability. Klehe and Latham (2008) claim that measures of typical performance are associated with prediction of motivation rather than ability. In contrast, maximal performance tests measure how well people can perform at their best (Klehe & Latham, 2008).

Those students who demonstrate a preference for visual-spatial learning struggle within the classroom and are expected to learn despite their teachers using strategies and activities that often make learning difficult, if not impossible. This is exemplified by Dunn, Griggs, Olson, Gorman, and Beasley's (1995) claim that the closer the match between students' learning styles and their teachers' teaching styles, the higher the academic result. This is supported by Pask (1988) who found that a mismatch between learning and teaching strategies leads to no relevant learning and poor task scores in vocational education and training courses.

Matching learning and teaching strategies leads to high quality learning and high task scores (Dunn & Dunn, 1993; Pask, 1988). Hattie's (2008) research has shown that matching style of learning and teaching methods has an *ES* = .41. This suggests that there is a statistically significant relationship between student achievement and the use of teaching strategies that match the learning style of students. Brown (2003) argues that when secondary school students' learning preferences match their instructor's teaching style, student motivation, and achievement usually improves. Ford and Chen (2001) also found that the relationship between learning styles and pedagogical practices could have a significant influence on learning outcomes. Many gifted and talented (G&T) students as well as students with autism spectrum disorder (ASD) demonstrate a preference for visual-spatial learning. In other words, these groups of students have a preference for using images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005). As such, they find it difficult to engage in classrooms where teachers use teaching strategies that rely heavily on auditory and word-based methods as a means of disseminating information (Sword, 2000).

Those students who display visual-spatial preferences require individual teaching strategies to promote educational success (Anderson, 2014; Burgoyne, 2010; Hattie, 2008; Mann, 2006). By identifying secondary school students with ASD who have a preference for visual-spatial learning, teachers will be able to successfully cater for their individual educational needs. Failure to identify and cater for the needs of individuals can have negative consequences for the individual, teacher, school, and community in general (Mann, 2005).

Students who have their individual educational needs catered for often experience academic, social, and personal success (Collinson, 2000). This is supported by the work of Hattie (2008) who conducted a meta-synthesis of 800 meta-analyses examining influences on student achievement. He identified teaching strategies (*ES* = 0.62), individualised instruction (*ES* = 0.22), and matching learning styles (*ES* = 0.17) as three factors that influence student achievement within the classroom context. In contrast, when the individual needs of students are not catered for there is a high probability that the student might become disengaged. Cancelli, Harris, Friedman, and Yoshida (1993) found that types of instruction (teacher-directed learning, chalk and talk) are related to disengagement behaviour that negatively impacts on academic achievement. This is supported by Kong, Wong, and Lam (2003) who assert that the methods used to cultivate learning in the classroom are far more important than the curriculum being studied.

Those students with high-level visual-spatial abilities are more likely to choose careers in fields related to mathematics, such as engineering and computer science, whilst those with auditory-sequential preferences generally pursue careers in the humanities and social sciences (Humphreys, Lubinski, & Yao, 1993; Shea, Lubinski, & Benbow, 2001).

This is exemplified by Baron-Cohen, Wheelwright, Stott, Bolton, and Goodyer's (1997) claim that individuals with high-level visual-spatial ability or a preference for visual-spatial learning are twice as likely to be employed in the field of engineering, than those without these skills or learning preference. According to Gohm, Humphreys, and Yao (1998) people identified as having high-level visual-spatial abilities are underrepresented in universities and the workplace relative to their ability level when compared with individuals with auditory-sequential strengths. Identifying individuals with a preference for visual-spatial learning can help them to develop their talents and use these talents to their fullest potential. The development of a self-administered, reliable, and valid psychometric instrument for measuring preferences for visual-spatial learning in secondary school aged children would facilitate this process.

Characteristics of VSL

Within the classroom VSL display characteristics, which differentiate them from other styles of learning. VSL are often placed in binary opposition to auditory-sequential learners (ASL). However, psychological research has shown that these two abilities are located on opposite ends of a common spectrum (Mann, 2006; Silverman, 2000). As such, a psychometric instrument developed to measure preferences for visual-spatial learning in secondary school students should also include items that measure preferences for auditory-sequential learning. By having items that contradict the literature (Mann, 2005; Silverman, 2005, 2013) on visual-spatial learning these items can be used to identify where a student falls on the spectrum between visual-spatial learning and auditory-sequential learning. The concepts of the VSL and the ASL were developed by Silverman (2000).

Whilst an ASL has auditory preferences and strengths, a VSL has visual preferences and strengths. VSL relate well to space, whereas ASL relate well to time. ASL are step-by-step learners (Silverman, 2013). In other words, they work sequentially through ideas during the learning process. VSL, in contrast, are whole-part learners (Silverman, 2005). They learn best by first seeing a broad overview of the entire content to be learnt then breaking it down into its constituent parts. For this reason, they learn concepts all at once and grasp complex concepts easily (Silverman, 1989a, 1989b). Alternatively, an ASL has to progress sequentially from easy to more difficult material. For this reason, they learn best through rote memorization. As such, they may need some repetition to reinforce learning (Silverman, 2005).

Conversely, VSL learn best by seeing the relationships between concepts (Silverman, 2005). They are turned off by repetition because they learn concepts permanently. ASL and VSL differ in terms of their critical thinking ability. ASL are analytical thinkers, breaking down ideas into single and manageable components, whilst VSL are good at combining parts of a whole in new and different ways (Sword, 2000). Because of this, VSL often see the big picture but may miss details. Students who display auditory-sequential preferences attend well to details (Silverman & Freed, 1991).

Learning styles. Within the classroom, ASL and VSL have distinct learning styles. In terms of educational instruction, ASL follow oral directions well but have a short-term auditory memory. VSL need visual methods of instruction and have a good long-term visual memory (Silverman, 2005). ASL can write quickly and neatly in their exercise books. VSL prefer keyboarding to writing. ASL are well organised, whilst VSL create unique methods of organisation (Mann, 2005; Silverman, 1999; Silverman & Freed, 1991). In the classroom both ASL and VSL have different interactions with their teachers. VSL are very sensitive to their teacher's reactions. ASL, on the other hand, learn in spite of emotional reactions (Silverman, 2005). Because these two types of students learn in different ways classroom teachers need a reliable and valid instrument for measuring preferences for visual-spatial learning.

Organisational ability. Whilst there are many characteristics of students with preferences for visual-spatial learning there are two main factors, organisation and spatial awareness, that underlie this learning style. Organisation for students with a preference for visual-spatial learning is often a stumbling block (Mann, 2005). VSL are usually disorganised and may miss details. These students are highly aware of space but pay little attention to time (Silverman & Freed, 1991). The limited organisational ability of VSL is well documented in the literature. Silverman (2000) believes that VSL create unique methods of organisation. This is exemplified by Silverman and Freed's (1991) claim that "a visual-spatial child's organisational strategies often appear non-existent" (p. 1). Organisation for many of these individuals is a stumbling block. For students with auditory-sequential strengths and a preference for auditory-sequential learning, organisation is a strength (Silverman, 2005). As such, organisation (disorganisation) should be an underlying factor on any reliable and valid psychometric instrument designed to measure preferences for visual-spatial learning in secondary school students. Any instrument subjected to a factor analysis to determine internal consistency should contain the construct of organisation (disorganisation) in addition to visualisation and spatial ability as underlying factors.

Academic curriculum. In terms of curriculum areas, VSL and ASL display distinct preferences. Whilst ASL prefer arithmetic and computation in mathematics, VSL are better at mathematical reasoning (Mann, 2005; Van Garderen & Montague, 2003). Students who display a preference for ASL in general prefer algebra whilst VSL display a preference towards geometry (Campbell, 1993; Clements, 1998; Clements & Battista, 1992). ASL can show their steps in calculations easily. VSL generally come up with answers intuitively (Silverman, 2005). This is supported by Hegarty and Kozhevnikov's (1999) assertion that spatial ability is highly correlated with success in mathematics education. Sherman (1979) supports this assertion by claiming that spatial ability is one of the main factors significantly affecting mathematical performance. Kaufman (1990) furthers this argument by stating that this correlation increases with the complexity of the mathematical tasks.

In terms of science, ASL prefer chemistry whilst VSL have a tendency towards physics (Cummings, Marx, Thornton, & Kuhl, 1999; Kozhevnikov, Motes, & Hegarty, 2007; Thornton, 1999a, 1999b). This is exemplified by Kozhevnikov et al.'s (2007) claim that "visualisation plays a central role in conceptualisation processes of physics" (p. 549). The assertion that VSL have a preference towards physics is supported by numerous studies in physics education (Champagne, Klopfer, & Anderson, 1980; Cummings et al., 1999; Sokoloff & Thornton, 1997; Thornton, 1999a, 1999b; Thornton & Sokoloff, 1990) that demonstrated students have a poor understanding of the curriculum area after traditional lecture based instruction.

When learning second languages ASL prefer to be taught through formal instruction. VSL, on the other hand, master second languages through immersion in real-life contexts (Silverman, 2000). In early schooling ASL learn words phonetically, whilst VSL learn whole words easily (Browder & Xin, 1998). This means that students who display a preference for visual-spatial ability need to visualise a word to spell it rather than being able to sound it out

(Marcell & Armstrong, 1982; Silverman, 2005; Wheldall, Beaman, & Madelaine, 2009). Because of the characteristics of ASL these students are often seen to be academically talented maintaining high grades for all curriculum areas and are early bloomers. In contrast, VSL may have uneven grades and develop academically at a later age. They often appear creatively, technologically, emotionally, or mechanically gifted (Silverman, 2005).

Groups with Visual-Spatial Preferences

Many groups of students within the classroom demonstrate significant visual-spatial ability (Anderson, Colombo, & Shaddy, 2007; Ashwin, Ricciardelli, & Baron-Cohen, 2009; Koh, Milne, & Dobkins, 2010; Deruelle, Rondan, Gepner, & Tardiff, 2008; Haist, Adamo, Westerfield, Courchesne, & Townsend, 2005; Reis & McCoach, 2010). The high-level spatial ability of students with ASD and G&T students has been referred to extensively in the research literature.

ASD. ASD is an umbrella term for individuals who display problems and difficulties with social interaction, impaired language and communication skills, and unusual patterns of thought and physical behaviour (Haq & Le Couteur, 2004; Jordan, 2005; Wing, 1996). Research has shown that many individuals with ASD have exceptional spatial ability (Anderson et al., 2007; Ashwin et al., 2009; Koh et al., 2010; Deruelle et al., 2008; Haist et al., 2005).

Some commentators (Ashwin, Ashwin, Rhydderch, Howells, & Baron-Cohen, 2009; Behrmann, Thomas, & Humphreys, 2006; Happy & Frith, 2006; Perreault, Gurnesey Dawson, Mottron, & Bertone, 2011; Samson, Mottron, Soulieres, & Zeffiro, 2012) have shown that people with ASD perform better than control groups on tasks involving characteristics such as visual acuity or clearness of vision. Caron, Mottron, Rainville, and

Chouinard (2004) demonstrated through a study involving navigating a human-size labyrinth, that individuals with ASD have advanced discrimination, detection, and memory for visual patterns. They are also able to link images on maps with those in the real world. O'Riordan, Plaisted, Baron-Cohen, and Driver (2001) found during a study of children with ASD that they performed better than typically developing children on difficult visual-search tasks. Similarly, Edgin and Pennington (2005) found that students with ASD had faster reaction times on the embedded figures task, which involves locating shapes within a complex drawing.

Studies have shown that people with ASD are particularly good at perceiving individual details, but new findings (Bertone, Mottron, Jelenic, & Faubert, 2005) suggest that they can also detect large-scale patterns effectively. The results of these studies are supported by Grandin's (2006) claim that "one of the most profound mysteries of autism has been the remarkable ability of most autistic people to excel at visual-spatial skills while performing so poorly at verbal skills" (p. 1). Weiss (1989) and Huttenlocher (1984) believe that the visual systems in individuals with ASD are expanded to compensate for their deficits in language. A functional MRI study by Ring et al. (1999) indicates that people with this condition depend more on the visual parts of the brain on the embedded figures task. These research findings are supported by Baron-Cohen and Hammer's (1997) theory that individuals with ASD have an extreme form of male brain. They begin their argument by claiming that men, in general have superior spatial ability and reduced social skills, compared with women. They expand on this argument by claiming than individuals with ASD have an extreme form of the male brain type, high-level spatial skills, and social skills deficits

(Baron-Cohen & Hammer, 1997). This is further supported by Frith's (1989) claim that individuals with the condition are especially gifted at spatial analysis.

Students with ASD have problems learning things that cannot be thought about in pictures (Grandin, 2006). Numerous studies (Caron et al., 2004; Edgin & Pennington, 2005; Grandin, 2006; O'Riordan et al., 2001) have shown that people with ASD process visual information differently from others. The idea that high-level visual-spatial ability is a characteristic of individuals with ASD has been extended to the classroom context and learning styles (Evers, Noens, Steyaert, & Wagemans, 2011; Landry, Mitchell, & Burack, 2009; Richmond, Thorpe, Berryhill, Klugman, & Olsson, 2013; Van Eylen, De Graef, Steyaert, Wagemans, & Noens, 2013; White & Saldana, 2011). By using visual-spatial teaching styles these students may experience success within the classroom context. This is supported by Hodgdon's (1999) claim that these students do not understand their world very well; "they tend to be visual learners in a very auditory world" (p. 65).

Most traditional teaching methods used in working with students with ASD rely heavily on auditory instruction. The condition encompasses a wide variety of needs and abilities within the range of children with this disability, and not all children within this grouping benefit from copious oral based instruction (Tissot & Evans, 2003). Neuropsychological studies of individuals with ASD (Minshew, Goldstein, Muenz, & Payton, 1992; Quill, 1997) have shown better abilities in visual-spatial organization compared with typically developing individuals. All children can benefit from teachers using visual pedagogical strategies but this is especially true for children with ASD. Plaisted, O'Riordan, and Cohen (1998) claim that children with this pervasive developmental disorder are VSL rather than ASL and prefer alternative modes of communication, such as pictures rather than written words. Tissot and Evans (2003) claim that these students would benefit from pedagogical strategies emphasizing a visual approach. Teachers can help children with ASD function more independently by structuring the environment with visuals (Meadan, Ostrosky, Triplett, Michna, & Fettig, 2011). Having the condition does not mean being unable to learn but it does mean that there are differences in how learning happens (Larkey, 2006).

The most strongly recommended approach for teaching students with ASD is visual aids (Chausse, Tadey, Stehr, Phaneuf, & Newton, 2015). Pictographic clues often help a student with ASD learn (Quill, 1997). Using visual supports enables them to focus on the message (Quill, 1995). According to Hodgdon (2000) visual supports, when implemented correctly, allow students with ASD the freedom to engage in life, regardless of impairment.

Visual supports have been successfully used to teach these children a variety of skills including literacy skills, cooking, encouraging positive behaviour, and providing schedules. Roa and Gagie (2006) claim that “visual supports help bring structure, routine, and sequence that many children with ASD require in order to carry on their daily activities” (p. 27). This is further supported by Dalryaple’s (1989) assertion that “as a rule of thumb, the more people with ASD can be provided with visual cues, the better they will understand what they are supposed to do” (p. 5). By identifying students with a preference for visual-spatial learning, classroom teachers will be able to use visual teaching methods that research (Dettmer, Simpson, Smith-Myles, & Ganz, 2000; Johnson, Nelson, Evans, & Palazolo, 2003; Lovannone, Dunlap, Huber, & Kincaid, 2003; Tissot & Evans, 2003) has shown to be effective. Kluth and Darmody-Latham (2003) have suggested using visuals such as graphic organisers, flow charts, and Venn diagrams in addition to verbal instruction for students with

ASD. Rao and Gagie (2006) emphasise the importance of providing visual supports so that students with ASD can process verbal communication. Dettmer et al. (2000) found that the use of visual supports significantly reduced task confusion. This is supported by Grandin's (1995) statement that "spatial words such as over and under had no meaning to me until I had a visual image to fix them in my memory" (p. 30).

G&T students. Acute visual skills are also found in students identified as G&T (Reis & McCoach, 2010). This is because visual thinking is associated with being intellectually gifted (Grandin, 2006). Holton (1971) uses Albert Einstein as an example of a gifted visual thinker. He failed his high school language requirement and relied on visual methods to study. Einstein's theory of relativity was based on visual imagery of moving boxcars and riding on light beams. West (1997) provides other examples of gifted scientists - Leonardo de Vinci, Faraday and Maxwell - who were visual thinkers. Silverman (2005) claims that 33% of the gifted population within a school are strongly visual-spatial. An additional 30% show a slight preference towards the visual-spatial style. This suggests that the majority of the gifted student population could potentially benefit from matching visual-spatial teaching methods with their learning preference.

Scientific Developments Associated with Visual-Spatial Ability

Historical developments in the field of science have contributed to the development of the concept of the VSL. Spatial intelligence has both evolutionary and adaptive importance. Newcombe and Frick (2010) argue that individuals must be able to navigate in the world to survive. Scientific research using both animals and humans (Gazzaniga, 1973; Kimura, 1992; Robinson & Coyle, 1980; Rogers, 2000; Sherman, Garbanati, Rosen, Yutzey, &

Denenberg, 1980; Vallortigara, 2000) has demonstrated that the right hemisphere of the brain is responsible for spatial ability and spatial functioning.

Neurological studies showing variations in the organization of the human brain provide experimental evidence for a structural source of the variation in spatial abilities (McGee, 1979). Visual-spatial processing and mental manipulation of shapes and images is an essential brain function (Heinze et al., 1994; MacNeilage, Rogers, & Vallortigara, 2009) that enables individuals to select and process high priority information in the visual fields. MacNeilage et al. (2009) claim that every individual has a special evolutionary status. Those with right hemisphere dominance have a greater sense of how objects interrelate in space. This suggests that some individuals have greater spatial abilities than others. As such, individuals can be identified based on their spatial abilities. Spatial ability is also influenced by the level of conflict between the left and right hemispheres (Joseph, 1988).

Research has demonstrated that there is a relationship between spatial tasks and the right hemisphere of the brain. Gazzaniga, Bogen, and Sperry (1965), and Gibbs, Appleton, Gazzaniga, Bogen, and Sperry (1965) demonstrated that there was a disturbance in the ability to mentally manipulate two-dimensional and three-dimensional figures when the cerebral hemispheres in a man were disconnected and the left hemisphere was stimulated. Studies of brain damaged patients' show that injury to the right hemisphere can stop the generation of visual images from stored long-term memories, whilst at the same time not affecting language and verbal memory (Grandin, 2006). Another theory running strongly through the literature (Corbetta & Shulman, 2002; Dittuno & Mann, 1990; Levy, Hasson, Avidan, Hendler, & Malach, 2001; Shulman et al., 2010; Von Karolyi, Winner, Gray, & Sherman,

2003) is that individuals with left hemisphere brain deficits develop right-hemisphere strengths to overcome the deficit.

Von Karolyi et al. (2003) report that studies have shown superior levels of visual-spatial abilities in students with dyslexia caused by left hemisphere deficits. Levy et al. (2001) claim that there is a link between educational achievement and stimulation of the spatial elements of the right hemisphere. This is supported by their claim "unless the right hemisphere is activated and engaged, attention is low and learning is poor" (p. 1). Research (Brown & Campione, 1972; Bruck, Cavanagh, & Ceci, 1991; Levin & Mayer, 1993; Mandler & Ritchey, 1977; Shepard, 1967; Standing, 1973) consistently indicates that forming visual images can be a powerful means of storing information in long-term memory. People of all ages have a remarkably accurate memory for visual information. People's memory for visual material is often better than it is for strictly verbal material (Shepard, 1967).

Individuals who use images, pictures, colours, and maps to organise and communicate ideas are referred to as VSL and have a preference for visual-spatial learning (Silverman, 2005). Scientific research (Galea, Kavaliers, Ossenkopp, Innes, & Hargreaves, 1994; Kimura, 1992; Van Garderen, 2006) into the brain has shown that individuals can have varying levels of ability in using images, objects, and symbols to organise and communicate ideas. A theme running strongly through the academic literature (Caron et al., 2004; Lord, Schopler, & Revicki, 1982; Plaisted et al., 1998) is the preference for visual-spatial learning of students with ASD, and those who are G&T. This means that classroom teachers need to use visual-spatial teaching strategies to allow these students to organise information and communicate their ideas so that they can achieve educational success (Gamoran, 1989; Hallinan & Kubitschek, 1999; Terwel, 2005). To cater for these students, they first need to be identified within the classroom context. The development and validation of a new measure of visual-spatial learning will assist secondary school teachers to identify and support this type of learner.

Psychological Developments Associated with Visual-spatial Ability

Developments in the field of psychology have contributed to the evolution of the concept of the VSL. Research into the psychology of intelligence and cognitive processes has established that spatial thinking is the principle complement to verbal thinking (Newcombe & Frick, 2010; Ramadas, 2009). Spatial ability is the capacity to understand, remember, and visualise the spatial relations amongst objects (Shea et al., 2001). Factor analytic research has shown that visualisation is a well-defined underlying skill within general intelligence in adults (Bornstein, 2009; Carroll, 1993; Herrmann, Hern´andez-Lloreda, Call, Hare, & Tomasello, 2010).

Historical background. Research on cognitive styles began in the late 1940s and early 1950s when researchers (Hanfmann, 1941; Klein, 1951; Witkin, 1950; Witkin & Ash, 1948) attempted to identify the way people perceive, think, solve problems, learn, and relate to others. A number of articles were published in the literature (Humphrey, 1976; Witkin et al., 1954) with a primary focus on personalities and social relationships. A study conducted in 1941 by Hanfmann showed that individuals used either a perceptual or conceptual approach when they grouped blocks. This was supported by Witkin and Ash (1948) who achieved similar results on the rod-and-frame test.

The test involved a participant sitting in a darkened room with a researcher. The participant was given a glowing rod and a glowing frame. The researcher manipulated the angle of the rod, frame, and the participant’s chair. The participant was then instructed to manipulate the rod so that it is perfectly upright. If the participant adjusted the rod so that it was leaning in the direction of the frame they were categorised as field dependent because of his/her reliance on visual clues. Individuals who disregarded the visual clues when completing the task were categorised as field independent (Lester, 1968; Nyborg, 1974; Sigmand, Goodenough, & Flannagan, 1979).

In the late 1950s the idea that there was a binary opposition between cognitive styles became popular. There were no attempts to integrate them. Experiments during this period of time involved giving participants a task and two or more possible ways of solving it. When the participant chose a solution this was believed to be evidence of the individual's cognitive style (Kozhevnikov, 2007). Interest in cognitive styles lost momentum in the 1970s. Despite the loss of interest in this field, the categories of Visualizers and Verbalizers were developed by Paivio (1971), and Richardson (1977). Further research into these categories has been conducted by many other commentators (Cassidy, 2004; Chinea & Chen, 2008; Cox, 1999; Riding & Cheema, 1991). These categories constituted the foundations of Silverman's (2000) concepts of the VSL and ASL. Research into the field of cognitive styles was resurrected in the 1980s when psychological researchers (Sternberg & Zhang, 2001) in the field of education argued that cognitive styles have predictive power for academic achievement.

Theoretical underpinnings. Spatial intelligence was one of the types of intelligence proposed in Gardner's (1983, 1993) multiple intelligences theory and has contributed to the development of the concept of the VSL (Mann, 2005, 2006; Silverman, 2000, 2005, 2013). Piaget's (1976) theory of sensorimotor experience lays the foundation of visual intelligence. The sensorimotor stage is the first of Piaget's four stages of development during which infants coordinate visual experiences with physical movement (Berk, 2008; Brown & Desforges, 1979; Inhelder, Chipman, Zwingmann, & Piaget, 1976). This theory suggests that categories can be developed based on visual-spatial ability.

Following Piaget's line of thought, Wachs' (1980) claims that the determining factor for visual intelligence is not what passes through the eye but rather what a person can understand from a particular visual experience. Bruner's (1966) iconic representation and symbolic representation address this issue. Bruner (1964) argues that perception is an active practice. Iconic representation is the idea that information is stored visually in the form of images. These images are then formed into a symbolic code (symbolic representation).

Spatial ability is closely related to visual thinking. However, it is believed by a number of commentators (Dixon, 1983; Olson, 1984) that there is not one specific pattern of characteristics that manifest in individuals with high-level spatial abilities. Combinations of the traits described vary widely from individual to individual, yet there are some common behaviours that will be seen in these individuals who process information visually (Mann, 2006). These common characteristics provide the basis of instruments designed to measure visual-spatial ability and preferences for visual-spatial learning.

The claim by a number of researchers (Conrad, 1964; Holding, 1992; Matthews, Hunt, & MacLeod, 1980) that individuals can transfer information from visual to verbal form and back again supports Silverman's (2005) claim that visual-spatial ability and auditory-sequential ability fall on a spectrum. According to her, 33% of students have a strong preference for using images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005). An additional 30% show a slight preference for the visual-spatial learning style. 23% use verbal language, written word, and analytical thinking to organise and communicate ideas (Silverman, 2005).

Debate exists in the literature about the application of multiple intelligences theory in the classroom. Weber (1992) and Durie (1997) believe that multiple intelligences theory should only underpin pedagogical strategies within the classroom, whilst Chapman and King (2001) believe that it should solely inform assessment strategies. Ribot (2004) argues that the theory of multiple intelligences should be applied to all elements of classroom teaching. This is supported by Gardner and Walters (1993), Hearne and Stone (1995), and Hoerr (1994) who suggest that educators should assess their students' preferred learning style then provide teaching and learning opportunities that correspond with this learning style to ensure quality learning takes place. The preferred learning style of students is identified through measures of typical performance, rather than measures of maximal performance (Cronbach, 1960; Klehe & Latham, 2008). By identifying secondary school students with a preference for visual-spatial learning, teachers will be able to use appropriate pedagogical and assessment strategies to cater for their individual educational needs. The concept of the VSL, developed by Silverman (2005), is based on the research conducted by Gardner (1983) and others (Freed, 1996; Masson 1996; Silverman, 1998). VSL are individuals who think primarily in pictures and have visual strengths. They have a strong preference for using images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005). ASL, on the other hand, are individuals who think primarily in words and have auditory strengths. They use verbal language, written word, and analytical thinking to organise and communicate ideas (Silverman, 2005).

Cognitive profiles. Although much work has been done on multiple intelligences and spatial ability, very little research (Mann, 2005; Silverman, 2000; Van Nijnatten, 2013) exists on identifying students who demonstrate a preference for visual-spatial learning. The majority of the research has been conducted by Silverman (1989a, 1989b, 1997, 1999, 2000, 2005, 2013). Individuals differ in terms of the specific profile of intelligence they display. Researchers discuss two methods of representing knowledge, the verbal code and the imagistic code (Gardner, 1993). The assertion that there are differences between the visual-spatial learning style and auditory-sequential learning style is supported by the work of Bartlett (1932), Paivio (1971), and Richardson (1977) who claim that individuals can be classified as either Visualizers or Verbalizers. Visualizers rely primarily on imagery when attempting to perform cognitive tasks. Verbalizers, in contrast, rely primarily on verbal-analytical skills. The concepts of the Visualizer and Verbalizer correspond with Silverman's (2000) concepts of the VSL and ASL. Presson and Hazelrigg (1984) argue that learning through visual experience is more flexible. It allows for deeper understanding of content, whilst increasing motivation to learn. This is exemplified by the adage "a picture is worth a thousand words."

Kozhevnikov, Hegarty, and Mayer (2002a) state that there are two groups of Visualizers, those with high spatial ability and those with low spatial ability. Visualizers with low spatial ability are good at identifying the form, colour, brightness, and other aspects of an object's appearance (Kozhevnikov et al., 2002a). These people are good at pictorial imagery and excel at constructing detailed and vivid mental images. High spatial Visualizers are good at identifying the spatial relationships between parts of an object and how those objects move or are represented in space. They can easily perform mental rotations on complex three-dimensional images (Kozhevnikov et al., 2002a). This is supported by Burton and Fogarty's (2003) assertion that high spatial Visualizers are better identified by instruments that use a combination of geometrical shapes and self-report items, or items on self-report instruments that reflect "objective" spatial ability tests.

This argument is also supported by Baron-Cohen and Hammer's (1997) theory that individuals with ASD have an extreme form of male brain. They begin their argument by claiming that men, in general have superior spatial ability and reduced social skills, compared with women. Not every male will have a spatial advantage but the likelihood of having a spatial advantage is raised if one is male. Baron-Cohen and Hammer (1997) extend on this argument by claiming than individuals with ASD have an extreme form of the male brain type, high-level spatial ability and social skills deficits. They provide evidence for this claim by referring to the research of Shah and Frith (1983) who found that children with this pervasive developmental disorder performed better than typically developing peers on the embedded figures test and block design subtest of the Weschler IQ tests. Frith (1989) claims that individuals with ASD are especially gifted at spatial analysis.

Mathematical ability. Students with a preference for visual-spatial learning demonstrate a preference for mathematical reasoning and problem solving (Hegarty & Kozhevnikov, 1999). The new instrument, VSLQ, for measuring preferences for visual-spatial learning builds on Silverman's (2000) VSI by including items relating to mathematical ability. Although mathematical reasoning and problem solving have been identified by Silveman (2000) as characteristics of students who have a preference for visual-spatial learning, no items relating to this were included in the VSI. Eight items relating to mathematical thinking have been included in the VSLQ (see Table 2.1). The VSLQ was developed as an instrument for measuring preferences for visual-spatial learning in secondary school students. As such, the terminology used in the Australian Curriculum for Mathematics influenced the development of the items. The terms ‘Algebra’ and ‘Geometry’ are used within the items because these are explicitly stated in the Achievements Standards for Mathematics from Year Eight to Year Ten (Australian Curriculum, Assessment, and Reporting Authority, 2016). Hattie (2008) argues that effective teachers make learning visible for students and have a common language for learning. As such, secondary school students within Australia are aware of the terminology used in the items within the VSLQ.

Table 2.1

Items on VSLQ Related to Mathematical Thinking

Item	Content
10	I find problem solving questions in mathematics more interesting than regular equations
13	When I am doing Mathematics the answers to the questions tend to just come to me
20	I hate studying algebra in mathematics
32	I love doing times tables
53	I am good at mathematics questions that I have been shown how to do; however, I find problem solving questions difficult
57	I always show my working when completing problems in mathematics
61	I enjoy studying algebra in mathematics
62	I hate studying geometry (shapes and angles) in mathematics

Presentation of visual-spatial ability. Research suggests that there are differing levels of ability within the group of students who display high-level visual-spatial ability and a preference for visual-spatial learning (Blazhenkova, & Kozhevnikov, 2009, 2010; Kozhevnikov, Kosslyn, & Shephard, 2005; Silverman, 2005). Johnson-Laird (1985) analysed scores on intelligence tests and identified two factors, verbal ability and spatial ability. Carroll (1993) defines spatial ability as the capacity to understand and remember the spatial relations among objects. It involves many sub skills, such as the visual manipulation of objects (Gardner, 1993; Olson, 1984; West, 1997), the ability to comprehend the relationships between fluid, changing patterns (Dixon, 1983), and the ability to manipulate complex visual material (Cooper & Regan, 1984; Shea et al., 2001). Spatial ability is a dimension of cognitive ability that relates to how an individual perceives the world and acquires new knowledge (Gardner, 1983, 1993; Shea et al., 2001). It consists of a number of subcomponents: spatial visualisation, spatial awareness, and object visualisation (Blazhenkova & Kozhevnikov, 2010). These subcomponents could constitute the underlying factors that underpin the development of any psychometric instrument developed to measure preferences for visual-spatial learning in secondary school students.

Individuals who possess spatial strengths are adept at using images to search for solutions to problems and express their thoughts. Kwon, Reiss, and Menon (2000) assert that 'visuospatial ability' is a factor in working memory, which is responsible for the maintenance and manipulation of spatial information. "Working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning" (Baddeley, 1992, p. 556). West (1997) suggests that there is a hierarchy of spatial thinking skills. This suggests that there is a spectrum from auditory-sequential ability to high-level visual-spatial ability, which corresponds with Silverman's (2000) concepts of the ASL and VSL. Learning through auditory-sequential methods means great precision but lacks flexibility. A person with sequential dominance may perceive the world differently to someone with spatial dominance (Silverman, 2000). According to Silverman (2005), individuals favour one method of learning over others. For this reason, the newly developed VSLQ will build on Silverman's

(2000) VSI by identifying where on the auditory-sequential learning and visual-spatial learning spectrum a secondary school student falls.

Silverman's (2000) VSI only includes items that measure preferences for visual-spatial learning. In contrast, the VSLQ consists of items that measure preferences for both visual-spatial learning and auditory-sequential learning. By demonstrating the reliability and validity of the VSLQ this instrument will also build on the lack of statistical evidence provided to support the efficacy of Silverman's (2000) VSI. A short, reliable, and valid questionnaire for measuring preferences for visual-spatial learning will allow a classroom teacher to identify secondary school students with this learning preference. The teacher can then use visual-spatial teaching strategies that will allow students with a preference for visual-spatial learning to organise and communicate ideas, leading to educational success within the classroom.

Spatial-ability and auditory-sequential spectrum. Research in the field of psychology has established that there is a difference between visual-spatial and auditory-sequential ability (Blazhenkova & Kozhevnikov, 2009, 2010; Kozhevnikov et al., 2002b; Kozhevnikov et al., 2005). However, rather than being in binary opposition they are located on a spectrum. This suggests that students can have a diverse array of characteristics. Within this diverse array of characteristics is a preference towards visual-spatial ability or auditory-sequential ability (Silverman, 2005). This is supported by a series of studies conducted by Kozhevnikov et al. (2002a, 2002b), and Kozhevnikov et al. (2005). Kozhevnikov et al. (2005) found that rather than individuals being solely Visualizers or Verbalizers there were multiple sub-groups with crossovers between each. Verbalizers tended to be a homogenous group with an intermediate level of spatial ability (Kozhevnikov et al., 2002a, 2002b).

The assertion that visual-spatial and auditory-sequential ability falls on a spectrum is supported by the work of Krutetskii (1976). It is believed that individuals can be classified into three groups - Verbalizers, Visualizers, and Mixers. Verbalizers prefer verbal-logical rather than imagery modes when attempting to solve problems. This category corresponds with Silverman's (2000, 2005) concept of the ASL. Visualizers are those who prefer to use visual imagery. This category corresponds with Silverman's (2000, 2005) concept of the VSL. According to Silverman's (2000) research, VSL have a preference for visual-spatial learning. Mixers fall between the two previous categories and have no preference for either visual or verbal learning.

Krutetskii's (1976) claims about the existence of three different groups within the student population are supported by Silverman's (2000, 2005) assertion that 33% of students are strongly visual-spatial. An additional 30% show a slight preference for the visual-spatial learning style. Only 23% are strongly auditory-sequential. Moses (1980), Lean and Clements (1981), and Presmeg (1986a, 1986b, 1992) assert that individuals can be placed on a continuum with regard to their preference for using visual imagery whilst solving mathematical problems. The development of a new instrument for measuring preferences for visual-spatial learning will identify secondary school students who have a strong preference for this type of learning. The presence of items on the VSLQ that measure preferences for auditory-sequential learning also allow the diverse array of characteristics a student demonstrates along the auditory-sequential and visual-spatial spectrum to be identified. By demonstrating the reliability and validity of this instrument, users of this measure can ensure that the results of this questionnaire are accurate. Classroom teachers can then use visual-spatial teaching strategies that focus on using images, pictures, colours, and maps to organise and communicate ideas to their students (Silverman, 2005). Research has shown that these strategies will lead to educational success for students with a preference for visual-spatial learning.

Educational Developments Associated with Visual-Spatial Ability

The concept of the VSL has also been facilitated by historical developments in the field of education. An educational innovation towards the end of the century was the recognition that students learn differently from each other. With this revelation came the introduction of personality types, learning styles, and multiple intelligences as a means of adapting to the individual differences of students within the classroom context. In the later decades of the twentieth century, research on the Visualizer-Verbalizer cognitive style began to appear in the educational literature (Cox, 1999; Cox, Stenning, & Oberlander, 1994; Riding & Cheema, 1991; Stenning, Cox, & Oberlander, 1995). It was first claimed that students could be classified according to how they process mathematical information. Students who used verbal-logical modes when solving mathematical problems were referred to as an analytic-type student. Alternatively, students who preferred to use imagery were referred to as a geometric-type student (Krutetskii, 1976).

Eventually, the idea that different cognitive styles are in binary opposition to each other became unpopular. Researchers (Lean & Clements, 1981; Moses, 1980; Presmeg, 1986a, 1986b) hypothesised that students could be placed on a continuum based on their preference for either the imagery or verbal-logical cognitive style. For this reason, a reliable and valid psychometric instrument developed to measure preferences for visual-spatial learning in secondary school students should include items that measure a preference for the verbal-logical learning style. Taylor (1968) proposed a multiple-talent approach to working within the classroom that was a precursor to Gardner's paradigm. This is supported by Carroll (1993), and Burton and Fogarty (2003) who claim that visualisation is a well-defined component skill within generalised intelligence. An increase in the research and literature (Chapman & King, 2001; Earl, 2003; Lawrence-Brown, 2004; Nunley, 2004; Rebora, 2008; Tomlinson, 1999, 2001) on differentiated instruction provides further evidence to support the idea of the VSL. This is because it suggests that students can process, organise, and communicate ideas in different ways. Students who have a preference for visual-spatial learning, for example, use images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005).

Differentiated instruction is a paradigm for effective teaching and learning, which involves providing different opportunities for students from diverse groups to acquire content and skills within the classroom. It also means developing teaching materials and assessment methods so that all students within the classroom context can experience educational success. The notion of differentiation is based on the ideas of Gardner (1983, 1993). The concept of differentiation also provides evidence to support the idea of the VSL. The growth in the literature on differentiation (Baum, Cooper, & Neu, 2001; George, 2010) has led to an explosion in the number of psychometric instruments developed to identify different learning preferences so that students can have their individual educational needs catered for. Silverman (2000) developed the VSI as an instrument for measuring preferences for visual-spatial learning in primary school students. A newly developed instrument, VSLQ, aims to address the concerns raised in the literature regarding the reliability and validity of Silverman’s (2000) instrument. However, the focus of this instrument is secondary school students.

Measuring Visual-Spatial Ability

Many different learning preferences are demonstrated in classroom settings. To better help students with a preference for visual-spatial learning develop their gifts and talents, teachers and parents must have access to a reliable and valid identification tool. Measures of learning preferences are concerned with typical performance measurement (Cronbach, 1960). They measure a respondent's motivation rather than his/her ability. Klehe and Latham (2008) claim that measures of typical performance are associated with prediction of motivation rather ability. In contrast, measures of visual-spatial ability are generally concerned with maximal performance measurement. Maximal performance tests measure how well people can perform at their best (Klehe & Latham, 2008). Students who display preferences for visual-spatial learning require targeted teaching strategies based on visual-spatial methods. Instruments designed to measure visual-spatial ability often involve the manipulation of geometric shapes. In contrast, instruments designed to measure preferences for visual-spatial learning are self-report and verbally anchored.

Manipulation of geometric shapes. Instruments that involve the manipulation of geometric shapes are measures of maximum performance (competencies), rather than typical performance (choices) (Klehe & Latham, 2008). Sackett, Zedeck, and Fogli (1988) concluded that differences between people on a measure of maximum performance reflect individual differences in ability. An example of an instrument that involves the manipulation of abstract geometrical shapes and measures maximal performance is Newton and Bristoll's (2009) SAT. The items on the instrument are concerned with an individual's ability to mentally manipulate shapes, to identify patterns, and make logical deductions. The instrument involves 32 items requiring individuals to match shapes, rotate and manipulate shapes, deconstruct large shapes, assemble a series of smaller shapes to construct larger shapes, and follow directions on a map (see Appendix A for items on SAT).

Silverman's (2013) research has shown that VSL read maps well. This is because students with a preference for visual-spatial learning use images, pictures, colours, and maps to organise and communicate ideas. However, Silverman's (2000) VSI only contains one item related to mapping (Item 10: "Would you rather read a map than follow directions?"). The VSLQ aims to build on Silverman's (2000) instrument by including three items related to mapping (Item 9: "I am good at reading maps," Item 49: "I find it easy to follow directions when they are told to me," Item 52: "I find it difficult to read maps. I prefer that someone gives me verbal or written directions to a location.") The construct validity of any new instrument designed to measure preferences for visual-spatial learning in secondary school students should be correlated against geometric items on traditional spatial tasks that involve reading maps. Burton (2003) claims that spatial instruments using abstract geometrical shapes are more effective than those that require participants to delve into their long-term memory. Burton and Fogarty (2003) elaborate on this argument by asserting that measures of self-report imagery are more effective at measuring spatial ability when they are similar to those involved in many of the "objective" spatial tests. For this reason, any new instrument developed for measuring preferences for visual-spatial learning should be compared against an "objective" spatial test. However, a number of researchers (Dean, 1994; Dean & Morris, 1995; Kosslyn, Brunn, Cave, & Wallach, 1984; Poltrock & Agnoli, 1986; Poltrock & Brown, 1984) have argued that further research is needed to establish the relationship between self-report measures of typical performance in relation to spatial ability and "objective" spatial ability tests that measure maximal performance. Researchers (Guion, 1991; DuBois, Sackett, Zedeck, & Fogli, 1993; Marcus, Goffin, Johnston, & Rothstein, 2007; Sackett et al., 1988; Vance, MacCallum, Coovert, & Hedge, 1988) claim that there is low correlation between measures of typical and maximal performance (r = 0.11 to 0.32).

Verbally anchored measures. The second type of instrument requires the participant to delve into their long-term memory. These instruments are verbally anchored measures of imaginal capacity. Unlike instruments that involve the manipulation of geometric shapes and measure maximal performance, these verbally anchored measures focus on typical performance. Whilst “objective” spatial ability tests measure an individual’s best performance in a task, typical performance instruments examine an individual’s day-to-day performance (Klehe & Latham, 2008). Currently there is only one instrument, Silverman’s (2000) VSI, available for identifying VSL. This instrument is a verbally anchored, self-report measure of typical performance.

VSI. The VSI was created by Silverman in 2000 to identify VSL in the primary years of schooling. VSL are students who display a preference for visual-spatial learning. It is a verbally anchored construct. The instrument consists of 14 items (see Table 2.2). The items focus on four of the characteristics of students who have a preference for visual-spatial learning: visual acquisition of information, visual organisation, processing of visual information, and communication of knowledge through visual methods. Silverman (2000) developed the VSI as a student self-rating scale designed to identify individuals as demonstrating a preference for either visual-spatial or auditory-sequential learning. There is also a teacher rating scale. However, because the instrument is being used to demonstrate the validity of a self-rating scale, this version of the instrument is not being used. The items on the VSI were developed by Silverman (2000) for primary aged students. The focus of the

VSLQ is measuring preferences for visual-spatial learning in secondary school students. Not all of the items on Silverman's (2000) VSI are appropriate for secondary aged students and their cognitive experiences. As such, some of the items will be reworded and adjusted to ensure for an individual's age level and cognitive experiences.

Table 2.2

Items on Silverman's (2000) VSI

Item	Not true	Somewhat true	Mostly true	True	Very true
1. I hate speaking in front of a group	1	2	3	4	5
2. I think mainly in pictures instead of words	1	2	3	4	5
3. I am good at spelling	1	2	3	4	5
4. I often lose track of time	1	2	3	4	5
5. I know more than others think I know	1	2	3	4	5
6. I don't do well on tests with time limits	1	2	3	4	5
7. I have neat handwriting	1	2	3	4	5
8. I have a wild imagination	1	2	3	4	5
9. I like to take things apart and find out how they work	1	2	3	4	5
10. I hate writing assignments	1	2	3	4	5
11. I solve problems in unusual ways	1	2	3	4	5
12. It's much easier for me to tell you about things than to write about them	1	2	3	4	5
13. I have a hard time explaining how I come up with my answers	1	2	3	4	5
14. I am well organized	1	2	3	4	5

Silverman's (2000) VSI uses a 5-point Likert scale: 1 = not true; 2 = somewhat true; 3 = mostly true; 4 = true; 5 = very true. The items on the VSI measure a student's preference for using images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005). The instrument was validated with 750 fifth and sixth graders of whom 40% were

Hispanic, 2% were ‘other minorities,’ and 58% were Caucasian. Silverman (2000) reported α = .71 (see Table 2.3). However, according to Van Nijnatten (2013), and Mann (2005) the validity of this instrument is questionable. According to these researchers the reliability coefficient score was achieved by commingling data from a range of sources (Mann, 2005). Through a follow up study Mann (2005) only obtained α = .46, which demonstrates an unacceptable level of internal consistency.

Table 2.3

Reliability Analysis of Items on Silverman’s (2000) VSI

Item	N	M	SD	α
1	554	2.8375	1.4813	0.7007
2	554	2.7365	1.2510	0.7005
3	554	2.8917	1.3750	0.7041
4	554	2.7455	1.4175	0.6673
5	554	2.8773	1.4204	0.6824
6	554	2.7383	1.3878	0.6795
7	554	2.9134	1.3406	0.6840
8	554	3.2310	1.2560	0.7097
9	554	2.6462	1.4612	0.6922
10	554	2.6318	1.4300	0.6621
11	554	2.6444	1.2199	0.6911
12	554	3.1769	1.2861	0.6819
13	554	2.8123	1.2732	0.6921
14	554	2.8953	1.3379	0.6919

Note. Reproduced from “Identifying visual-spatial and auditory-sequential learning: A validation study,” by L. K. Silverman, 2000, retrieved from http://visual-spatial learner.visualspatial.org/Articles/idvsls.pdf

In addition to the questionable reliability and validity data of the VSI, Silverman (2000) has constructed the 5-point Likert scale in such a way to influence the responses of the respondents. The scale is designed so that 4 of the potential responses suggest that an individual is a VSL: 2 = somewhat true; 3 = mostly true; 4 = true; 5 = very true. As such, any response to an item other than 1 (not true) suggests that an individual is a VSL. Silverman (2000, 2005) claims that 33% of students have a strong preference for visual-spatial learning, an additional 30% show a slight preference, and 23% have a preference for auditory-sequential learning. By having four out of the five options on the Likert scale, as positive descriptors, suggesting that a student is a VSL it may lead to more students being identified as having a preference for visual-spatial learning than are actually present within a classroom. This is supported by Bartram and Yielding's (1973) assertion that subjects tend to assign positive descriptors, rather than negative ones, to stimuli.

If a student is identified as having a preference for visual-spatial learning but actually has a preference for another learning style a classroom teacher may use teaching strategies that make learning difficult. In a study of 206 students, Peacock (2001) found that 72% of students were frustrated by a mismatch between teaching and learning styles; 76% of this group said it affected their learning. Silverman's (2000) research may also be biased because participants were forced to choose a rating sale. The VSI does not include an option of responding with 'unsure.' Researchers (Hawkins & Coney, 1981; Payne, 1951) found that providing a choice of 'unsure,' significantly reduced the number of meaningless responses on psychometric instruments. Forcing subjects to indicate their opinion when they actually have no opinion or are unsure of their position on an issue can lead to claims of bias in a study (Hawkins & Coney, 1981; Payne, 1951).

Nevertheless, Silverman's (2000) VSI is widely used as a measure of preferences for visual-spatial learning. This is because the psychological constructs associated with preferences for visual-spatial learning and visual-spatial ability are multidimensional. The

VSI has two underlying factors: visual-spatial learning and auditory-sequential learning. This exemplifies and is supported by Kozhevnikov et al.'s (2005) assertion that visual-spatial ability and auditory-sequential ability consist of three cognitive elements that fall on a spectrum. They advocate the object-spatial-verbal theoretical model of cognitive style (see Figure 2.7) that identifies three methods of organising and communicating ideas. Visualizers either construct and focus on the details of an object or focus on the spatial relations between objects. Verbalizers process and represent information verbally (Kozhevnikov et al., 2005). Despite the criticisms of Silverman's (2000) instrument its wide spread use within classrooms makes it a useful instrument for determining the construct validity of a new questionnaire for measuring preferences for visual-spatial learning in secondary school students.

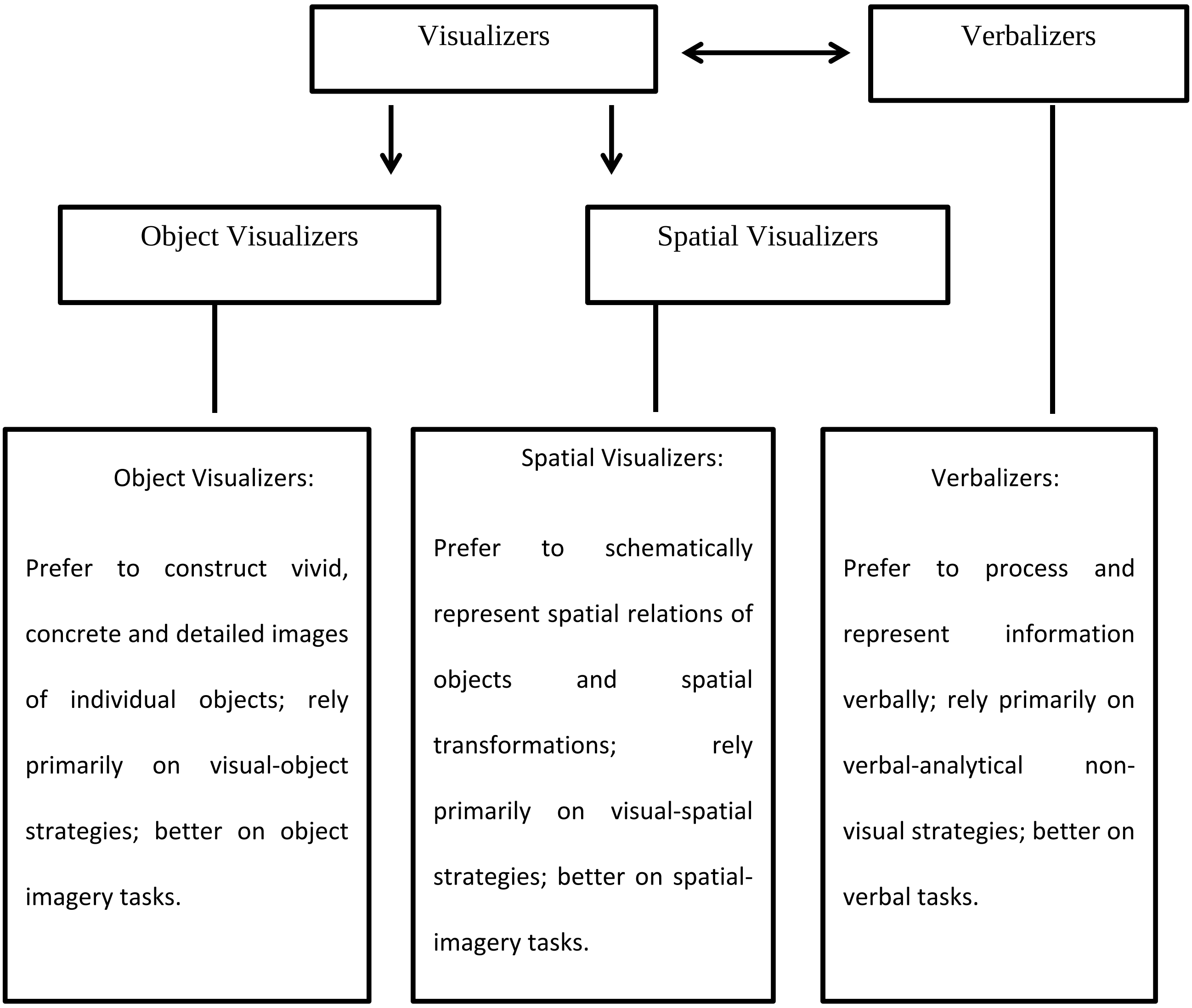


Figure 2.1. Object-Spatial-Verbal Cognitive Style Model (Kozhevnikov et al., 2005)

Development of the VSLQ

VSLQ. Capp (2006) developed an instrument entitled the VSLQ to measure preferences for visual-spatial learning in secondary school students based on the current literature (Armstrong, 1994; Chapman & King, 2001; Gardner, 1983; Ribot, 2004; Silverman & Freed, 1991; Sword, 2000). The new measure builds on Silverman's (2000) VSI with the aim of differentiating Visualizers, who use images, pictures, colours, and maps to organise and communicate ideas, and Verbalizers, who process and represent information verbally, as espoused in Kozhevnikov et al.'s (2005) object-spatial-verbal cognitive style model. The items were sourced from existing psychometric instruments in the field, including Blazhenkova et al.'s (2006) Object-Spatial Imagery and Verbal Questionnaire (OSIVQ), Richardson's (1977) Visualizer-Verbalizer Questionnaire (VVQ), and Silverman's (2000) VSI.

The instrument was developed by Capp (2006) during his work with the Queensland's Association for Gifted and Talented Children Inc. Whilst working with G&T students, and students with ASD he noticed that there was a very limited number of instruments available for helping teachers identify students in secondary schools who demonstrated a preference for visual-spatial learning. The instrument was designed as a verbally anchored, self-report questionnaire rather than an "objective" spatial test. "Objective" spatial tests generally measure maximal performance in relation to visual-spatial ability, preferences for visual-spatial learning relate to typical performance. This is not an unusual methodology and there are a number of long-standing, well-validated verbally anchored measures of visual-spatial ability and imaginal capacity in the research literature (e.g. VVQ, OSIVQ, Vividness of Visual Imagery Questionnaire etc). The content-related validity of the VSLQ was ensured by using the current literature (Armstrong, 1994; Chapman & King, 2001; Gardner, 1983; Ribot, 2004; Silverman & Freed, 1991; Sword, 2000) on preferences for visual-spatial learning to construct the items on the instrument.

The instrument was also modelled on a number of psychometric instruments that purport to measure visual-spatial ability or preferences for visual-spatial learning - Blazhenkova et al.'s (2006) OSIVQ, Richardson's (1977) VVQ, and Silverman's (2000) VSI.

The 2006 version of the VSLQ consisted of 70 items (see Appendix B for items on VSLQ) and used a 5-point Likert scale (1 = strongly agree, 2 = agree, 3 = unsure, 4 = disagree, 5 = strongly disagree). The items measure typical performance and focus on how students with a preference for visual-spatial learning use images, pictures, colours, and maps to organise information and communicate ideas (Silverman, 2005). Seven of the items on the instrument were developed based on the items on Silverman's (2000) VSI (see Table 2.4). One of the items on the VSLQ was kept the same as on the VSI ("I have neat handwriting"). Others were reworded to make them easier for secondary students to understand. For example, Item 11 on the VSI ("I solve problems in unusual ways") was reworded in Item 16 on the VSLQ ("I generally find my own methods of solving problems rather than using the ones my teacher suggests"). Other items were reworded because they were limiting. Item 6 on the VSI stated, "I don't do well on tests." Organisation for students with a preference for visual-spatial learning is often a stumbling block (Mann, 2005). VSL are usually disorganised and may miss details. These students are highly aware of space but pay little attention to time (Silverman & Freed, 1991). For this reason, Item 66 on the VSLQ was extended to all areas of schooling, "I generally find it difficult to get my work done in class."

Table 2.4

Comparison of Items on Silverman's (2000) VSI and VSLQ

Silverman's (2000) VSI item	Capp's (2006) VSLQ
(2) I think mainly in pictures instead of words	(1) When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read
(7) I have neat handwriting	(8) I have neat handwriting
(11) I solve problems in unusual ways	(16) I generally find my own methods of solving problems rather than using the ones my teacher suggests
(9) I like to take things apart to find how they work	(28) I want to know everything; I am very curious
(8) I have a wild imagination	(40) I like to day dream
(10) I hate writing assignments	(44) I prefer to type my assignments rather than write them by hand
(6) I don't do well on tests with time limits	(66) I generally find it difficult to get my work finished in class

Forty-seven items were developed to reflect the literature on preferences for visual-spatial learning (see Table 2.5). Silverman's (2000) VSI did not cover the breadth of the literature on preferences for visual-spatial learning. For this reason, items on the VSLQ were also developed based on the academic literature. The items focussed on how secondary school students with a preference for visual-spatial learning use images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005).

Table 2.5

Relationship Between Characteristics of VSL and Items on VSLQ

VSL characteristics	VSLQ items
Thinks primarily in pictures	(1) When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read.
Has visual strengths	(7) When I walk into a room I generally notice everything (14) I am very good at remembering things I have seen
Relates well to space	(59) I can remember how to get to a location after I have been there only once
Is a whole-part learner	(4) I prefer my teacher to give me an overview of a topic before exploring elements in depth.
Learns complex concepts easily	(5) My classmates are jealous that I seem to understand complex material easily struggles with easy concepts
Is a good synthesizer	(6) I find it easy to identify the connections and relationships between the ideas my teacher explains
Reads maps well	(9) I am good at reading maps
Is better at mathematics reasoning than computation	(10) I find problem solving questions in mathematics more interesting than regular questions
Must visualise words to spell them	(11) When I am learning a new word I prefer to visualise the whole word in my head rather than sounding it out
Prefers keyboarding to writing	(44) I prefer to type my assignments rather than write them
Creates unique methods of organisation	(12) Most people think that I am very disorganised. However, I have my own system of organisation.
Arrives at correct solution intuitively	(13) When I am doing mathematics the answers to the questions tend to just come to me
Learns concepts permanently; is turned off by drill and repetition	(15) When I learn something I never forget it
Develops own methods of problem solving	(16) I generally find my own methods of solving problems rather than the ones my teacher suggests (18) People think I come up with strange solutions to problems
Is very sensitive to teacher's attitudes	(17) I hate when my teacher is upset or angry
May have uneven grades	(19) My grades/results are all over the place
Masters other languages through immersion	(22) I find it difficult to learn languages other than English in class

Is creatively, mechanically, emotionally or technologically gifted	(50) One of my favourite subjects at school is either art or music
Is a late bloomer	(23) I think that I am getting better at school as I get older
Poor listening skills; often seems not to be listening	(64) I hate listening to my teacher talk and give instructions
Has difficulty finishing tasks/school work	(66) I generally find it difficult to get my work finished in class
Has poor handwriting	(55) My teachers tell me I have poor or messy handwriting.
Loves Lego, puzzles, jigsaws, computer games, televisions and making things	(34) I have a wide range of interests both at school and outside school (43) I am good at jigsaws (67) I enjoy playing computer games and watching television
Likes art and/or music	(41) When I am doing something I like to be as creative as possible (50) One of my favourite subjects at school is either art or music
Has a poor sense of time	(2) I am not very good at getting to class on time, handing assignments in by the due date and getting to appointments on time (24) When I am interested in something I can concentrate on it for a long time (29) If I am interested in something I won't stop until it is finished (66) I generally find it difficult to get my work finished in class
Is emotionally very sensitive	(17) I hate it when my teacher is upset or angry (25) I believe that being compassionate to other people is the most important thing someone can do (27) I can't understand why people do immoral things (37) I hate it when people are treated unfairly (38) I can't understand why some people my age make immature judgments (42) If I disagree with something I have to speak up and tell everyone
Has difficulty with spelling/times tables	(20) I hate studying algebra in mathematics (31) I have trouble with spelling
Can remember the way somewhere	(59) I can remember how to get to a location after I have been there only once after going there only once

Has a vivid imagination-rich fantasy life	(40) I like to daydream
Is very disorganised	(2) I am not very good at getting to class on time, handing assignments in by the due date and getting to appointments on time
	(12) Most people think that I am disorganised. However, I have my own system of organisation.
	(66) I generally find it difficult to finish my work in class
A good sense of humour	(35) I think that I have a good sense of humour
	(69) My friends would say that I am funny

Twenty-three items were developed to reflect the literature on auditory-sequential learning (see Table 2.6), as a means of determining where on the spectrum between preference for visual-spatial and auditory-sequential learning an individual falls. This is because psychological research (Blazhenkova & Kozhevnikov, 2009; Farah, Hammond, Levine, & Calvanio, 1988; Kosslyn, 1995; Kozhevnikov et al., 2005; Logie, 1995) has shown that auditory-sequential ability and visual-spatial ability are on different ends of the same spectrum. A secondary school student can show any combination of these characteristics. These items measure how a student with a preference for auditory-sequential learning process and represent information verbally (Kozhevnikov et al., 2005).

Table 2.6

Items on VSLQ That Contradict the Characteristics of VSL

VSL characteristics	VSLQ item
Is very disorganised	(3) My bedroom is very neat
Has poor handwriting or difficulty keeping in the lines or grips the pen very hard and presses on the paper when writing	(8) I have neat handwriting
Dislikes algebra and chemistry	(21) I love studying chemistry in science
	(61) I enjoy studying algebra in mathematics
Poor at calculation	(32) I love doing times tables
Thinks primarily in pictures	(45) I find it easier to understand what I have read than what I have seen in a diagram or picture
Disorganised, forgets details	(46) I am good at meeting deadlines
Is a whole-part learner	(47) I find it difficult to understand my teacher if he/she does not go step by step through the information or skill
Likes complex tasks and does well on them	(48) My friends seem to understand complex information presented by the teacher but I find it difficult to understand
Poor auditory memory, does not remember three-step instructions	(49) I find it easy to follow directions when they are told to me
	(58) I am able to follow verbal

	instructions given by the teacher
Has visual strengths and relates well to space; poor auditory memory, does not remember three-step instructions	(51) I find it difficult to read maps. I prefer that someone gives me verbal or written directions to a location.
Better at mathematical analysis than computation	(52) I am good at mathematics questions that I have been shown how to do; however, I find problem solving questions difficult.
Learns whole words easily; must visualize words to spell them; difficulty learning phonics	(53) When I am trying to remember how to spell a word, I like to sound it out.
Is very disorganized	(54) I am very well organized. I have a routine for everything.
Submits short, sloppy work of poor quality	(26) Everything I do has to be perfect (56) I always show my working when completing problems in mathematics. (70) I always put 100% effort into everything I do
Hates drill and repetition	(57) I find it easier to learn something if I repeat it a few times
May have very uneven grades	(60) I generally do well in all my subjects at school
Enjoys geometry and physics	(62) I hate studying geometry (shapes and angles) in mathematics
May have uneven grades; inattentive in class; easily distracted	(63) My teachers say that I academically talented
Masters other languages through immersion	(65) The easiest way for me to learn a language is in class

Seven items on the VSLQ were similar to items on Blazhenkova et al.'s (2006) OSIVQ (see Table 2.7). Three items on the OSIVQ measured typical performance in relation to geometric ability. These three items were condensed to one on the VSLQ. Both the items on the OSIVQ and VSLQ measure typical performance related to mental manipulation of geometric figures (Klehe & Latham, 2008). One of the three items on the OSIVQ did not relate to the educational context. Preferences for visual-spatial learning relate to the educational context. For this reason, the three items on the OSIVQ were condensed to one item (Item 62: "I hate studying geometry [shapes and angles] in mathematics”). Hegarty and Kozhevnikov’s (1999) claim that spatial ability is highly correlated with success in mathematics education. Secondary school students with a preference for visual-spatial learning demonstrate a preference for mathematical reasoning and problem solving (Hegarty & Kozhevnikov, 1999). Item 62 on the VSLQ enables teachers to identify where a student falls on the visual-spatial learning and auditory-sequential learning spectrum.

Two items on the OSIVQ, Item 8 (“I have a photographic memory”), and Item 25 (“I can close my eyes and easily picture scenes that I have experienced”), were rewritten to be relevant to secondary school students. The two items were also expanded into five items (Item 1: “When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read;” Item 7: “When I walk into a room I generally notice everything;” Item 14: “I am very good at remembering things that I have seen;” Item 39: “I seem to notice everything around me;” Item 49: “I can remember how to get to a location after I have been there only once”). VSL are whole-part learners (Silverman, 2005). They learn best by first seeing a broad overview of the entire content to be learnt then breaking it down into its constituent parts. For this reason, they learn concepts all at once and grasp complex concepts easily (Silverman, 1989). VSL often see the big picture but may miss details (Silverman & Freed, 1991). Some commentators (Ashwin et al., 2009; Behrmann et al., 2006; Happy & Frith, 2006; Perreault et al., 2011; Samson et al., 2012) have shown that people with ASD perform better than control groups on tasks involving characteristics such as visual acuity or clearness of vision. Caron et al.

(2004) demonstrated through a study involving navigating a human-size labyrinth, that individuals with ASD have advanced discrimination, detection, and memory for visual patterns. O'Riordan et al. (2001) found during a study of children with ASD that they performed better than typically developing children on difficult visual-search tasks. Item 14 ("I am a good Tetris player") is very dated, as many students no longer play this computer game. As such, this item was reworded in the VSLQ (Item 67: "I enjoy playing computer games and watching television").

Table 2.7

Comparison of Items on Blazhenkova et al.'s (2006) OSIVQ and VSLQ

OSIVQ item	VSLQ item
(1) I was very good in 3-D geometry as a student. (9) I can easily imagine and mentally rotate 3-D geometric figures. (20) In high school, I had less difficulty with geometry than with art.	(62) I hate studying geometry (shapes and angles) in mathematics
(8) I have a photographic memory.	(1) When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read. (14) I am very good at remembering things that I have seen (39) I seem to notice everything around me
(14) I am a good Tetris player.	(67) I enjoy playing computer games and watching television
(25) I can close my eyes and easily picture a scene that I have experienced	(7) When I walk into a room I generally notice everything (49) I can remember how to get to a location after I have been there only once

Three items on the VSLQ were also similar to items on Richardson's (1977) VVQ (see Table 2.8). To make item 10 on the VVQ ("My powers of imagination are higher than average") easier to understand for secondary school students it was reworded on the VSLQ (Item 40: "I like to daydream"). Item 11 on the VVQ ("My thinking often consists of mental pictures or images") was extended into two items on the VSLQ (Item 1: "When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read," Item 11: "When I am learning a new word I prefer to visualize the whole word in my head rather than sounding it out"). Whilst both the items in the VVQ and VSLQ measure typical performance, the questions on the VSLQ relate to the educational context. In contrast, Richardson's (1977) VVQ measures imaginal capacity. Mayer and Simms (1994) found that students with a preference for visual spatial learning are able to devote more cognitive resources to building connections between visual representations and written or verbally presented material, than students without this learning preference. This is supported by Cronbach and Snow (1977) who found that VSL are able to construct and hold visual representations of pictures, diagrams, and words in working memory. VSL are able to construct connections between visual and verbal information when it is presented either contiguously or successively. ASL, on the other hand, struggle to make connections between visual and verbal information when they are not presented contingently (Mayer & Simms, 1994).

Table 2.8

Comparison of Items on Richardson's (1977) VVQ and the VSLQ

VVQ item	VSLQ item
(10) My powers of imagination are higher than average	(40) I like to daydream
(11) My thinking often consists of mental pictures or images	(1) When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read. (11) When I am learning a new word I prefer to visualize the whole word in my head rather than sounding it out

An effective psychometric instrument has both reliability and validity. When developed in 2006, Capp's VSLQ was not subjected to any form of statistical analysis. Therefore, the objective of Study 1 reported in this thesis was to investigate the internal reliability of the instrument using an EFA.

Chapter 3: Study 1

> Art is a process of elimination. The sculptor produces the beautiful stature by chipping away such parts of the marble block as are not needed – it is the process of elimination (Dean, 2010).

The initial study that developed the VSLQ (Capp, 2006) was implemented with a population of 125 Australian secondary school students in Years 8 to 12. No statistical analysis was conducted on this data. The respondents completed both Capp's (2006) VSLQ, and Silverman's (2000) VSI. This allowed for a precursor examination of the VSLQ to see if a high score on this instrument equated to a high score on Silverman's (2000) VSI.

Results of this study demonstrated that there was a positive relationship between a high score on Capp's (2006) VSLQ, and a high score on Silverman's (2000) VSI. Because no statistical analysis was conducted, statistical analytic procedures in the form of an EFA and CFA needed to be conducted to demonstrate the reliability of the instrument (Stommel, Wang, Given, & Given, 2007). During the 2006 study the VSLQ was implemented with a population of 125 students. According to the literature (Bartlett II, Kotrlik, & Higgins, 2001; Burmeister & Aitken, 2012; MacCallum, Widaman, Zhang, & Hong, 1999; Velicer, & Fava, 1998) this constitutes a very small sample size in relation to a 70-item instrument. Bartlett et al. (2001) argue that the optimal ratio is ten respondents to one item on a questionnaire. In contrast, Burmeister and Aitken (2012), and Tabachnick and Fidell (2007) identify an optimal ratio size of 20:1. As such, the optimal number of respondents in Study 1 should have been between 700 and 1400. The results of the EFA during Study 1 need to be examined from the paradigm that a small sample size influences the way item loadings should be interpreted. A small sample size means that the item loading on a factor needs to be higher to be considered significant (Bartlett II et al., 2001).

The processes of EFA and CFA are elements of a psychometric analysis that provide evidence of the reliability of an instrument by demonstrating its internal consistency. The EFA will be used to identify the factors underlying the VSLQ as it has not previously been subjected to a statistical analysis. CFA will be used to verify the factors extracted during the EFA, and test the relationships between the items and the underlying factors. Despite the unacceptable level of internal consistency and lack of evidence of construct validity of Silverman’s (2000) VSI, its wide spread use within classrooms makes it a useful tool for demonstrating the construct validity of the VSLQ. The assumption that there is a positive relationship between the VSLQ and VSI will be tested through a correlational analysis. This study aims to build on Silverman’s (2000) VSI through the development of a new reliable and valid measure of preferences for visual-spatial learning in secondary school students.

Psychometrics is the field of study concerned with the theory and technique of psychological measurement. The field is primarily concerned with the construction and validation of measurement instruments such as questionnaires, tests, and personality assessments. These instruments generally measure knowledge (Ferketich, 2007), abilities (Ferketich, Figueredo, & Knapp, 1991; Ferketich & Verran, 2007), attitudes (Rao & Sinharay, 2007), and personality traits (Shavelson & Ruiz-Primo, 2000; Stout, 2002). Closely associated with psychometrics are the concepts of reliability and validity. These questions need to be addressed in relation to the VSLQ.

The overall aim of this study is to build on Silverman's (2000) VSI by demonstrating the reliability and validity of the new measure. The first step in the process is to demonstrate that the instrument has internal consistency. This will be achieved by completing an EFA to identify the factors that underlie the VSLQ. A CFA will test the relationship between the identified underlying factors and the items on the instrument. Once the internal consistency of the instrument has been demonstrated, the construct validity of the VSLQ will be explored.

The first step in demonstrating the construct validity of the VSLQ is to demonstrate that the instrument has content validity. This was achieved by using the current literature on preferences for visual-spatial learning to develop the items on the instrument. A number of items were also based on those found on pre-existing psychometric instruments (VSI, OSIVQ, VVQ) for measuring typical performance in relation to visual-spatial ability and preferences for visual-spatial learning.

Content validity is important in relation to the VSLQ. Lynn (1986) defines content validity as a process of determining the content representativeness or the content relevance of items on an instrument. Haynes, Richard, and Kubany (1995) add to this definition by advocating that a determination of content validity must take into account the purpose of the particular instrument. For example, an instrument developed to measure preferences for visual-spatial learning would not be used to evaluate post-traumatic stress disorder in soldiers returning from active duty. Content validity as a type of validity has been questioned by a number of commentators (Carmines & Zeller, 1979; Cronbach, 1970; Messick, 1981).

The criticisms of content validity often stem from the confusion between this type of validity and face validity. Face validity, unlike content validity, is based on assumptions made by lay people rather than individuals with a working knowledge of the area under examination. Face validity is often referred to as validity by assumption because decisions are made about items on an instrument and its purpose (Lynn, 1986; Mosier, 1947). Content validity requires the use of recognized subject matter experts to evaluate whether test items assess defined content. Content validity is most often addressed in academic and vocational testing, where test items need to reflect the knowledge actually required for a given topic area (e.g. biology) or job skill (e.g. bar tending). It can also be used in clinical settings (Lawshe, 1975; Pennington, 2003; Wilson, Pan, & Schumsky, 2012). Content validity according to a number of commentators (Guion, 1977; Hambleton & Rogers, 1991; Messick, 1993a, 1993b; Suen, 1990) is important because the data obtained from an instrument can be analysed and interpreted due to the assumption that it is measuring what it claims to measure (Haynes et al., 1995). Content validity provides evidence towards the determination of construct validity.

One of the problems with content validity is that it is unstable and can degrade over time (Haynes et al., 1995). New theories and research may be conducted into the content area (Cronbach, 1971; Haynes & Waialae, 1994). As such, instruments need to be periodically revised to ensure that it still has content validity. If this does not take place the instrument will produce uninterpretable data (Gardner, 1995). For this reason, the items on Capp's (2006) VSLQ were re-examined to ensure that they still have content validity. The content validity of the 2006 version of the instrument was determined by using the current literature at the time on preferences for visual-spatial learning (Armstrong, 1994; Chapman & King, 2001; Durie, 1997; Gardner, 1983; Ribot, 2004; Silverman & Freed, 1991; Silverman, 1997, 2000, 2005; Sword, 2000) to construct the items on the instrument. Significant research (Anderson, 2014; Ashwin et al., 2009, 2010; Burgoyne, 2010; Evans et al., 2011; Newcombe & Frick, 2010; Park et al., 2010; Silverman, 2013; Van Nijatten, 2013) into visual-spatial ability and preferences for visual-spatial learning has occurred since then. As such, items that no longer reflect the literature on preferences for visual-spatial learning and visual-spatial ability will be removed from the VSLQ.

It is imperative that a psychometric instrument measures only a small number of factors (Yang, 2003). By measuring only a small number of homogenous factors an instrument is said to have internal consistency. Internal consistency is one of the types of reliability referred to in the psychometric literature (Field, 2009; Netemeyer, Bearden, & Sharma, 2003). If an instrument is to yield meaningful scores, the items must all be indicators of some common underlying construct. Items on an instrument should share common variance (Gardner, 1995). To determine if an instrument is uni-dimensional or multidimensional a factor analysis should be conducted (DeVellis, 1991). Internal consistency is usually measured through a factor analysis. For this reason, the 2006 data collected using the VSLQ was subjected to an EFA to detect the factor structure of the instrument.

Factor analysis is a collection of methods for explaining the correlations among the underlying variables in an instrument, in terms of factors (Bruce, 2004; Cudeck, 2000). Pallant (2007) elaborates on this explanation by classifying factor analysis as a data reduction technique. It is used to simplify multivariate data to its smaller underlying factors. Two methods of factor analysis are EFA and CFA.

EFA is a statistical method used to uncover the underlying structure of a relatively large set of previously untested variables. It is based on a common factor model in which measured variables are expressed as a function of common factors, unique factors and errors of measurement (Cudeck, 2000; Thompson, 2004). The primary purpose of an EFA is to arrive at a conceptual understanding of a set of measured variables within a newly constructed instrument. In other words, it explores how many factors exist among a set of variables and the degree to which the variables (items) are related to the factors (Kahn, 2006). This is achieved by determining the number and nature of common factors. These factors are believed to account for the correlations among the measured variables (Everitt & Hothorn, 2011; Fabrigar, MacCallum, Wegener, & Strahan, 1999; Maroof, 2012). It is a data driven process that is often conducted in the early stages of an investigation. As such, an EFA will be conducted during Study 1 on the 2006 archival data collected using the VSLQ.

Hypothetical judgments are made about the relationships between the underlying factors identified during the EFA. CFA, on the other hand, is a theory driven approach (Bruce, 2004; DeVon et al., 2007; Everitt & Hothorn, 2011; Field, 2009; Harrington, 2009; Hoyle, 2000). The process is similar to an EFA. However, it is often used in the later stages of an investigation to confirm specific hypotheses (Kahn, 2006). Both analytical processes are used to provide evidence of the reliability of a psychometric instrument, in the form of internal consistency. These two forms of factor analysis will be used to provide evidence of the internal consistency of the VSLQ.

Internal consistency assesses item interrelatedness on a psychometric instrument. Items composing a scale should show high levels of internal consistency (Netemeyer et al., 2003). Internal consistency, as a concept and process, is not free from criticism. Kline (1986) believes that "high internal consistency can be…antithetical to high validity…the importance of internal-consistency reliability has been exaggerated in psychometry" (pp. 118-119). A high level of homogeneity may suggest a high level of item redundancy. This results in items rephrasing questions in many different ways (Boyle, 1991).

An EFA would detect the most relevant items (i.e., "questions") with the aim of reducing the size of the VSLQ from 70 items. This makes it a cumbersome and long diagnostic instrument, which represents a significant time imposition on people. Classroom teachers cannot spend an entire lesson having students complete a questionnaire. For this reason, psychometric instruments in the field of education need to be short and not time consuming. This is supported by the claims of a number of commentators (Churchill & Peter, 1984; Cortina, 1993; DeVellis, 1991; Netemeyer et al., 2003; Nunnally & Bernstein, 1994) that most scales are self-administered and that respondent fatigue and/or non-cooperation need to be considered, scale brevity is often advantageous. Reducing the number of items would make the VSLQ a more time efficient measure for classroom teachers.

By demonstrating the reliability of the VSLQ it ensures that the results of the instrument are strong (DeVon et al., 2007). In this research project, factor analysis in the form of both an EFA and CFA will be used to show the internal consistency of the instrument. This is because reliability relates to the interpretation of scores from psychometric instruments. The results of the VSLQ need to be able to be analysed and evaluated to ensure that it measures preferences for visual-spatial learning. During Study 1 an EFA was conducted using Principal Component Analysis (PCA). PCA is one of the most common methodological choices made in applications of EFA (Flowers & Algozzine, 2000; Kwan, 2000; Preacher & MacCallum, 2003; Shiarella, McCarthy, & Tucker, 2000; Yanico & Lu, 2000). It yields observable composite variables, which account for a mixture of common and unique sources of variance. Within the literature some commentators (Schoenmann, 1990; Steiger, 1990; Velicer, & Jackson, 1990a, 1990b) point out that there is almost no difference between PCA and other statistical methods (Maximum Likelihood, Principal Axis Factoring etc.), or that PCA is preferable. One of the criticisms of PCA is that “the distinction between common and unique variance is not recognised, and no attempt is made to separate unique variance from the factors being extracted” (Preacher & MacCallum, 2003, p. 20). However, unlike other statistical methods PCA also allows for data reduction (Field, 2009). Velicer and Jackson (1990a, 1990b) argue that this methodology is superior to other factors for analysing common factors. Approximately 50% of studies published in peer-reviewed journals used PCA, rather than another statistical methodology (Fabrigar et al., 1999).

Validity, on the other hand, is concerned with what the test measures. The American Educational Research Association, Psychological Association, and National Council on Measurement in Education (1999) define validity as "the degree to which evidence and theory support the interpretations of test scores" (p. 1). Validity is the most important paradigm to consider in relation to a questionnaire. It refers to the degree to which evidence supports any inferences a researcher makes based on the data. According to Hopkins (2008) internal consistency is the minimum that is needed for classroom research to be interpretable. In other words, the researcher measures what they claim to measure. This is supported by Hammersley (1987) who believes an instrument is valid if “it represents accurately those features of the phenomena that it is intended to describe, explain or theorise” (p. 79). The literature (Aldridge & Levine, 2001; Hopkins, 2008; Johnson & Christensen, 2004; Wiersma & Jurs, 2005) identifies many different types of validity. The construct validity of the VSLQ is of primary concern in this research project.

Construct validity tests the relationships amongst the underlying constructs of an instrument (Cronbach & Meehl, 1955; Hair, Black, Babin, Anderson, & Tatham, 2006; Western & Rosenthal, 2003). Establishing construct validity involves a combination of theory and hypothesis testing. Theory is used to generate a series of hypotheses. Evidence is used to then support or disprove these hypotheses. If evidence is found to support these hypotheses it can be claimed that an instrument has construct validity (Ruane, 2005). “Construct validity is used when neither a pertinent criterion of prediction nor a well-defined domain of content exists for determining validity” (Singleton & Straits, 2005, p. 76). The validity of the instrument being measured is determined by the theoretical relationships amongst the underlying constructs. It consists of a number of subtypes of validity: divergent and convergent.

Divergent validity is demonstrated when there is low correlation between factors that are believed to be distinct (Campbell & Fiske, 1959; John & Benet-Martinez, 2000; Krathwohl, 2009; Lucas, Diener, & Sub, 1996; Warner, 2008). When measures of the same construct are highly correlated, there is evidence of convergent validity (Anatasi, 1968; Bagozzi, Yi, & Phillips, 1991; Bohrnstedt, 1970; Cunningham, Preacher, & Banaji, 2001; Nunnally, 1978; Singleton & Straits, 2005). The type of validity demonstrated is dependent on the nature of the relationship expected (Harrington, 2009). This is supported by Krathwohl's (2009) claim that "we seek evidence based on relations to other variables" (p.89).

The construct validity of the VSLQ will be demonstrated by providing evidence that the items on the instrument are related to the underlying factors associated with preferences for visual-spatial learning. This will be achieved by comparing the results of the VSLQ against those of Silverman's (2000) VSI, and Newton and Bristoll's (2009) SAT. Silverman's (2000) VSI aims to measure the underlying factors of visual-spatial learning and auditory-sequential learning. In contrast, Newton and Bristoll's (2009) SAT measures the underlying factors of geometric manipulation and mapping ability. The VSLQ will be compared with the results of these two psychometric instruments because they are underpinned by different factors associated with preferences for visual-spatial learning and visual-spatial ability. This is in line with Kozhevnikov et al.'s (2005) assertion that the processes associated with preferences for visual-spatial learning and visual-spatial ability consist of three cognitive elements – object imagery, spatial imagery, and verbal - that fall on a spectrum.

Although the VSLQ is a verbal questionnaire of imaginal capacity that measures typical performance, the results of this instrument will be compared against those of an "objective" spatial test that measures maximal performance, Newton and Bristoll's (2009) SAT. This is because Burton and Fogarty (2003) argue that self-report measures of imagery ability are more effective "if the stimuli used in the self-report scales approximate those used in spatial tests" (p. 39). However, a number of researchers (Dean, 1994; Dean & Morris, 1995; Kosslyn et al., 1984; Poltrock & Agnoli, 1986; Poltrock & Brown, 1984) have argued that further research is needed to establish the relationship between self-report measures of spatial ability and "objective' spatial ability tests. A positive correlation between the factors underlying the VSLQ and the relevant underlying factors on Silverman's (2000) VSI and Newton and Bristoll's (2009) SAT would provide evidence of the convergent validity of the VSLQ. A negative correlation between contradictory factors underlying Silverman's (2000) VSI and the VSLQ would provide evidence of the divergent validity of the instrument.

It is hypothesised that the factors underlying the VSLQ will have a high correlation with the visual-spatial learning factor underling Silverman's (2000) VSI. Following Burton and Fogarty's (2003) assertion that "objective" spatial ability tests are a more accurate reflection of spatial ability than subjective self-rating scales, it can be hypothesised that the underlying factors associated with visual-spatial learning on the VSLQ and those underlying the Newton and Bristoll's (2009) SAT will have a high correlation. A low correlation or negative correlation is expected between the underlying factors that measure visual-spatial learning on the VSLQ and the auditory-sequential learning factor on Silverman's (2000) instrument. Study 1 will begin the process of demonstrating the internal consistency of the VSLQ by examining the EFA that was conducted on archival data collected during 2006.

Method

Participants. The VSLQ was implemented with a population of 125 Australian secondary school students (72 females) in Years 8 to 12. Overall, the sample exhibited variability in respect to year level: Year 8 (n = 36), Year 9 (n = 15), Year 10 (n = 40), Year 11 (n = 25), Year 12 (n = 9). The average age of the participant pool was 15.2 years. The mean age of the females was 14.6 years. The males had a mean age of 16.1.

Procedure. The 2006 data collected using the VSLQ was run through SPSS. The first step was to conduct a data screening (Schwartz, 2011). The frequencies for each of the items were graphed as histograms. The distributions of each of the histograms were then examined. Normal distribution is important in a set of data because if it is normally distributed a researcher can make inferences about the values of the variable. A non-normal distribution makes inferences difficult. Those demonstrating a non-normal distribution were removed from the instrument. Jackson, Purc-Stephenson, and Gillaspy (2009) claim that data needs to be examined for normality. The remaining items were then examined for kurtosis and skewness. This was achieved by dividing the kurtosis statistic by the standard error measurement and by dividing the skewness statistic by the standard error measurement. To confirm skewness or kurtosis the histograms from step one were re-examined. All items (*n* =

32) identified to have either a non-normal distribution, kurtosis or skewness were removed from the VSLQ (see Table 3.1). This left 38 items remaining for further analysis.

Table 3.1

Items Removed From VSLQ due to a Non-Normal Distribution, Kurtosis, and Skewness

Item	Content
2	I am not very good at getting to class on time, handing assignments in by the due date and getting to appointments on time
4	I prefer my teacher to give me an overview of a topic before exploring elements in depth
6	I find it easy to identify the connections and relationships between the ideas my teacher explains
10	I find problem solving questions in mathematics more interesting than regular equations
14	I am very good at remembering things that I have seen
15	When I learn something I never forget
19	My grades/results at school are all over the place
24	When I am interested in something I can concentrate on it for a long time
25	I believe that being compassionate to other people is the most important thing someone can do
30	I am always full of energy
31	I have trouble with spelling
32	I love doing timetables
34	I have a wide range of interests both at school and outside schools
36	I love reading
38	I can’t understand why some people my age make immature judgments
39	I seem to notice everything around me
40	I like to day dream
41	When I am doing something I like to be as creative as possible
42	I am very well organized. I have a routine for everything
44	I prefer to type my assignments rather than write them by hand
45	I find it easier to understand what I have read than what I have seen in a diagram or picture
47	I find it difficult to understand my teacher if he/she does not go step by step through the information or skill
50	One of my favourite subjects at school is either art or music
52	I am good at mathematics questions that I have been shown how to do; however, I find problem solving questions difficult
57	I find it easier to learn something if I repeat it a few times

59	I can remember how to get to a location after I have been there only once
60	I generally do very well in all my subjects at school
61	I enjoy studying algebra in mathematics
63	My teachers say that I am academically talented
64	I hate listening to my teacher talk and give instructions
65	The easiest way for me to learn a language is in class
68	My parents always claim that my bedroom is messy

The content-related validity of the VSLQ was demonstrated in 2006 using the current literature at the time on preferences for visual-spatial learning (Armstrong, 1994; Chapman & King, 2001; Durie, 1997; Gardner, 1983; Ribot, 2004; Silverman & Freed, 1991; Silverman, 2005; Sword, 2000). Significant research (Anderson, 2014; Ashwin et al., 2009, 2010; Burgoyne, 2010; Evans et al., 2011; Newcombe & Frick, 2010; Park et al., 2010; Silverman, 2013; Van Nijatten, 2013) into visual-spatial ability and preferences for visual-spatial learning has occurred since then. Eighteen items were removed from the instrument because they no longer accurately reflected the literature on VSL and preferences for visual-spatial learning (see Table 3.2).

Table 3.2

Items Removed From the VSLQ for not Reflecting the key Characteristics of VSL

Item	Content
5	My classmates are jealous that I seem to understand complex material easily
17	I hate it when my teacher is upset or angry
18	People think I come up with strange solutions to problems
22	I find it difficult to learn languages other than English in class.
23	I think that I am getting better at school as I get older
26	Everything I do has to be perfect
27	I can't understand why people do immoral things
28	I want to know everything; I am very curious.
29	If I am interested in something I won't stop until it is finished
33	Most of my friends are older than me or adults

35	I think that I have a good sense of humour
37	I hate when people are treated unfairly
46	I am very good at meeting deadlines
48	My friends seem to understand complex information presented by the teacher but I find it difficult to understand
49	I find it easy to follow directions when they are told to me
54	If I disagree with something I have to speak up and tell everyone
66	I generally find it difficult to get my work finished in class
70	I always put 100% into everything I do

The 2006 version of the VSLQ was originally developed to identify secondary school students as either VSL or ASL. Subsequent work on the questionnaire has shown a focus on measuring preferences for visual-spatial learning only. Consequently, the following items were removed from the 2006 version of the instrument: Item 22 (“I find it difficult to learn languages other than English in class”); Item 26 (“Everything I do has to be perfect”); Item 46 (“I am very good at meeting deadlines”); Item 49 (“I find it easy to follow directions when they are told to me”); Item 54 (“I am very well organized. I have a routine for everything”); and, Item 70 (“I always put 100% into everything I do”). Other items were removed because they were no longer deemed relevant in the measurement of preferences for visual-spatial learning: Item 5 (“My classmates are jealous that I seem to understand complex material easily”); Item 17 (“I hate it when my teacher is upset of angry”); Item 18 (“People think I come up with strange solutions to problems”); Item 23 (“I think that I am getting better at school as I get older”); Item 27 (“I can’t understand why people do immoral things”); Item 28 (“I want to know everything; I am very curious”); Item 29 (“If I am interested in something I won’t stop until it is finished”); Item 33 (“Most of my friends are older than me or adults”); Item 35 (“I think that I have a good sense of humour”); Item 37 (“I hate when people are treated unfairly”);

Item 48 ("My friends seem to understand complex information presented by the teacher but I find it difficult to understand"); and, Item 66 ("I generally find it difficult to get my work finished in class").

Overall, the revision process led to 50 items being removed from Capp's (2006) VSLQ. The remaining 20 items (see Table 3.3) can be grouped according to how VSL use images to organise (e.g. Item 1: "When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read"), and process information (e.g. Item 9: "I am good at reading maps"), their organisational ability (e.g. Item 12: "Most people think I am very disorganized. However, I have my own system of organization"), and academic interests (e.g. Item 20: "I hate studying algebra in mathematics").

Table 3.3

Twenty Remaining Items on VSLQ

Item	Content
1	When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read.
3	My bedroom is very neat
7	When I walk into a room I generally notice everything
8	I have neat handwriting
9	I am good at reading maps
11	When I am learning a new word I prefer to visualize the whole word in my head rather than sounding it out
12	Most people think I am very disorganized. However, I have my own system of organization.
13	When I am doing mathematics the answers to the questions tend to just come to me
16	I generally find my own methods of solving problems rather than using the ones my teacher suggests
20	I hate studying algebra in mathematics
21	I love studying chemistry in science

43	I am good at jigsaws
51	I find it difficult to read maps. I prefer that someone gives me verbal or written directions to a location.
53	When I am trying to remember how to spell a word, I like to sound it out
55	My teachers tell me I have poor or messy handwriting
56	I always show my working when completing problems in mathematics
58	I am able to easily follow verbal instructions given by the teacher
62	I hate studying geometry (shapes and angles) in mathematics
67	I enjoy playing computer games and watching television
69	My friends would say that I am funny

The remaining 20 items were subjected to a PCA (see Table 3.4). Item 12 ("Most people think I am very disorganized. However, I have my own system of organization"), and Item 55 ("My teachers tell me I have poor or messy handwriting") demonstrated a significant positive correlation (r = .44). Both Item 12 and Item 55 relate to the organisational ability of students with a preference for visual-spatial learning. Significant negative correlations were found between two sets of items. A negative correlation (r = -.57) was found between Item 8 ("I have neat handwriting"), and Item 55 ("My teachers tell me I have poor or messy handwriting"). A negative correlation (r = -.58) was also identified between Item 9 ("I am good at reading maps"), and Item 51 ("I find it difficult to read maps. I prefer that someone gives me verbal or written directions to a location"). A negative correlation was expected between Items 8 and 55 because they are reversed items measuring organisational skills associated with writing. A negative correlation was also expected between Items 9 and 51, as they are reversed items relating to mapping ability. No correlation (r = .00) was identified between Item 8 ("I have neat handwriting"), and Item 9 ("I am good at reading maps). Items 8 and 9 measure different characteristics of students who have a preference for visual-spatial learning. Item 8 measures organisational ability. In contrast, Item 9 relates to the processing of images in relation to maps.

Table 3.4

Inter-Correlation Matrix *of 20-Item Version of VSLQ*

Item 1	3	7	8	9	11	12	13	16	20	21	43	51	53	55	56	58	62	67	69
Correlation																			
1 1.00	-.123	.005	.087	-.183	-.113	.051	-.185	.071	.214	-.069	-.136	.208	.069	.097	-.171	-.155	.131	.213	-020
3 -.123	1.00	.087	.271	.108	.108	-.160	-.048	-.064	.067	-.020	.068	-.037	.039	-.053	.187	.075	-.184	-.107	-.083
7 .005	.087	1.00	.032	.035	.174	.046	.076	.150	-.072	-.086	.109	.028	.000	-.050	-.012	.053	.167	.082	.039
8 .087	.271	.032	1.00	.000	.115	-.308	-.204	-.284	.009	-.157	.080	.077	-.025	-.575	.252	-.068	-.109	-.081	-.084
9 -.183	.108	.035	.000	1.00	.062	-.088	.275	.097	-.031	.242	.289	-.588	.029	.035	.148	.233	.223	.052	-.025
11 -.113	.108	.174	.115	-.062	1.00	.015	.025	.115	-.067	-.114	-.022	-.077	-.268	-.078	.118	-.018	-.078	.017	-.019
12 .051	-.160	.046	-.308	-.088	.015	1.00	-.041	.214	.045	.056	.085	.044	.063	.442	-.297	-.167	.076	.341	.142
13 -.185	-.048	.076	-.204	.275	.025	-.041	1.00	.356	-.099	.181	.108	-.158	-.109	.112	.060	.259	-.248	-.131	.074
16 .071	-.064	.150	-.284	.097	.115	.214	.356	1.00	-.010	.086	.106	.041	-.001	.253	-.156	-.094	.087	.129	.057
20 .214	.067	-.072	.009	-.031	-.067	.045	-.099	-.010	1.00	-.150	-.147	.147	.171	.084	-.121	.020	.135	.091	.208
21 -.069	-.020	-.086	-.157	.242	-.114	.056	.181	.086	-.150	1.00	.026	-.164	.014	.225	-.060	-.057	-.205	-.037	-.021
43 -.136	.068	.109	.080	.289	-.022	.085	.108	.106	-.147	.026	1.00	-.034	.029	.013	.081	.170	-.064	.092	.158
51 .208	-.037	.028	.077	-.588	-.077	.044	-.158	.041	.147	-.164	-.034	1.00	.073	.031	-.113	-.089	.297	.125	.081
53 .069	.039	.000	-.025	.029	-.268	.063	-.109	-.001	.171	.014	.029	.073	1.00	.050	-.039	-.147	.143	.045	.040
55 .097	-.053	-.050	-.575	.035	-.078	.442	.112	.253	.084	.225	.013	.031	.050	1.00	-.339	.059	.041	.186	.056
56 -.171	.187	.012	.252	.148	.118	-.297	.060	-.156	-.121	-.060	.081	-.113	-.039	-.339	1.00	.260	-.114	-.134	.079
58 -.155	.075	.053	-.068	.233	-.018	-.167	.259	-.094	.020	-.057	.170	-.089	-.147	.059	.260	1.00	-.101	-.015	-.089
62 .131	-.184	.167	-.109	-.223	-.078	.076	-.248	.087	.135	-.205	-.064	.297	.143	.041	-.114	-.101	1.00	.290	.012
67 .213	-.107	.082	-.081	.052	-.017	.341	-.131	.129	.091	-.037	.092	.125	.045	.186	-.134	-.015	.290	1.00	.007
69 -.020	-.083	.039	-.084	-.025	-.019	.142	.074	.057	.208	-.021	.158	.081	.040	.056	.079	-.089	.012	.007	1.00

Item 1	3	7	8	9	11	12	13	16	20	21	43	51	53	55	56	58	62	67	69
Sig (1-tailed)																			
1	.086	.477	.167	.021	.106	.286	.020	.216	.008	.224	.065	.010	.223	.140	.028	.042	.072	.009	.411
3 .086		.168	.001	.116	.115	.038	.298	.239	.230	.414	.225	.342	.334	.277	.018	.202	.020	.117	.180
7 .477	.168		.360	.351	.026	.304	.201	.047	.211	.170	.113	.378	.499	.290	.446	.279	.031	.182	.332
8 .167	.001	.360		.499	.100	.000	.011	.001	.460	.040	.186	.197	.392	.000	.002	.225	.112	.185	.177
9 .021	.116	.351	.499		.245	.165	.001	.140	.365	.003	.001	.000	.373	.349	.050	.004	.006	.281	.389
11 .106	.115	.026	.100	.245		.436	.389	.100	.229	.103	.405	.196	.001	.194	.095	.420	.194	.425	.415
12 .286	.038	.304	.000	.165	.436		.326	.008	.307	.268	.173	.311	.242	.000	.000	.032	.201	.000	.057
13 .020	.298	.201	.011	.001	.389	.326		.000	.135	.022	.115	.039	.113	.107	.252	.002	.003	.073	.206
16 .216	.239	.047	.001	.140	.100	.008	.000		.454	.171	.120	.323	.497	.002	.041	.149	.168	.076	.264
20 .008	.230	.211	.460	.365	.229	.307	.135	.454		.047	.051	.051	.028	.175	.090	.413	.067	.158	.010
21 .224	.414	.170	.040	.003	.103	.268	.022	.171	.047		.385	.034	.440	.006	.252	.263	.011	.343	.407
43 .065	.225	.113	.186	.001	.405	.173	.115	.120	.051	.385		.354	.374	.443	.185	.029	.241	.153	.039
51 .010	.342	.378	.197	.000	.196	.311	.039	.323	.051	.034	.354		.210	.365	.104	.162	.000	.083	.184
53 .223	.334	.499	.392	.373	.001	.242	.113	.497	.028	.440	.374	.210		.288	.334	.051	.056	.310	.329
55 .140	.277	.290	.000	.349	.194	.000	.107	.002	.175	.006	.443	.365	.288		.000	.258	.326	.019	.266
56 .028	.018	.446	.002	.050	.095	.000	.252	.041	.090	.252	.185	.104	.334	.000		.002	.102	.068	.190
58 .042	.202	.279	.225	.004	.420	.032	.002	.149	.413	.263	.029	.162	.051	.258	.002		.132	.434	.162
62 .072	.020	.031	.112	.006	.194	.201	.003	.168	.067	.011	.241	.000	.056	.326	.102	.132		.001	.449
67 .009	.117	.182	.185	.281	.425	.000	.073	.076	.158	.343	.153	.083	.310	.019	.068	.434	.001		.471
69 .411	.180	.332	.177	.389	.415	.057	.206	.264	.010	.407	.039	.184	.329	.266	.190	.162	.449	.471	

Correlations of < .40 were excluded from the analysis. To determine if the analysis was adequate the *KMO* and *BTS* were examined. The *KMO* = .56 was regarded as mediocre (Field, 2009), and *BTS* = .00. Once it was determined that the minimum criteria for an analysis was met the Scree plot, correlation component matrix, and total variance were examined. The point of inflection was identified on the Scree plot. The correlation component matrix (see Table 3.5) was examined to identify the minimum number of factors that most of the items loaded onto. A total of 9 factors were identified. In 17 of the items at least one of the first 4 factors was underlying the instrument. Together the process of identifying the point of inflection on the Scree plot and examining the correlation component matrix determined the number of factors that would be measured by the VSLQ. Any items that did not fall within these factors were removed.

Table 3.5

Component Matrix of 20-Item Version of VSLQ

	Component								
	1	2	3	4	5	6	7	8	9
Item									
1	.422								-.405
3							.466		.556
7			.634						
8	-.580	-.454							
9	-.419	.558		.426					
11			.488	-.488					
12	.582								
13		.606							
16	.463							.438	
20				.435			.554		
21		.477							
34			.410						
51	-.456	.448							
53				.592					
55	.535	.550							
56	-.589								
58						-.582			
62		.496							
67	.455								
69					.445	.550			

The total variance loadings (see Tables 3.6) for these factors were examined to ensure that they were at an acceptable level. All 9 factors extracted from the VSLQ had an eigenvalue of > 1.00. However, Fabrigan et al. (1999), and Zwick and Velicer (1986) claim that using an eigenvalue cut off of > 1.00 is problematic as it overestimates the number of factors. Linacre (2002) argues that a cut off of > 1.40 is more effective. Four eigenvalues (2.78, 2.45, 1.55, 1.43) met Linacre's (2002) criteria. An examination of the Scree plot, component matrix, and variance loadings led to a four-factor solution. These four factors accounted for 41.17% of the variance on the instrument. Consequently, 3 more items were removed from the instrument (Item 3: "My bedroom is very neat"; Item 58: "I am able to easily follow verbal instructions given by the teacher"; and, Item 69: "My friends would say that I am funny").

Table 3.6

Total Variance of 20-Item Version of VSLQ

	Initial Eigenvalues			Extraction Sums of Squared Loadings
Component	Total	% of variance	Cumulative %	Total
1	2.789	13.944	13.944	2.789
2	2.459	12.293	26.237	2.459
3	1.556	7.780	34.017	1.556
4	1.430	7.150	41.167	1.430
5	1.321	6.157	47.324	1.231
6	1.157	5.785	53.110	1.157
7	1.117	5.584	58.694	1.117
8	1.068	5.341	64.035	1.068
9	1.004	5.019	69.054	1.004
10	.963	4.813	73.867	
11	.790	3.950	77.817	
12	.769	3.846	81.662	
13	.681	3.407	85.070	
14	.621	3.103	88.173	
15	.579	2.894	91.067	
16	.469	2.343	93.411	
17	.398	1.988	95.399	
18	.355	1.775	97.174	
19	.322	1.609	98.783	
20	.243	1.27	100.00	

A PCA was then conducted on the remaining 17 items (see Table 3.7). Item 12 ("Most people think I am very disorganized. However, I have my own system of organization"), and Item 67 ("I enjoy playing computer games and watching television") demonstrated a moderate positive correlation (*r* = .34). Both Item 12 and Item 67 relate to the underlying factors associated with visual-spatial learning. Item 13 ("When I am doing mathematics the answers to the questions tend to just come to me"), and Item 16 ("I generally find my own methods of solving problems rather than using the ones my teacher suggests") had a moderate positive correlation (*r* = .35). Both Items 13 and 16 relate to the curriculum area of mathematics, which is generally a strength in VSL. Van Garderen (2006) and Silverman (2000) found a positive correlation between visual-spatial ability and mathematical performance for VSL. A strong negative correlation continued between Items 8 and 55 (*r* = -.57), and Items 9 and 51 (*r* = -.58). No correlation (*r* = .00) between Items 8 and 9 continued. No correlation was also found between Item 7 ("When I walk into a room I generally notice everything"), and Item 53 ("When I am trying to remember how to spell a word, I like to sound it out"). Item 7 relates to a characteristic of visual-spatial learning, whilst Item 53 measures auditory-sequential learning.

Table 3.7

PCA of 17-Item Version of VSLQ

Item	1	7	8	9	11	12	13	16	20	21	43	51	53	55	56	62	67
Correlation																	
1	1.00	.005	.087	-.183	-.113	.051	-.185	.071	.214	-.069	-.136	.208	.069	.097	-.171	.131	.213
7	.005	1.00	.032	.035	.174	.046	.076	.150	-.072	-.086	.109	.028	.000	-.050	-.012	.167	.082
8	.087	.032	1.00	.000	.115	-.308	-.204	-.284	.009	-.157	.080	.077	-.025	-.575	.252	-.109	-.081
9	-.183	.035	.000	1.00	-.062	-.088	.275	.097	-.031	.242	.289	-.588	.029	.035	.148	-.223	.052
11	-.113	.174	.115	-.062	1.00	.015	.025	.115	-.067	-.114	-.022	-.077	-.268	-.078	.118	-.078	.017
12	.051	.046	-.308	-.088	.015	1.00	-.041	.214	.045	.056	.085	.044	.063	.442	-.297	.076	.341
13	-.185	.076	-.204	.275	.025	-.041	1.00	.356	-.099	.181	.108	-.158	-.109	.112	.060	-.248	-.131
16	.071	.150	-.284	.097	.115	.214	.356	1.00	-.010	.086	.106	.041	-.001	.253	-.156	.087	.129
20	.214	-.072	.009	-.031	-.067	.045	-.099	-.010	1.00	-.150	-.147	.147	.171	.084	-.121	.135	.091
21	-.069	-.086	-.157	.242	-.114	.056	.181	.086	-.150	1.00	.026	-.164	.014	.225	-.060	-.205	-.037
43	-.136	.109	.080	.289	-.022	.085	.108	.106	-.147	.026	1.00	-.034	.029	.013	.081	-.064	.092
51	.208	.028	.077	-.588	-.077	.044	-.158	.041	.147	-.164	-.034	1.00	.073	.031	-.113	.297	.125
53	.069	.000	-.025	.029	-.268	.063	-.109	-.001	.171	.014	.029	.073	1.00	.050	-.039	.143	.045
55	.097	-.050	-.575	.035	-.078	.442	.112	.253	.084	.225	.013	.031	.050	1.00	-.339	.041	.186
56	-.171	-.012	.252	.148	.118	-.297	.060	-.156	-.121	-.060	.081	-.113	-.039	-.339	1.00	-.114	-.134
62	.131	.167	-.109	-.223	-.078	.076	-.248	.087	.135	-.205	-.064	.297	.143	.041	-.114	1.00	.290
67	.213	.082	-.081	.052	.017	.341	-.131	.129	.091	-.037	.092	.125	.045	.186	-.134	.290	1.00
Item	1	7	8	9	11	12	13	16	20	21	43	51	53	55	56	62	67
Sig (1-tailed)																	
1		.477	.167	.021	.106	.286	.020	.216	.008	.224	.065	.010	.223	.140	.028	.072	.009
7	.477		.360	.351	.026	.304	.201	.047	.211	.170	.113	.378	.499	.290	.446	.031	.182
8	.167	.360		.499	.100	.000	.011	.001	.460	.040	.186	.197	.392	.000	.002	.112	.185
9	.021	.351	.499		.245	.165	.001	.140	.365	.003	.001	.000	.373	.349	.050	.006	.281
11	.106	.026	.100	.245		.436	.389	.100	.229	.103	.405	.196	.001	.194	.095	.194	.425
12	.286	.304	.000	.165	.436		.326	.008	.307	.268	.173	.311	.242	.000	.000	.201	.000
13	.020	.201	.011	.001	.389	.326		.000	.135	.022	.115	.039	.113	.107	.252	.003	.073
16	.216	.047	.001	.140	.100	.008	.000		.454	.171	.120	.323	.497	.002	.041	.168	.076
20	.008	.211	.460	.265	.229	.307	.135	.454		.047	.051	.051	.028	.175	.090	.067	.158
21	.224	.170	.040	.003	.103	.268	.022	.171	.047		.385	.034	.440	.006	.252	.011	.343
43	.065	.113	.186	.001	.405	.173	.115	.120	.051	.385		.354	.374	.443	.185	.241	153
51	.010	.378	.197	.000	.196	.311	.039	.323	.051	.034	.354		.210	.365	.104	.000	.083
53	.223	.499	.392	.373	.001	.242	.113	.497	.028	.440	.374	.210		.288	.334	.056	.310
55	.140	.290	.000	.349	.194	.000	.107	.002	.175	.006	.443	.365	.288		.000	.326	.019
56	.028	.446	.002	.050	.095	.000	.252	.041	.090	.252	.185	.104	.334	.000		.102	.068
62	.072	.031	.112	.006	.194	.201	.003	.168	.067	.011	.241	.000	.056	.326	.102		.001
67	.009	.182	.185	.281	.425	.000	.073	.076	.158	.343	.153	.083	.310	.019	.068	.001	

Correlations of < .40 were excluded from the analysis. The *KMO* = .59 and *BTS* = .00. Once it was determined that the minimum criteria for analysis was met, the Scree plot, correlation component matrix, and total variance were examined. The point of inflection was identified on the Scree plot. The correlation component matrix (see Table 3.8) was examined to identify the minimum number of factors that most of the items loaded onto. A total of six factors were identified. In 15 of the items at least one of the first 4 factors was underlying the instrument. Together the process of identifying the point of inflection on the Scree plot and examining the correlation component matrix determined the number of factors that would be measured by the VSLQ. Any items that did not fall within these factors were removed.

Table 3.8

Component Matrix of 17-Item Version of VSLQ

	Component					
Item	1	2	3	4	5	6
1						.449
7			.628			
8	-.517	-.503				
9		.594		.519		
11			.617			
12	.604					
13		.603			.495	
16	.444					
20						.605
21		.512				
34				.513		
51	-.518	.425				
53				.524		
55	.629	.489				
56	-.585			.406		
62		.476				
67	.491					

The total variance loadings (see Table 3.9) for these factors were examined to ensure that they were at an acceptable level. All 6 factors extracted from the VSLQ had an eigenvalue of > 1.00. Three eigenvalues (2.61, 2.40, 1.52) met Linacre's (2002) criteria of > 1.40. An examination of the Scree plot, component matrix, and variance loadings suggested that the fourth factor with an eigenvalue of 1.37 should be included in the instrument. Zwick and Velicer (1986) assert that the Scree test as a means of determining factors is more accurate and less variable than using eigenvalues. As such, using both the eigenvalue and Scree plot to determine the underlying factors on the VSLQ, would make the result more accurate. These four factors accounted for 46.60% of the variance on the instrument. Consequently, two more items were removed from the instrument (Item 1: "When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read"; and, Item 20: "I hate studying algebra in mathematics").

Table 3.9

Total Variance of 17-Item Version of VSLQ

	Initial Eigenvalues			Extraction Sum of Squared Loadings
Component	Total	% of variance	Cumulative %	Total
1	2.614	15.375	15.375	2.614
2	2.409	14.173	29.548	2.409
3	1.528	1.988	35.537	1.528
4	1.371	8.063	46.600	1.371
5	1.113	6.549	53.149	1.113
6	1.071	6.299	59.448	1.071
7	.972	5.719	65.167	
8	.885	5.203	70.370	
9	.823	4.840	75.210	
10	.764	4.496	79.906	
11	.681	4.007	83.712	
12	.645	3.796	87.508	
13	.603	3.547	91.055	
14	.499	2.938	93.993	
15	.410	2.413	96.406	
16	.362	2.128	98.534	
17	.249	1.466	100.00	

A final PCA was then conducted on the remaining 15 items (see Table 3.10). A significant positive correlation was found between items 8 and 55 (r = .57), and Items 12 and 55 (r = .44). Item 8 ("I have neat handwriting") and Item 55 ("My teachers tell me I have poor or messy handwriting") both relate to organisational skills when handwriting. However, a negative correlation would have been expected because they are reverse items. Item 12 ("Most people think I am very disorganized. However, I have my own system of organization"), and Item 55 relate to disorganisation, which is an underlying factor associated with visual-spatial learning. A significant negative correlation (r = -.58) was also identified between Item 9 ("I am good at reading maps"), and Item 51 ("I find it difficult to read maps. I prefer that someone gives me verbal or written directions to a location"). A negative correlation was expected between Items 9 and 51, as they are reversed items relating to mapping ability. No correlation (r = .00) was also found between Item 7 ("When I walk into a room I generally notice everything"), and Item 53 ("When I am trying to remember how to spell a word, I like to sound it out"). Item 7 relates to a characteristic of visual-spatial learning, whilst Item 53 measures auditory-sequential learning. A negative correlation would have been expected because they measure different learning styles. No correlation (r = .00) between Items 8 and 9 continued.

Table 3.10

PCA of 15-Item Version of VSLQ

Item	7	8	9	11	12	13	16	21	43	51	53	55	56	62	67
Correlation															
7	1.00	.032	.035	.174	.046	.076	.150	-.086	.109	.028	.000	-.050	-.012	.167	.082
8	.032	1.00	.000	.115	-.308	-.204	-.284	-.157	.080	.077	-.025	.575	.252	-.109	-.081
9	.035	.000	1.00	-.062	-.088	.275	.097	.242	.289	-.588	.029	.035	.148	.223	.052
11	.174	.115	-.062	1.00	.015	.025	.115	-.114	-.022	-.077	-.268	-.078	.118	-.078	.017
12	.046	-.308	-.088	.015	1.00	-.041	.214	.056	.085	.044	.063	.442	-.297	.076	.341
13	.076	-.204	.275	.025	-.041	1.00	.356	.181	.108	-.158	-.109	.112	.060	-.248	-.131
16	.150	-.284	.097	.115	.214	.356	1.00	.086	.106	.041	-.001	.253	-.156	.087	.129
21	-.086	-.157	.242	-.114	.056	.181	.086	1.00	.026	-.164	.014	.225	-.060	-.205	-.037
43	.109	.080	.289	-.022	.085	.108	.106	.026	1.00	-.034	.029	.013	.081	-.064	.092
51	.028	.077	-.588	-.077	.044	-.158	.041	-.164	-.034	1.00	.073	.031	-.113	.297	.125
53	.000	-.025	.029	-.268	.063	-.109	-.001	.014	.029	.073	1.00	.050	-.039	.143	.045
55	-.050	-.575	.035	-.078	.442	.112	.253	.225	.013	.031	.050	1.00	-.339	.041	.186
56	.012	.252	.148	.118	-.297	.060	-.156	-.060	.081	-.113	-.039	-.339	1.00	-.114	-.134
62	.167	-.109	-.223	-.078	.076	-.248	.087	-.205	-.064	.297	.143	.041	-.114	1.00	.290
67	.082	-.081	.053	.017	.341	-.131	.129	-.037	.092	.125	.045	.186	-.134	.290	1.00
Item	7	8	9	11	12	13	16	21	43	51	53	55	56	62	67
Sig (1-tailed)															
7		.360	.351	.026	.304	.201	.047	.170	.113	.378	.499	.290	.446	.031	.182
8	.360		.499	.100	.000	.011	.001	.040	.186	.197	.392	.000	.002	.112	.185
9	.351	.499		.245	.165	.001	.140	.003	.001	.000	.373	.349	.050	.006	.281
11	.026	.100	.245		.436	.389	.100	.103	.405	.196	.001	.194	.095	.194	.425
12	.304	.000	.165	.436		.326	.008	.268	.173	.311	.242	.000	.000	.201	.000
13	.201	.011	.001	.389	.326		.000	.022	.115	.039	.113	.107	.252	.003	.073
16	.047	.001	.140	.100	.008	.000		.171	.120	.323	.497	.002	.041	.168	.076
21	.170	.040	.003	.103	.268	.022	.171		.385	.034	.440	.006	.252	.011	.343
43	.113	.186	.001	.405	.173	.115	.120	.385		.354	.374	.443	.185	.241	.153
51	.378	.197	.000	.196	.311	.039	.323	.034	.354		.210	.365	.104	.000	.083
53	.499	.392	.373	.011	.242	.113	.497	.440	.374	.210		.288	.334	.056	.310
55	.290	.000	.349	.194	.000	.107	.002	.006	.443	.365	.288		.000	.326	.019
56	.446	.002	.050	.095	.000	.252	.041	.252	.185	.104	.334	.000		.102	.068
62	.031	.112	.006	.194	.201	.003	.168	.011	.241	.000	.056	.326	.102		.001
67	.182	.185	.281	.425	.000	.073	.076	.343	.153	.083	.310	.019	.068	.001	

Correlations of < .40 were excluded from the analysis. The *KMO* = .60 and *BTS* = .00. The total variance (see Table 3.11) of the 15 items was examined to ensure that they covered enough of the variance within the factors. All 5 factors extracted from the VSLQ had an eigenvalue of > 1.00. However, following the claims of Fabrigan et al. (1999), Zwick and Velicer (1986), and Linacre's (2002) a cut off of > 1.40 was used. Three eigenvalues (2.52, 2.25, 1.50) met the criteria. An examination of the Scree plot, component matrix, and variance loadings supported the inclusion of the fourth factor (1.35). These four factors accounted for 50.9% of the variance on the instrument. No items were removed from the VSLQ.

Table 3.11

Total Variance of 15-Item Version of VSLQ

	Initial Eigenvalues			Extraction Sum of Squared Loadings
Component	Total	% of variance	Cumulative %	Total
1	2.527	16.848	16.848	2.257
2	2.250	14.997	31.845	2.250
3	1.506	10.039	41.884	1.506
4	1.353	9.023	50.907	1.353
5	1.111	7.045	58.312	1.111
6	.942	6.279	64.590	
7	.829	5.530	70.120	
8	.790	5.264	75.384	
9	.763	5.085	80.469	
10	.708	4.719	85.188	
11	.618	4.121	89.310	
12	.512	3.412	97.722	
13	.442	2.943	95.665	
14	.388	2.585	98.250	
15	.262	1.750	100.00	

Results

At a correlation of > .40, 15 items were retained on the VSLQ. Four factors were extracted from the items. The eigenvalues of the first 3 factors (2.52, 2.25, 1.50) met the eigenvalue cut off (> 1.40) established by Fabrigan et al. (1999), Zwick and Velicer (1986), and Linacre's (2002). Despite not meeting the eigenvalue cut off > 1.40 the fourth factor (1.35) was included through an examination of the Scree plot. These four factors explained a total of 50.90% of variance in the instrument. Due to the relatively equal magnitudes in the set of eigenvalues it can be argued that there is little multicollinearity in the set of data analysed during Study 1 (Freund & Littell, 2000). This is further supported by Field's (2009) assertion that r above .80 suggest multicollinearity may be present in a set of data. All $r < .60$ for the 15-item version of the VSLQ.

The first two factors were dominant with eigenvalues > 2.00. Factors one and two reflect the characteristics of organisation (disorganisation) and spatial awareness, respectively. The organisational difficulty of VSL has been discussed extensively in the literature (Von Karolyi et al., 2003; Mann, 2005; Silverman, 2002; Silverman & Freed, 1991). Organisation for students with a preference for visual-spatial learning is often a stumbling block (Mann, 2005). VSL are usually disorganised and may miss details. These students are highly aware of space but pay little attention to time (Silverman & Freed, 1991). Silverman (2003) claims that students with a preference for visual-spatial learning tend to be organisationally impaired and unconscious of time. Kozhevnikov et al.'s (2005) object-spatial-verbal cognitive style model identifies the ability to transform and represent spatial relations of objects as a characteristic of VSL. This is supported by Silverman's (2003) claim that students with a preference for visual-spatial learning relate well to space.

Factors three and four are smaller with eigenvalues < 2.00. Factor three reflects object-visualisation. Factor four measures spatial-visualisation. Kozhevnikov et al.'s (2005) object-spatial-verbal cognitive style model identifies object-visualisation as a characteristic of students who have high levels of visual-spatial ability and a preference for visual-spatial learning. They prefer to construct vivid, concrete, and detailed images of individual objects, rely primarily on visual-object strategies, and are better on object imagery tasks. The VSL, according to Silverman (2005), thinks primarily in pictures. Spatial-visualisation is the ability to mentally rotate two-dimensional and three-dimensional figures (Weckbacher, 2007). Mann (2005) has identified visual transformation as a strength in students who have a preference for visual-spatial learning.

Four items on the VSLQ loaded onto multiple factors. Item 8 loaded onto factors 1 and 2. Item 9 loaded onto factors 2 and 4. Item 51 loaded onto factors 1 and 2. Item 55 loaded onto factors 1 and 2. Hutchenson (1999) argues that when an item loads onto multiple factors it causes ambiguity and confusion. For this reason, the four items were assigned to the dominant factor. Items 8, 9 and 51 were assigned to factor 2. Item 55 was assigned to factor 1 (see Table 3.12). Comrey and Lee (1992) argue that items should be loaded onto the primary factor with the strongest loading.

Table 3.12

Underlying Factors on the 15-Item Version of VSLQ

Factor	Characteristic	Eigenvalues	Item	Loadings
1	Organisation (disorganisation)	2.52	8 - I have neat handwriting	-.517
			12 - Most people think I am very disorganized. However, I have my own system of organization	.604
			16 - I generally find my own methods of solving problems rather than using the ones my teacher suggests	.444
			55 - My teachers tell me I have poor or messy handwriting	.629
			56 - I always show my working when completing problems in mathematics	-.585
			67 – I enjoy playing computer games and watching television	.476
2	Spatial awareness	2.25	9 - I am good at reading maps	.594
			13 - When I am doing mathematics the answers to the questions tend to just come to me	.603 .512
			21 - I love studying chemistry in science	.425
			51 - I find it difficult to read maps. I prefer that someone gives me verbal or written directions to a location.	.491
			62 – I hate studying geometry (shapes and angles) in mathematics	
3	Object-visualisation	1.50	7 - When I walk into a room I generally notice everything	.628
			11 - When I am learning a new word I prefer to visualize the whole word in my head rather than sounding it out	.617
4	Spatial visualisation	1.35	34 - I am good at jigsaws	.513
			53 - When I am trying to remember how to spell a word, I like to sound it out	.524

Discussion

The main aim of Study 1 was to identify the factors underlying Capp's (2006) VSLQ. The results of Study 1 support the literature in the field of visual-spatial ability and visual-spatial learning. Four factors (organisation [disorganisation], spatial awareness, object-visualisation, spatial visualisation) were identified during the EFA. Burton and Fogarty (2003) claim that visual imagery is a multidimensional concept. Organisation (disorganisation) was identified as the dominant factor. Silverman and Freed (1991) discuss the disorganised nature of VSL. Silverman (2013) furthers this argument claiming that they are organisationally impaired and unconscious about time. Research (Bakken, Friis, Lovoll, Smeby, & Martinsen, 2007; Kenworthy et al., 2005) has shown that students with ASD have both visual-spatial strengths and difficulties with organisation. The six items on the VSLQ that load onto the organisation (disorganisation) factor reflect the extensive literature on the organisational ability of students with a preference for visual-spatial learning.

The remaining three factors reflect the visual system of Kozhevnikov et al.'s (2005) object-spatial-verbal cognitive style model, which outlines how Visualizers focus on the spatial relations between objects. Central to this model is the recognition that individuals differ in the degree to which they depend on imagery to process information. This is supported by Green and Schroder (1990) who argue that within the visual dimension individuals possess varying degrees of ability. Kozhevnikov et al. (2005) assert that the visual-spatial system can be subdivided into an object Visualizer dimension and a spatial Visualizer dimension, with object Visualizers encoding and processing information holistically, whilst spatial Visualizers generate and process images analytically. The nine items on the VSLQ that fall on these three factors help differentiate the degree to which a student depends on different sub-factors within imagery to process information. They also help to identify where a student falls along the visual-spatial learning and auditory-sequential learning spectrum. Due to the small number of participants in Study 1 (n = 125) the loadings of the 15 items onto the 4 factors cannot be argued to be significant in line with the arguments of Bartlett II et al. (2001), and Burmeister and Aitken (2012). A small sample size means that the item loading on a factor needs to be higher to be considered significant (Bartlett II et al., 2001). All of the factor loadings were < .63. As such, the loadings of the 15 items onto the 4 factors can be claimed to be not significant. Tabachnick and Fidell (2001, 2007) identify the risk of erroneous conclusions occurring as a result a small participant to item ratio, resulting in the extraction of erroneous factors or miss-assignment of items to factors.

Items that loaded onto multiple factors during Study 1 were assigned to the dominant factor. Comrey and Lee (1992) claim that items should be loaded onto the primary factor with the strongest loading. Hutchenson (1999) argues that when an item loads onto multiple factors it causes ambiguity and confusion. Costello and Osborne (2005) have identified small sample size as a possible cause of items being loaded onto an incorrect factor or multiple factors. In Study 1 the participant to item ratio was < 2:1. Costello and Osborne's (2005) research has shown that very small sample size can result in at least two items being loaded onto the wrong or multiple factors. The researcher will aim to increase the participant to item ratio in Study 2 to reduce the likelihood of errors of inference. Tabachnick and Fidell (2001) have identified item wording as a possible cause of cross loading items.

Due to the confusing wording of Item 51 ("I find it difficult to read maps. I prefer that someone gives me verbal or written directions to a location"), this item will be reworded in Study 2. In Study 1 this item may have caused confusion with the respondent. The respondent may find maps easy to read but prefer verbal or written directions. Alternatively, the respondent may find reading maps difficult but not like verbal or written directions. Item 9 ("I am good at reading maps") addresses map reading ability. For this reason, Item 51 will be reworded in Study 2 to "I prefer that someone gives me verbal or written directions to a location." The remaining three items that loaded onto multiple factors may have been the result of a small population sample. Researchers (Givens, Smith, & Tweedie, 1997; Rothstein, Sutton, & Borenstein, 2005; Sterne, Gavaghan, & Egger, 2000) have shown that small sample sizes tend to have much larger positive effect sizes on data.

The EFA reduced Capp's (2006) VSLQ from 70 items to 15. Scale brevity is advantageous in relation to questionnaires. Reducing the length of the VSLQ may help to improve the accuracy of responses and response rates. 78.57% of items on Capp's (2006) VSLQ were removed during Study 1. By providing classroom teachers with a shorter and more accurate instrument for identifying secondary school students who have a preference for visual-spatial learning, they will be able to use it at the beginning of a lesson to identify the learning preferences of their students. Longer instruments that take more time to complete negatively impact on teaching time. By identifying these students, teachers will be able to use appropriate teaching strategies to cater for their students' individual learning needs. Study 1 began the process of developing a reliable and valid instrument for measuring preferences for visual-spatial learning in secondary school students. The process of providing evidence of the reliability of the VSLQ will continue during Study 2.

Chapter 4: Study 2

> Researchers need to have measures with good reliability and validity that are appropriate for use across diverse populations. CFA may be one step in that process (Harrington, 2009).

In Study 1 an EFA was used to identify the underlying factors being measured by the VSLQ. At a correlation of > .40, 15 items were retained (see Table 4.1). Four factors were extracted from the items. The eigenvalues of the first 3 factors (2.52, 2.25, 1.50) met the eigenvalue cut off (> 1.40) established by Fabrigan et al. (1999), Zwick and Velicer (1986), and Linacre (2002). Despite not meeting the eigenvalue cut off of > 1.40 the fourth factor (1.35) was included through an examination of the Scree plot. These four factors explained a total of 50.90% of variance in the instrument.

Table 4.1

Fifteen Item Version of the VSLQ

Item	Content
1	When I walk into a room I generally notice everything
2	I have neat handwriting
3	I am good at reading maps
4	When I am learning a new word I prefer to visualize the whole word in my head rather than sounding it out
5	Most people think I am very disorganised. However, I have my own system of organisation.
6	When I am doing mathematics the answers to the questions tend to just come to me
7	I generally find my own methods of solving problems rather than using the ones my teacher suggests
8	I love studying chemistry in science
8	I prefer that someone gives me verbal or written directions to a location.
10	When I am trying to remember how to spell a word, I like to sound it out
11	My teachers tell me I have poor or messy handwriting
12	I always show my working when completing problems in mathematics
13	I am able to easily follow verbal instructions given by the teacher
14	I hate studying geometry (shapes and angles) in mathematics
15	I enjoy playing computer games and watching television

In Study 2, a CFA was used to test the hypothetical judgments developed during the previous study. In Study 1, four underlying factors were identified. Factors one and two reflect the characteristics of organisation (disorganisation) and spatial awareness, respectively. The organisational difficulties of VSL have been discussed extensively in the literature (Von Karolyi et al., 2003; Mann, 2005; Silverman, 2002; Silverman & Freed, 1991). Kozhevnikov et al. (2005) identifies the ability to transform and represent spatial relations of objects as a characteristic of VSL. This is supported by Silverman's (2003) claim that students with a preference for visual-spatial learning relate well to space. Factors three and four reflect object-visualisation and spatial-visualisation. Kozhevnikov et al. (2005) identifies object-visualisation as a characteristic of students who have visual-spatial strengths and a preference for visual-spatial learning. Spatial-visualisation is the ability to mentally rotate two-dimensional and three-dimensional figures (Weckbacher, 2007). Mann (2005) has identified the ability to mentally rotate shapes as a strength in students who have a preference for visual-spatial learning. The aim of Study 2 is to complete the process of providing evidence of the internal consistency of the revised 15-item version of the VSLQ. Demonstrating the reliability of the instrument, in the form of internal consistency, is a prerequisite to demonstrating its construct validity.

Method

Participants. To demonstrate internal consistency, the revised 15-item version of the VSLQ was implemented with a population of 227 students in Years 8 to 12. Overall, the sample exhibited variability in respect to year level: Year 8 (n = 47), Year 9 (n = 55), Year 10 (n = 36), Year 11 (n = 74), Year 12 (n = 15). The average age of the participant pool was 16.10 years. The mean age of the females was 16.6 years. The males had a mean age of 15.10.

Procedure. Prior to the CFA a number of hypothetical judgments were made about the nature of the relationships between the underlying factors on the VSLQ. During Study 1, four factors were identified as underlying the 15-item version of the VSLQ. However, a re-examination of the Scree plot suggested that a two-factor solution was appropriate. Factors 1 and 2 had eigenvalues > 2.00 (2.52, 2.25). Velicer and Jackson (1990) argue that using only eigenvalues as the criterion for determining the number of factors to include in an analysis can lead to the retention of too many factors. During Study 1, four items (8, 9, 51, 55) loaded onto multiple factors. Costello and Osborne's (2005) research has shown that a very small sample size can result in at least two items being loaded onto the wrong or multiple factors. This is further supported by Tabachnick and Fidell (2001, 2007) who identify the risk of erroneous conclusions occurring as a result a small participant to item ratio, resulting in the extraction of erroneous factors or miss-assignment of items to factors. The sample size in Study 1 was small (n = 125), resulting in a very small participant to item ratio (< 2:1). These four items loaded primarily onto the two dominant factors.

The assumption that only two factors, organisation (disorganisation) and spatial awareness, underlie the VSLQ is supported by the current literature (Lean & Clements, 1981; Mann, 2005; Mayer & Massa, 2003; Silverman, 2013) in the field. The assertion that organisation (disorganisation) is a factor underlying a preference for visual-spatial learning is supported by Silverman (2013) who claims that VSL tend to be organisationally impaired. She also claims that VSL have a different brain organisation to ASL. Mayer and Massa (2003) claim that spatial ability is an underlying factor of visual learning. Kozhevnikov et al. (2005) assert that object-visualisation and spatial-visualisation fall on a spectrum with object-visualisation being a pre-cursor to spatial ability. This is supported by Lean and Clements (1981) who claim that spatial ability is a fundamental precursor to mathematical ability. Those students with high-level spatial abilities are more likely to choose careers in fields related to mathematics, such as engineering (Mann, 2005).

Four factors could have emerged in the 15-item version of the VSLQ due to the negative wording of some of the items on the instrument (Item 5: “Most people think I am disorganised. However, I have my own system of organisation;” Item 8: “I prefer that someone gives me verbal or written directions to a location;” Item 11: “My teachers tell me I have poor or messy handwriting;” Item 14: “I hate studying geometry [shapes and angles] in mathematics”). This is supported by the claims of a number of researchers (Bolin & Dodder, 1990; Cordery & Sevastos, 1993; Fried & Ferris, 1986; Kelloway, Canto, & Southwell, 1992; Roberts, Lewinsohn & Seeley, 1993) that superfluous factors emerge as a result of negatively worded items. This is because the link between negatively worded items is believed to be different to those that are positively worded. The 15-item version of the VSLQ contained four negatively worded items, which may account for the two additional factors that were identified during Study 1. Items 8 and 11 loaded onto two factors, which may have occurred as a result of the item’s negative wording.

Using the paradigm that the 15-item version of the VSLQ contains two underlying factors the data collected during Study 2 was run through SPSS. The first step was to conduct a data screening (Schwartz, 2011). The frequencies for each of the items were graphed as histograms. The distributions of each of the histograms were then examined. Normal distribution is important in a set of data because if it is normally distributed a researcher can make inferences about the values of the variable. A non-normal distribution makes inferences difficult. No items were removed from the 15-item version of the VSLQ due to a non-normal distribution. The items were then examined for kurtosis and skewness.

Doane and Seward (2011a, 2011b) argue that for n = 225 skewness scores should fall within -0.28 and 0.28. Values outside this range would suggest a non-normal population. Hae-Young (2013) believes that skewness scores should fall between -.43 and .43. In contrast, Schwab (2002) argues that "a variable is reasonably close to normal if its skewness and kurtosis have values between –1.0 and 1.0." According to statistical convention, Cameron (2013) asserts that skewness should fall in the range from -2.00 and 2.00 if data is normally distributed. Bulmer (1979) has established a set of rules for interpreting skewness. If skewness is less than -1.00 or greater than 1.00, the distribution is highly skewed. If skewness is between -1.00 and -0.50 or between 0.50 and 1.00 the distribution is moderately skewed. If skewness is between -0.50 and 0.50, the distribution is approximately symmetric. As debate exists in the literature about the boundaries for non-normal skewness scores a liberal position will be taken. It can be argued that all of the items fall within acceptable levels of skewness and are thus open to analysis. The largest skewness score was 0.94, which met the standards established by both Cameron (2013), and Bulmer (1979).

All of the items on the 15-item version of the VSLQ demonstrated acceptable levels of kurtosis. Hae-Young (2013) identifies scores between 0.00 and -1.29 as acceptable levels for kurtosis. According to statistical convention, Cameron (2013) asserts that kurtosis should fall in the range from 2.00 and -2.00 if data is normally distributed. All of the kurtosis scores fell within the acceptable range of -.031 and -1.18. As such, it can be claimed that all of the items on the 15-item version of the VSLQ fall within acceptable levels of a normal distribution and are thus open to evaluation using a CFA. The largest kurtosis score was -1.16, which met the standards established by both Cameron (2013), and Hae-Young (2013).

The data was then analysed using AMOS. Each of the 15 items on the VSLQ were assigned to one of the two factors – organisation (disorganisation) or spatial awareness. Items 2, 5, 7, 12, and 13 were loaded on the factor entitled organisation (disorganisation). Items 1, 3, 4, 6, 8, 9, 10, 11, 14, and 15 were loaded on the factor entitled spatial awareness. Loading all of the 15 items onto the two factors did not achieve an acceptable X^2 score. Fields (2009) defines a X^2 distribution as the sum of squares of several normally distributed variables, which is used to test hypotheses about categorical data to determine if the observed data fits a hypothesised model. To improve the X^2, items on the VSLQ with low factor loading scores (< .30) that were not doing much were removed from the instrument. This methodology is supported by Tabachnick and Fidell (2007), and Yong and Pearce (2013) who argue that factor loadings must be .30 or greater because anything lower would suggest a really weak relationship between the factor and the relevant item. Seven items were removed from the instrument (see Table 4.2).

Table 4.2

Items Removed From the 15-Item Version of VSLQ

Item	Content
1	When I walk into a room I generally notice everything
4	When I am learning a new word I prefer to visualize the whole word in my head rather than sounding it out
7	I generally find my own methods of solving problems rather than using the ones my teacher suggests
8	I love studying chemistry in science
9	I am good at jigsaws

11	When I am trying to remember how to spell out a word, I like to sound it out
15	I enjoying playing computer games and watching television

Items 4 (“When I am learning a new word I prefer to visualize the whole word in my head rather than sounding it out”), and 11 (“When I am trying to remember how to spell out a word, I like to sound it out”) may have been removed from the 15-item version of the VSLQ because debate exists in the literature about the underlying influences on typical performance in relation to spelling. Rourke and Finlayson (1978) found that performance in spelling of students with superior visual-perceptual and visual-spatial abilities ranged from very low, to average or above. The performance in spelling of students with high-level verbal and auditory-perceptual abilities was found to be superior to students with a preference for visual-spatial learning (Rourke & Finlayson, 1978). Silverman (2013) contradicts this research claiming that students with a preference for visual-spatial learning have superior performance in spelling when they visualise words. Franceschini, Gori, Ruffino, Pedrolli, and Facoetti (2012), Frith (1980), and Plaza and Cohen (2007) found that both visual-spatial and phonological factors are involved in spelling. The contradictory research into how students spell words may have led to the poor X^2 score during the AMOS analysis.

Silverman (2005) claims that playing computer games and watching television suggests a preference for visual-spatial learning. However, Okagaki and Frensch (1994), and Spence and Feng (2010) have found that video game playing influences spatial performance, rather than being evidence of high-level visual-spatial ability or visual-spatial preference. This is further supported by Greenfield (2014) who found that watching television and computer games could develop visual skills, rather than being related to visual-spatial ability. Early television watching may influence computer game play and vice versa. Television and computer game play may both "demand and develop some of the visual-spatial skills" (Greenfield, 2014, p. 84). The debate over the relationship between television viewing, computer game play, and visual-spatial ability may have contributed to the poor X^2 score during the AMOS analysis. Computer game play relates to maximal performance, rather than being a measure of typical performance. Similarly, Item 9 ("I am good at jigsaws") relates to maximal performance of a task. The VSLQ and underlying factors measure typical performance. The contrasting nature of measures of typical and maximal performance may have led to the poor X^2 score during the AMOS analysis.

Item 8 ("I love chemistry"), is a reverse question that measures where on the visual-spatial learning and auditory-sequential learning spectrum that a student falls. Silverman (2005) claims that students with a preference for auditory-sequential learning enjoy chemistry. As such, there is a relationship between typical performance of ASL and enjoyment in chemistry. Enjoyment in a curriculum area is influenced by many variables – ability, learning preference, performance etc. (Good, Aronson, & Inzlicht, 2003). This may have accounted for the poor X^2 score during the AMOS analysis. Research (Bodner & McMillen, 1986; Small & Morton, 1983) also contradicts Silverman's (2005) claims in relation to chemistry. Bodner and McMillen (1986) found a correlation between spatial ability and achievement in general chemistry on both spatial and non-spatial tasks. Small and Morton (1983) claim that auditory-sequential ability and a preference for auditory-sequential learning do not ensure success in organic chemistry. Pribyl and Bodner (1987) found a correlation between spatial ability and performance on spatial tasks in organic chemistry. This is in contradiction to Silverman's (2005) claim that ASL enjoy and are good at chemistry. Hindal (2014) argues that students with a preference for visual-spatial learning perform well at all examinations in this curriculum area. Good et al. (2003) found that enjoyment in a curriculum area is influenced by many different factors, including intrinsic and extrinsic motivation, academic achievement, learning etc. The contradictory literature around enjoyment and achievement in chemistry may have accounted for the poor X^2 score during the AMOS analysis, necessitating the item to be removed from the 15-item version of the VSLQ.

Item 1 ("When I walk into a room I generally notice everything"), was based on a similar item (Item 25: "I can close my eyes and easily picture a scene that I have experienced") on Blazhenkova et al.'s (2006) OSIVQ. This instrument was developed as a measure of typical performance in relation to visual-spatial ability and imaginal capacity. Because this item was not developed as a measure of typical performance in relation to visual-spatial learning, this may have negatively affected the X^2 score during the AMOS analysis. Item 7 ("I generally find my own methods of solving problems rather than using the ones my teacher suggests) focussed on problem solving strategies in all curriculum areas. A re-examination of the literature (Hegarty & Kozhevnikov, 1999; Mann, 2005; Silverman, 2005; Van Garderen & Montague, 2003) on visual-spatial ability and preferences for visual-spatial learning suggested that students apply this problem solving ability primarily to the field of mathematics. The broad nature of this item may have accounted for the poor X^2 score achieved during the data analysis using AMOS.

Table 4.3 outlines the remaining items on the VSLQ. The remaining eight items were then loaded onto the two factors (see Figure 4.1). Items 3, 6, 10, and 14 were loaded onto the factor entitled spatial awareness (SA). Items 2, 5, 12, and 13 were loaded onto the factor entitled organisation (disorganisation) (O).

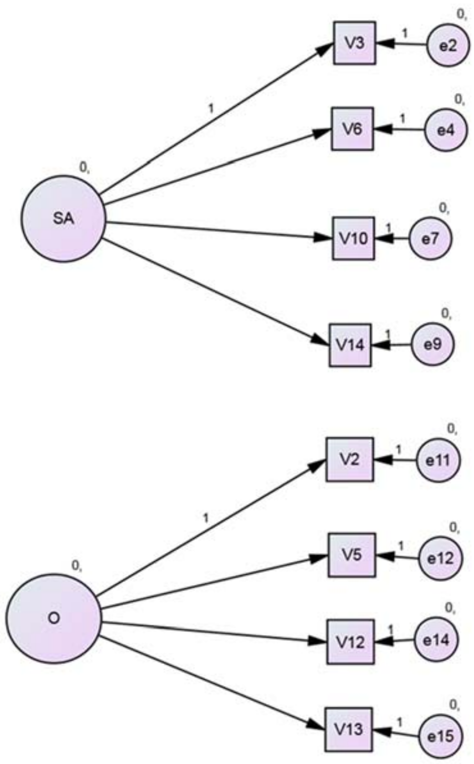
Table 4.3

Eight-Item Version of VSLQ

Item	Content
2	I have neat handwriting
3	I am good at reading maps
5	Most people think I am very disorganised. However, have my own system of organisation.
6	When I am doing mathematics the answers to the questions tend to just come to me
10	I prefer that someone gives me verbal or written directions to a location.
12	My teachers tell me I have poor or messy handwriting
13	I always show my working when completing problems in mathematics
14	I hate studying geometry (shapes and angles) in mathematics

Figure 4.1

CFA With 8-Item and 2-Factor Version of VSLQ



The data was re-analysed using AMOS. At an X^2 = 52.98, *df* = 20, *p* < .001 the relationship between the factors and the items is significant beyond the 0.00025 level (Lowry, 1999). This is further supported by the *RMSEA* = 0.05. MacCallum, Browne, and Sugawara (1996) have used *RMSEA* = 0.01, 0.05, and 0.08 to indicate excellent, good, and mediocre fit, respectively. However, others have suggested *RMSEA* = 0.10 as the cut-off for poor fitting models. Chen, Curan, Bollen, Kirby, and Paxton (2008) believe that there is little empirical support for the use of *RMSEA* = 0.05 or any other value as universal cut-off values to determine adequate model fit. Although the results of this study have an acceptable X^2 score the mediocre *RMSEA* (> 0.05) may be attributed to the nature of the items on the VSLQ. A number of the questions are negatively worded items. Kim and Richardson (2003) believe that responses to negative items differ from those positively worded. Nevertheless, a *RMSEA* = 0.05 is within acceptable levels. To provide further evidence that the VSLQ has adequate model fit, the results were analysed using Mplus. The results of the revised 8-item version of the VSLQ fit even better within a categorical factor model.

Results

Many researchers, such as Marsh, Balla, and Hau (1996), recommend that individuals utilize a range of fit indices. Indeed, Jaccard and Wan (1996) recommend using indices from different classes as well; this strategy overcomes the limitations of each index. Jackson et al. (2009) claim that effectively reported CFA studies should include a range of multiple fit indices (*chi square*, *df*, *p*, *RMSEA*, *CFI*, *TLI*). The CFA results were: *NC* = 2.64 (X^2 = 52.98/ *df* = 20), *p* < .001, *RMSEA* = 0.05, *CFI* = .91, *TLI* = .84, *NFI* = .86, *IFI* = .91.

Discussion

Study 2 built on Study 1 by providing further evidence that the 8-item version of the VSLQ has reliability, in the form of internal consistency. A psychometric instrument is acceptable if the results of the CFA meet acceptable criteria. Following the recommendations of Marsh et al. (1996), and Jaccard and Wan (1996) a range of measures were used to determine if the theoretical model is acceptable. The criterion for acceptance in terms of the *NC* ranges from less than two (Ullman, 2001) to less than five (Schumacker & Lomax, 2004). At *NC* = 2.64 the 8-item version of the VSLQ meets the level for acceptance as proposed by Schumacker and Lomax (2004). According to a number of researchers (Browne & Cudeck, 1993; Hu & Bentler, 1998; Steiger, 1990), the *RMSEA* should be less than .08 and ideally less than .05. A *RMSEA* score of 0.05 for the 8-item version of the VSLQ falls within acceptable limits for a reliable instrument. The *CFI* (.91) for the instrument indicated acceptable fit. This is supported by Fan, Thompson, and Wang (1999) who argue values that approach one indicate an acceptable fit. The TLI (.84) for the 8-item version of the VSLQ did not indicate acceptable fit. Hu and Bentler (1998) identify TLI values > .95 as being acceptable to demonstrate fit. This is further supported by Hooper, Coughlan, and Mullen (2008), McDonald and Ho (2002), and Sharma, Muhkerjee, Kumar, and Dillon (2005) who argue that TLI < .95 indicates a set of data may not have model fit. However, as the *n* < 250 in Study 2 the TLI of .84 may demonstrate model fit for the 8-item version of the VSLQ. This is supported by Hu and Bentler (1999) who found that between 10.60% and 73.20% of true models were rejected when the population samples were n < 250. According to Ullman (2001) the *NFI* varies from zero to one, where one is ideal placing the *NFI* (.86) for the 8-item version of the VSLQ outside an acceptable range. According to Hooper et al. (2008) NFI values should exceed .95. However, because the NFI is positively related to the sample size and that NFI values tend to be less than 1.00 when sample size is small (Hu & Bentler, 1998; Schermelleh-Engel, Moosbrugger, & Muller, 2003) values may not always exceed .95. Due to the small sample size in Study 2 (n = 227) the specific model may be correct although the NFI (.86) does not meet the criteria established by Hooper at al. (2008). *IFI* values that exceed .90 are regarded as acceptable. As such, the *IFI* value for the instrument is within acceptable levels. However, Bollen (1990) raises the issue of the effect sample size (*n*) on fit indices. Researchers (Givens et al., 1997; Rothstein et al., 2005; Sterne et al., 2000) have shown that small sample sizes tend to have much larger positive effect sizes. Cronbach et al. (1980) refers to this as "superrealization bias, when experimenters in small studies are able to monitor the quality of implementation, provide additional assistance, or create unrealistic conditions that could never be replicated on a large scale" (p. 3). Slavin and Smith (2008) found that studies with sample sizes of < 250 had a mean effect size of 0.27, while those with larger sample sizes had an effect size of 0.13, less than half as much. The Cronbach alpha score was not reported in the thesis because this score is highly influenced by sample size. Rouquette and Falissard (2011) argue that Cronbach alpha is not appropriate for studies with *n* < 300. This is because Cronbach alpha scores are more appropriate with larger population sample sizes (Shelvin, Miles, Davies, & Walker, 2000). Study 2 only had a sample size of *n* = 227, making Cronbach alpha an inappropriate statistical measure in this context.

By providing evidence that the 8-item version of the VSLQ has reliability, a secondary school classroom teacher can ensure that the instrument will obtain consistent results. Reliability indicates the accuracy or precision of an instrument (Norland-Tilburg, 1990). This is supported by Esposito's (2002) claim that failing to demonstrate the reliability of an instrument may undermine the quality and utilisation of data. Secondary school teachers can trust that a student identified as having a preference for visual-spatial learning has this preferred learning style. Identification must be followed by effective implementation (Mann, 2006). By using visual-spatial teaching methods students who have a preference for visual-spatial learning will enhance their abilities, and minimise their weaknesses. A supportive classroom environment is essential for students with a preference for visual-spatial learning (Silverman, 2002). Mann (2006) argues that students with spatial strengths who are nurtured and encouraged often pursue careers that fit their unique abilities.

During Study 2 the number of items on the 15-item version of the VSLQ was reduced to 8. The advantage of scale brevity is discussed in the literature (Churchill & Peter, 1984; Cortina, 1993; DeVellis, 1991; Netemeyer et al., 2003; Nunnally & Bernstein, 1994). This is supported by Jepson, Asch, Hershey, and Ubel's (2005) claim that there is a positive correlation between questionnaire length and response rate. Galesic and Bosnjak (2009) hypothesise that the length of a questionnaire is negatively related to initial willingness to engage with the instrument. In other words, when a questionnaire is long fewer participants start and complete the instrument. Students can complete the 8-item version of the VSLQ quickly at the beginning of a lesson. The results of the instrument can determine the pedagogical strategies implemented during a lesson to cater for the individual student's learning style. By demonstrating the reliability of the 8-item version of the VSLQ the classroom teacher can ensure that the results of the completed instruments are consistent. Study 3 will build on the results of Study 2 by providing evidence of the construct validity of the 8-item version of the VSLQ.

Chapter 5: Study 3

> The only relevant test of the validity of a hypothesis is comparison of prediction with experience (Friedman, 1953).

Studies 1 and 2 provided evidence of the internal consistency of the VSLQ. The EFA and CFA also provided some evidence towards the construct validity of the instrument.

To demonstrate that the revised 8-item version of the VSLQ has construct validity, it must be shown to achieve similar results to instruments that purport to measure the same underlying factors (convergent validity), whilst at the same time achieving different results to instruments that measure conflicting underlying factors (divergent validity) (Houston, Schmid, Lynch, & Duff, 1973; Messick, 1990). The revised 8-item version of the VSLQ will have convergent validity if the spatial awareness factor has a positive correlation with the visual-spatial learning factor on Silverman's (2000) VSI, and geometric manipulation and mapping ability factors on Newton and Bristoll's (2009) SAT. The organisation (disorganisation) factor will also have a positive correlation with the visual-spatial learning factor on Silverman's (2000) VSI, and geometric manipulation and mapping ability factors on Newton and Bristoll's (2009) SAT. The revised 8-item version of the VSLQ will have divergent validity if the organisation (disorganisation) factor has a negative correlation with the auditory-sequential learning factor on Silverman's (2000) VSI. There should also be a negative correlation between the spatial awareness factor on the revised 8-item version of the VSLQ and the auditory-sequential learning factor on Silverman's (2000) VSI.

Method

Participants. The revised 8-item version of the VSLQ was administered to 300 secondary school students in Years 8 to 12. Overall, the sample exhibited variability in respect to year level: Year 8 (n = 58), Year 9 (n = 87), Year 10 (n = 105), Year 11 (n = 24), Year 12 (n = 26). The average age of the participant pool was 14.6 years. The mean age of the females was 14.1 years. The males had a mean age of 15.8.

Measures. In addition to completing the revised 8-item version of the VSLQ, the students also completed Silverman's (2000) VSI, and Newton and Bristoll's (2009) SAT.

VSI. The instrument was created by Silverman in 2000 to identify VSL. The instrument consists of 14 items. Silverman (2000) developed the VSI as a verbally anchored, student self-rating scale designed to identify individuals as VSL or ASL. Silverman's (2000) VSI uses a 5-point Likert scale (1 = not true, 2 = somewhat true, 3 = mostly true, 4 = true, 5 = very true). The instrument was validated with 750 fifth and sixth graders of whom 40% were Hispanic, 2% were 'other minorities,' and 58% were Caucasian. Silverman (2000) reported $\alpha = .71$. In contrast, the VSLQ has been tested with Year 8 to 12 students.

Silverman's (2000) VSI is a measure of typical performance designed to differentiate VSL from ASL. As such, the instrument measures the underlying factors of visual-spatial learning and auditory-sequential learning. Eleven items load on the visual-spatial learning factor, three items load onto the auditory-sequential learning factor (see Table 5.1). A positive correlation between the spatial awareness factor on the 8-item version of the VSLQ and the visual-spatial learning factor on Silverman's (2000) VSI will provide evidence of the convergent validity of the 8-item version of the VSLQ. A positive correlation between the underlying factor of organisation (disorganisation) on the 8-item version of the VSLQ and the visual-spatial learning factor on Silverman's (2000) VSI would also provide evidence in support of the convergent validity of the instrument. A negative correlation between the underlying factor of organisation (disorganisation) on the 8-item version of the VSLQ and the auditory-sequential learning factor on Silverman's (2000) VSI will provide evidence of the divergent validity of the 8-item version of the VSLQ. A negative correlation between the underlying factor of spatial awareness on the 8-item version of the VSLQ and the auditory-sequential learning factor on Silverman's (2000) VSI will also provide evidence in support of the divergent validity of the 8-item version of the VSLQ.

Table 5.1

Underlying Factors on Silverman's (2000) VSI and Associated Items

Underlying factor	Items
Preferences for visual-spatial learning	1. I hate speaking in front of a group 2. I think mainly in pictures instead of words 4. I often lose track of times 5. I know more than others think I know 6. I don't do well on tests with time limits 8. I have a wild imagination. 9. I like to take things apart and find out how they work. 10. I hate writing assignments 11. I solve problems in unusual ways 12. It's much easier for me to tell you about things than to write about them 13. I have a hard time explaining how I come up with my answers
Preferences for auditory-sequential learning	3. I am good at spelling 7. I have neat handwriting 14. I am well organized

SAT. The items on Newton and Bristoll's (2009) SAT are concerned with an individual's ability to mentally manipulate shapes, to identify patterns, and make logical deductions. The instrument involves 32 items requiring individuals to match shapes, rotate and manipulate shapes, deconstruct large shapes, assemble a series of smaller shapes to construct larger shapes and follow directions on a map. This psychometric instrument measures maximal performance and requires participants to manipulate geometric shapes as a means of measuring their visual-spatial ability.

Newton and Bristoll's (2009) SAT consists of two underlying factors - geometric manipulation and mapping ability. Items 1-29 load on the geometric manipulation factor, items 30-32 load on the mapping ability factor. A positive correlation between the underlying factor of spatial awareness on the 8-item version of the VSLQ and the geometric manipulation and mapping ability factors on Newton and Bristoll's (2009) SAT will provide evidence of the convergent validity of the 8-item version of the VSLQ. A positive correlation between the underlying factor of organisation (disorganisation) on the 8-item version of the VSLQ and the geometric manipulation and spatial ability factors on Newton and Bristoll's (2009) SAT will also provide evidence of the convergent validity of the 8-item version of the VSLQ. The organisational difficulty of VSL has been discussed extensively in the literature (Von Karolyi et al., 2003; Mann, 2005; Silverman, 2002; Silverman & Freed, 1991). Organisation for students with a preference for visual-spatial learning is often a stumbling block (Mann, 2005). VSL are usually disorganised and may miss details. These students are highly aware of space but pay little attention to time (Silverman & Freed, 1991). Silverman (2013) claims that students with a preference for visual-spatial learning tend to be organisationally impaired and unconscious of time. As such, a high score on Newton and Bristoll's (2009) SAT measuring geometric manipulation and mapping ability should correspond with a high score on the items on the 8-item version of the VSLQ that measure disorganisation.

Data screening. Firstly, the results of the 8-item version of the VSLQ were submitted to a data screening using SPSS. Two of the items appeared to have skewness by looking at their *z* scores, which was determined by dividing the skewness score by the standard error score. Any score higher than $z = 1.60$ is outside acceptable levels. However, Field (2003) argues that for large data sets of more than 200 a visual examination of the histograms is more acceptable. From a visual examination, the items appeared to be within acceptable levels. To clarify the hypothesis that all of the items on the revised 8-item version of the VSLQ had an even distribution the PP plots were also examined. The PP Plots for the items supported the claim that the data had a normal distribution of the data.

A data screening using SPSS was then conducted on the results of Silverman's (2000) VSI. An examination of the *z* scores and a visual examination of the related histograms demonstrated that all items were platykurtic and bimodal. This form of negative kurtosis occurs when there are too few scores in the tails and is quite flat (Field, 2009). Bimodal refers to a set of data that has two modes. The majority of responses on Silverman's (2000) VSI were either one (not true) or five (very true) on the Likert scale. This is in line with the criticisms of this instrument. Silverman (2000) claims that the VSI was validated with a group of 750 elementary school students. However, Van Nijnatten (2013) and Mann (2005) question the statistical evidence provided by Silverman (2000).

The items on Silverman's (2000) VSI also show leniency. Leniency is the process of grouping similar items on a psychometric instrument together (Schmitt & Stults, 1986; Schriesheim, 1979, 1981a, 1981b). Bass and Avolio (1989) claim that leniency of items can result in participants being more generous or critical in their ratings or rankings. Schriesheim (1981a, 1981b) argues that leniency has an effect on the discriminant validity of items. He found that controlling for leniency negatively impacted convergent validity but that discriminant validity was substantially improved. Another criticism of this instrument is the structure of the five point Likert scale. Silverman (2000) has constructed the five-point Likert scale in such a way to influence the responses of the respondents. The scale is designed so that four of the potential responses suggest that an individual is a VSL (2 = somewhat true, 3 = mostly true, 4 = true, 5 = very true). As such, any response to an item other than 1 (not true) suggests that an individual is a VSL. This resulted in a non-normal distribution as evidenced during the data screening. The non-normal distribution of these two instruments was confirmed by an examination of the associated PP Plots.

To facilitate the process of correlating the results of the revised 8-item version of the VSLQ against those of Silverman's (2000) VSI the results of both of these instruments were converted to binary code (dichotomization). Although not a commonly used statistical approach, MacCallum, Zhang, Preacher, and Rucker (2002) found 11.5% of studies published in peer-reviewed journals contained at least one instance of dichotomization. Responses that suggested a preference towards visual-spatial learning or high visual-spatial ability were given a score of 1. All other responses were given a score of 0 (see Tables 5.2 and 5.3). The process of converting the responses from a Likert scale to binary code is supported by the work of Suits (1957). Converting the responses to binary code helped overcome the need for a polykurtik analysis due to the non-normal distribution of the results on these two psychometric instruments. This is supported by the work of MacCallum et al. (2002). They argue that dichotomization is appropriate in situations where the distribution of variables is extremely highly skewed, as in the case of the data collected using Silverman's (2000) VSI. To ensure consistency, the responses on Newton and Bristoll's (2009) SAT were also converted to binary code. Responses that demonstrated high-level geometric manipulation and mapping ability were given a score of 1. All other responses were given a score of 0 (see Table 5.4).

Table 5.2

Items on Silverman's (2000) VSI Converted to Binary Code

Item	Correct response	Binary code	Incorrect response	Binary code
1	2, 3, 4, 5	1	1	0
2	2, 3, 4, 5	1	1	0
3	1	1	2, 3, 4, 5	0
4	2, 3, 4, 5	1	1	0
5	2, 3, 4, 5	1	1	0
6	2, 3, 4, 5	1	1	0
7	1	1	2, 3, 4, 5	0
8	2, 3, 4, 5	1	1	0
9	2, 3, 4, 5	1	1	0
10	2, 3, 4, 5	1	1	0
11	2, 3, 4, 5	1	1	0
12	2, 3, 4, 5	1	1	0
13	2, 3, 4, 5	1	1	0
14	1	1	2, 3, 4, 5	0

Table 5.3

Items on 8-Item Version of the VSLQ Converted to Binary Code

Item	Correct response	Binary code	Incorrect response	Binary code
1	4, 5	1	1, 2, 3	0
2	1, 2	1	3, 4, 5	0
3	1, 2	1	3, 4, 5	0
4	1, 2	1	3, 4, 5	0
5	4, 5	1	1, 2, 3	0
6	1, 2	1	3, 4, 5	0
7	4, 5	1	1, 2, 3	0
8	4, 5	1	1, 2, 3	0

Table 5.4

Items on Newton and Bristoll's (2009) SAT Converted to Binary Code

Item	Correct response	Binary code	Incorrect response	Binary code
1	X	1	A-W	0
2	P	1	A-O, Q-X	0
3	M	1	A-L, N-X	0
4	V	1	A-U, W, X	0
5	G	1	A-F, H-X	0
6	A	1	B-X	0
7	D	1	A-C, E-X	0
8	T	1	A-S, U-X	0
9	C	1	A, B, D-X	0
10	B	1	A, C-X	0
11	V	1	A-U, W, X	0
12	E	1	A-D, F-X	0
13	U	1	A-T, V-X	0
14	K	1	A-J, L-X	0
15	F	1	A-E, G-X	0
16	S	1	A-R, T-X	0
17	H	1	A-G, I-X	0
18	K	1	A-J, L-X	0
19	J	1	A-I, K-X	0
20	L	1	A-K, M-X	0
21	O	1	A-N, P-X	0
22	N	1	A-M, O-X	0
23	Q	1	A-P, R-X	0
24	R	1	A-Q, S-X	0
25	I	1	A-H, J-X	0
26	C	1	A, B, D	0
27	B	1	A, C, D	0
28	D	1	A, B, C	0
29	D	1	A, B, C	0
30	B	1	A, C, D	0
31	A	1	B, C, D	0
32	A	1	B, C, D	0

Procedure

A Pearson correlation coefficient was computed to assess the relationships between the underlying factors on the 8-item version of the VSLQ, Silverman's (2000) VSI, and Newton and Bristoll's (2009) SAT (see Table 5.5). No relationship was found between the underlying factors of spatial awareness and organisation (disorganisation) on the 8-item version of the VSLQ (r = -.05, n = 294, p = .39). Due to the reverse direction of the Likert scale on the 8-item version of the VSLQ all correlation scores between the 8-item version of the VSLQ and Silverman's (2000) VSI needed to be reversed. A weak positive correlation was found between the organisation (disorganisation) factor measured by the 8-item version of the VSLQ and the visual-spatial learning factor measured by Silverman's (2000) VSI (r = -.15, n = 293, p < 0.01). A strong positive correlation was found between the spatial awareness factor measured by the 8-item version of the VSLQ and the visual-spatial learning factor measured by Silverman's (2000) VSI (r = -.40, n = 291, p < 0.001). No correlation was found between the organisation (disorganisation) factor on the 8-item version of the VSLQ and the auditory-spatial learning factor on Silverman's (2000) VSI (r = -.02, n = 296, p = .62). A negligible positive correlation was found between the spatial awareness factor on the 8-item version of the VSLQ and the auditory-sequential learning factor on Silverman's (2000) VSI (r = -.11, n = 294, p = .04).

The Pearson correlation coefficient scores were not reversed during the analysis of the scores on the 8-item version of the VSLQ and Newton and Bristoll's (2009) SAT. Newton and Bristoll's (2009) SAT does not use a Likert scale. A negligible positive correlation exists between the underlying factor of organisation (disorganisation) on the 8-item version of the VSLQ and the geometric manipulation factor on Newton and Bristoll's (2009) SAT (r = .17, n = 298, p < 0.004). A weak positive correlation exists between the underlying factor of organisation (disorganisation) on the 8-item version of the VSLQ and mapping ability on Newton and Bristoll's (2009) SAT (r = .23, n = 298, p < 0.001). A strong negative correlation exists between the underlying factor of spatial awareness on the 8-item version of the VSLQ and geometric manipulation on Newton and Bristoll's (2009) SAT (r = -.43, n

= 296, $p < 0.001$). A large negative correlation exists between spatial awareness on the 8-item version of the VSLQ and mapping ability on Newton and Bristoll's (2009) SAT ($r = -.44$, $n = 296$, $p < 0.001$).

Table 5.5

Correlation Between Underlying Factors on VSLQ, VSI and SAT

		Visual	Auditory	Organisation (Disorganisation)	Spatial Awareness	Geometric	Mapping
Visual	Pearson Correlation	1	.185**	-.151**	-.400**	.760**	.645**
	Sig. (2 tailed)		.001	.009	.000	.000	.000
	N	295	294	293	291	295	295
Auditory	Pearson correlation	.185**	1	-.029	-.115*	.342**	.392**
	Sig. (2 tailed)	.001		.622	.049	.000	000
	N	294	298	296	294	298	298
Organisation (Disorganisation)	Pearson correlation	-.151**	-.029	1	-.050	.172**	.233**
	Sig. (2 tailed)	.009	.622		.396	.003	.000
	N	293	296	298	294	298	298
Spatial Awareness	Pearson correlation	-.400**	-.115*	-.050	1	-.437**	-.445*
	Sig. (2 tailed)	.000	.049	.396		.000	.000
	N	291	294	294	296	296	296
Geometric	Pearson correlation	.760**	.342**	.172**	-.437**	1	.741**
	Sig. (2 tailed)	.000	.000	.003	.000		.000
	N	295	298	298	296	300	3000
Mapping	Pearson correlation	.645**	.392**	.233**	-.445*	.741**	1
	Sig. (2 tailed)	.000	.000	.000	.000	.000	
	N	295	298	298	296	300	300

Note. **. Correlation is at the 0.01 level (2 tailed). *. Correlation is at the 0.05 level (2 tailed). Scores for organisation and spatial awareness are reversed due to the reverse direction of the 5 point Likert scale on the VSLQ

Discussion

Study 3 provided evidence of the construct validity of the 8-item version of the VSLQ. Construct validity is a central concept in psychometric research (Western & Rosenthal, 2003). The construct validity of the 8-item version of the VSLQ was demonstrated by providing evidence of the convergent validity of the instrument. A weak positive correlation was found between the organisation (disorganisation) factor underlying the 8-item version of the VSLQ and visual-spatial learning factor underlying Silverman's (2000) VSI. Significant literature (Von Karolyi et al., 2003; Mann, 2005; Silverman, 2002; Silverman & Freed, 1991) has been published on the difficulties with organisation for students who have strong visual-spatial abilities and a preference for visual-spatial learning. This is further supported by the negligible positive correlation between the underlying factor of organisation (disorganisation) on the 8-item version of the VSLQ and the underlying factor of geometric manipulation on Newton and Bristoll's (2009) SAT. A weak positive correlation was also found between the underlying factor of organisation (disorganisation) on the 8-item version of the VSLQ and the mapping ability factor underlying Newton and Bristoll's (2009) SAT. Although there was a positive correlation between the underlying factors of organisation (disorganisation) and visual-spatial ability/learning on the three instruments, a stronger positive correlation was expected by the researcher in line with the arguments made in the literature about the relationship between the disorganisation of VSL and visual-spatial ability.

A strong positive correlation was found between the spatial awareness factor underlying the 8-item version of the VSLQ and the visual-spatial learning factor underlying Silverman's (2000) VSI. As both Silverman's (2000) VSI and the 8-item version of the VSLQ were established to identify students with a preference for visual-spatial learning this strong relationship between these two underlying factors was expected. Unlike VSL, students with a preference for auditory-sequential learning do not have difficulties with organisation. This is exemplified by the lack of correlation, either positive or negative, between the organisation (disorganisation) factor underlying the 8-item version of the VSLQ and auditory-sequential learning factor underlying Silverman's (2000) VSI. A strong negative correlation was expected between these two factors. Kozhevnikov et al. (2005) and Silverman (2005) assert that visual-spatial ability and auditory-sequential ability fall on a spectrum where individuals can show characteristics of both styles, rather than being in binary opposition to each other. This is supported by the negligible positive correlation between the underlying factor of spatial awareness on the 8-item version of the VSLQ and the auditory-sequential factor underlying Silverman's (2000) VSI.

Two of the results from Study 3 contradicted the literature on preferences for visual-spatial learning and visual-spatial ability. A strong negative correlation was identified between the spatial awareness factor underlying the 8-item version of the VSLQ and the underlying geometric manipulation factor on Newton and Bristoll's (2009) SAT. A strong positive correlation was expected between these two factors. This is supported by Silverman and Freed's (1991) claim that VSL excel at math analysis, and are great at geometry and physics. According to Haas (2003) students with a preference for visual-spatial learning "easily understand changes in perspective in problems, such as movement, translation, reflection, or rotation" (p. 31).

An unexpected large negative correlation was also found between the spatial awareness factor on the 8-item version of the VSLQ and the mapping ability factor underlying Newton and Bristoll's (2009) SAT. Hindal (2014) has identified map reading as a strength in students with high level visual-spatial abilities. Research evidence (Caron et al., 2004; Edgin & Pennington, 2005; Grandin, 2006) suggests that spatial cognition may be a strength in individuals with ASD. Caron et al. (2004) demonstrated, through a study involving navigating a human-size labyrinth, that students with ASD have advanced discrimination, detection, and memory for visual patterns. They are also able to link images on maps with those in the real world. O'Riordan et al. (2001) found during a study of children with ASD that they performed better than other children on difficult visual-search tasks.

These contradictory results could be attributed to the nature of Newton and Bristoll's (2009) SAT. This instrument contains "objective" spatial test items involving the manipulation of geometric shapes and the interpretation of maps. Studies (Dean, 1994; Dean & Morris, 1995; Kosslyn et al., 1984; Poltrock & Agnoli, 1986; Poltrock & Brown, 1984) have suggested that there is no relationship between self-report instruments and spatial-test performance. Lorenz and Neisser (1985) claim that subjective measures of imaginal experience correlate moderately well with each other but further research is needed to establish the relationship between these subjective measures and "objective" spatial tests. The unexpected results between the VSLQ and Newton and Bristoll's (2009) SAT could also be attributed to the different focus of the two instruments. The VSLQ measures typical performance, whilst Newton and Bristoll's (2009) SAT is verdical-assessed via maximal performance operationalization. Researchers (Guion, 1991; DuBois et al., 1993; Marcus et al., 2007; Sackett et al., 1988; Vance et al., 1988) claim that there is low correlation between measures of typical and maximum performance (r = 0.11 to 0.32).

These results may also have occurred because the data during this study was subjected to dichotomization. Although widely used in the literature, there is considerable methodological literature (Gustafson & Le, 2002; Krauth, 2003; MacCallum et al., 2002; Owen & Froman, 2005; Royston, Altman, & Sauerbrei, 2006; Senn, 2003; Steiner, 2002) demonstrating negative consequences of dichotomization. MacCallum et al. (2002), Cohen (1983), and Humphreys (1978) claim that dichotomization can lead to negative effects on measures of reliability and validity. Humphreys (1978) found that dichotomization will result in moderate to substantial decreases in statistical scores. This is supported by MacCallum et al.'s (2002) claim that dichotomization erodes the strength of relationships between variables, resulting in loss of statistical significance. This loss of statistical significance may be attributed to the process of dichotomization altering the nature of individual differences in the data collected using the VSLQ, VSI, and SAT. MacCallum et al. (2002) claims that it is not unusual to find that dichotomization results in either an increase or decrease in the correlation between the variables, simply due to sampling error. Another criticism of this methodology is noted by Cohen (1983), the loss of power caused by dichotomization can be attributed to a loss of sample size. Fedorov, Mannino, and Zhang (2009) assert that converting data to a binary outcome is equivalent to removing 36% of the data set. Loss of power, or effective loss of sample size, becomes more significant if both sets of variables are dichotomized. In Study 3 the data sets collected using the 8-item version of the VSLQ, VSI, and SAT were all subjected to dichotomization.

The data collected during Study 3 was platykurtic, bimodal, and showed leniency. As such, it was beneficial to eliminate such error through the dichotomization of the data. However, the process of converting the data to binary code may have changed the nature of the relationships within the data (Krauth, 2003). “Most of the information about individual differences in the original distribution has been discarded, and the remaining information is quite different from the original” (MacCallum et al., 2002, p. 23). Krauth (2003), Maxwell and Delaney (1993), and Vargha, Rudas, Delaney, and Maxwell (1996) identify spurious significant events as a potential consequence of dichotomization. The negative correlations between the spatial awareness factor underlying the 8-item version of the VSLQ and the underlying geometric manipulation factor on Newton and Bristoll’s (2009) SAT, and the spatial awareness factor on the 8-item version of the VSLQ and the mapping ability factor underlying Newton and Bristoll’s (2009) SAT may have been spurious significant events resulting from converting the data collected during Study 3 to binary code.

Combined with the results of Studies 1 and 2, the results of this study provide some evidence to support the claim that the 8-item version of the VSLQ has both reliability and construct validity. To be successful in school, students with a visual-spatial approach to learning need to have their strengths recognised and nurtured. By providing evidence of the reliability and construct validity of the 8-item version of the VSLQ secondary school classroom teachers can be confident in using the instrument to identify students who have a preference for visual-spatial learning. By identifying these students, visual-spatial teaching strategies based on the literature can be implemented to support their individual educational needs.

Chapter 6: General Discussion

> Perhaps the greater use of spatial tests, coupled with a much broader understanding of the importance of rediscovered spatial abilities, might help prevent conventional educational systems from dropping by the wayside those who are especially well suited to visual and spatial tasks - whether in creating grand illusions on film or in understanding visual patterns in the stock market or complex weather systems (West, 1998, p. 5).

Summary of Findings

The process of identifying secondary school students who display preferences for visual-spatial learning will help teachers to better cater for their individual learning needs. The VSLQ was developed to measure typical performance in relation to preferences for visual-spatial learning. The main aim of the current study was to provide evidence towards the reliability and validity of this verbally anchored, self-report measure.

Studies 1, 2 and 3 provided some evidence towards the argument that the 8-item version of the VSLQ has reliability, in the form of internal consistency, and construct validity (See Table 6.1). The EFA during Study 1 extracted two dominant factors - organisation (disorganisation) and spatial awareness. Both the organisation (disorganisation) (2.52) and spatial awareness (2.25) factors had acceptable eigenvalue scores. During the CFA in Study 2, four items (Item 1: “I have neat handwriting,” Item 3: “Most people think I am very disorganised. However, have my own system of organisation,” Item 6: “My teachers tell me I have poor or messy handwriting," Item 7: "I always show my working when completing problems in mathematics") loaded onto the organisation (disorganisation) factor. Organisation for students with a preference for visual-spatial learning is often a stumbling block (Mann, 2005). VSL are usually disorganised and may miss details. These students are highly aware of space but pay little attention to time (Silverman & Freed, 1991). Golon (2002) claims, "most, if not all, VSL are accused of being hopelessly unorganized" (p. 1). The limited organisational ability of VSL is well documented in the literature. Silverman (2000) believes that VSL create unique methods of organisation. This is exemplified by Silverman and Freed's (1991) claim that "a visual-spatial child's organisational strategies often appear non-existent" (p. 1).

Four items also loaded onto the spatial awareness factor (Item 2: "I am good at reading maps," Item 4: "When I am doing mathematics the answers to the questions tend to just come to me," Item 5: "I prefer that someone gives me verbal or written directions to a location," Item 8: "I hate studying geometry [shapes and angles] in mathematics"). Spatial ability has been identified as a factor through analysis of test scores in intelligence tests (Johnson-Laird, 1985). Researchers discuss two methods of representing knowledge, the verbal code and the imaginistic code (Gardner, 1993). The imaginistic code is the ability to create and manipulate images in the mind. Kozhenvikov et al. (2002) stated that there are two groups of Visualizers, those with high spatial ability and those with low spatial ability. High spatial Visualizers excel at understanding and representing the spatial relationships between objects. They can easily perform the rotations of three-dimensional images within their mind. Students with high spatial ability demonstrate skills in the field of mathematics (Hegarty &

Kozhevnikov, 1999). The characteristics of students with high spatial ability, supports the presence of two items on the 8-item version of the VSLQ that relate to mathematics. The presence of the two mapping questions on the instrument is supported by Silverman's (2013) assertion that students with high level visual-spatial abilities and a preference for visual-spatial learning are good at reading maps. The 8-item version of the VSLQ has an acceptable $X^2 = 52.98$, $df = 20$, $p < 0.001$. This suggests that the relationship between the two factors and the 8 items is not due to chance. However, the small number of respondents in both Study 1 ($n = 125$) and Study 2 ($n = 225$) may have increased the fit indices. This is supported by Bollen (1990), Givens et al. (1997), Rothstein et al. (2005), and Sterne et al. (2000) who claim that small sample sizes (< 250) tend to have much larger positive effect sizes.

Table 6.1

Reliability and Validity Data for 8-item Version of the VSLQ

Factor	Eigenvalue	VSI - Visual	VSI - Auditory	SAT - Geometric Manipulation	SAT - Mapping Ability		Item	Loading
Organisation (disorganisation)	2.257	.151	.029	.172	.233	1	I have neat handwriting	-.517
						2	Most people think I am disorganised. However, I have my own system of organisation.	.604
						3	My teachers tell me I have poor or messy handwriting	.629
						4	I always show my working when completing problems in mathematics	-.585
Spatial awareness	2.250	.400	.115	-.437	-.445	5	I am good at reading maps	.594
						6	When I am doing mathematics the answers to the questions tend to just come to me	.603
						7	I prefer that someone gives me verbal or written directions to a location	.425
						8	I hate studying geometry (shapes and angles) in mathematics	.491

The results of Study 3 provide some evidence to support the assertion that the revised 8-item version of the VSLQ has construct validity. A strong positive correlation between the spatial awareness factor on the VSLQ and visual-spatial learning factor on Silverman's (2000) VSI was expected, based on the literature. As both the 8-item version of the VSLQ and Silverman's (2000) VSI are verbally anchored, self-report instruments for measuring preferences for visual-spatial learning it was assumed that there would be a positive correlation between the spatial awareness and visual-spatial learning factors that underlie these instruments. The items on these two instruments that loaded onto the spatial awareness and visual-spatial learning factors measured the participant's ability to use images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005).

A weak positive correlation was found between the organisation (disorganisation) factor measured by the 8-item version of the VSLQ and the visual-spatial learning factor measured by Silverman's (2000) VSI. The limited organisational ability of VSL is well documented in the literature (Golon, 2002, 2004; Mann, 2005; Silverman, 2000; Silverman & Freed, 1991). No correlation was found between the organisation (disorganisation) factor on the 8-item version of the VSLQ and the auditory-spatial learning factor on Silverman's (2000) VSI. The positive correlation between the underlying factors of organisation (disorganisation) on the 8-item version of the VSLQ and visual-spatial learning on Silverman's (2000) VSI, and the lack of correlation between the factors of organisation (disorganisation) and auditory-sequential learning provide further evidence of the construct validity of the revised 8-item version of the VSLQ. Organisation for students with a preference for visual-spatial learning is often a stumbling block (Mann, 2005). VSL are usually disorganised and may miss details. These students are highly aware of space but pay little attention to time. "A visual-spatial child's organisational strategies often appear non-existent" (Silverman & Freed, 1991, p. 1). In contrast, ASL relate well to time and attend well to details (Silverman, 2005).

An analysis of the relationship between the spatial awareness factor on the revised 8-item version of the VSLQ and the factors of geometric manipulation and mapping ability on Newton and Bristoll's (2009) SAT contradicted the literature on preferences for visual-spatial learning. A strong negative correlation exists between the underlying factor of spatial awareness on the 8-item version of the VSLQ and geometric manipulation on Newton and Bristoll's (2009) SAT. A large negative correlation exists between the spatial awareness factor on the 8-item version of the VSLQ and mapping ability on Newton and Bristoll's (2009) SAT. According to the literature, having a preference for visual-spatial learning involves more than simply the ability to manipulate two-dimensional and three-dimensional shapes (Silverman, 2005). It also involves the ability to interpret and use a map effectively. Silverman (2005) has identified these two skills as some of the characteristics of a student who has a preference for visual-spatial learning. As such, it was assumed that there would be a positive correlation between the related factors on the two instruments. Researchers (Burton & Fogrty, 2003; Dean & Morris, 1991) argue that no relationship has been shown in the literature between self-report instruments and traditional "objective" spatial instruments involving geometric manipulation and other related items. Studies (Guion, 1991; DuBois et al., 1993; Marcus et al., 2007; Sackett et al., 1988; Vance et al., 1988) have also demonstrated very little correlation between typical performance (VSLQ) and maximal performance (SAT) measures.

Alternatively, these results may have occurred as a result of the dichotomization of the data in Study 3. Although this process was necessary due to the extremely highly skewed results obtained from Silverman's (2000) VSI, this statistical process may have negatively affected the *r* scores (Cohen, 1983; Humpreys, 1978; MacCallum et al., 2002). MacCallum et al. (2002) also takes another position on dichotomization. Finding a statistically significant relationship following dichotomization, such as that between the underlying factors of spatial awareness on the 8-item version of the VSLQ and visual-spatial learning on Silverman's (2000) VSI, is more impressive than the same finding without dichotomization.

The study also aimed to build on Silverman's (2000) VSI, a current self-report instrument designed to identify VSL in primary school contexts. Despite being widely used by classroom teachers as an instrument for measuring preferences for visual-spatial learning, concerns had been raised in the literature regarding the reliability and validity of Silverman's (2000) VSI. Silverman (2000) reported $\alpha = .71$. However, follow up studies by Van Nijnatten (2013), and Mann (2005) only obtained $\alpha = .46$, which demonstrates an unacceptable level of internal consistency. Silverman (2000) has not provided any evidence of the construct validity of this instrument. This study has demonstrated that the 8-item version of the VSLQ has acceptable internal consistency and construct validity. By demonstrating the construct validity of this instrument, secondary school teachers can be satisfied that the students identified as having a preference for visual-spatial learning will achieve success if visual-spatial teaching strategies are used within the classroom context.

In addition to the questionable reliability data of the VSI, Silverman (2000) has constructed the 5-point Likert scale in such a way as to influence the responses of the respondents. The scale is designed so that 4 of the potential responses suggest that an individual is a VSL (2 = somewhat true, 3 = mostly true, 4 = true, 5 = very true). As such, any response to an item other than 1 (not true) suggests that an individual is a VSL. By having four out of the five options on the Likert scale, as positive descriptors, suggesting that a student is a VSL it may lead classroom teachers to identify students as having a preference for visual-spatial learning when they have a different learning preference. This is supported by Bartram and Yielding's (1973) assertion that subjects tend to assign positive descriptors, rather than negative ones, to stimuli. The VSI also does not include an option of responding with 'unsure.' Researchers (Hawkins & Coney, 1981; Payne, 1951) found that providing a choice of 'unsure,' significantly reduced the number of meaningless responses on psychometric instruments. In contrast to Silverman's (2000) VSI, the revised 8-item version of the VSLQ has a 5-point Likert scale that ranges from strongly agree to strongly disagree, including unsure. As a result, the instrument may achieve more accurate results than those of Silverman's (2000) VSI. By providing respondents with the option of 'unsure' on the Likert scale, the 8-item version of the VSLQ also reduces the possibility of meaningless responses, resulting in teachers incorrectly identifying the student's learning style.

The 8-item version of the VSLQ has a smaller number of items (n = 8) than Silverman's (2000) VSI (n = 14). With a smaller number of items than Silverman's (2000) VSI, the 8-item version of the VSLQ may be a more useful and effective instrument for measuring preferences for visual-spatial learning within a secondary school classroom context. Dillman, Sinclair, and Clark (1993) claim that having a small number of items on a questionnaire improves the quality of responses. This is exemplified by Galesic and Bosnjak's (2009) claim that later items on a long psychometric instrument are associated with (a) shorter response times, (b) higher item non-response rates, and (c) less variability related to items structured in the same way. On long questionnaires Herzog and Bachman (1981) found that respondents were more likely to give identical answers to most or all of the items. This is exemplified by Burchell and Marsh's (1992) claim that more variance occurs in item response when questions are placed at the end of a long questionnaire compared with being placed at the start or on a short instrument. By providing classroom teachers with a shorter and more accurate instrument for identifying secondary school students who have a preference for visual-spatial learning they will be able to use it during a lesson to identify the learning preferences of their students. As a result, teachers will be able to use appropriate teaching strategies to cater for their students' individual learning needs.

Implications

Students in secondary schools who display high levels of visual-spatial ability and a preference for visual-spatial learning require appropriate teaching strategies. The revised 8-item version of the VSLQ provides classroom teachers with a reliable and valid instrument for identifying students who have a preference for visual-spatial learning. Students who have their individual educational needs catered for often experience academic, social and personal success. Mann (2006) asserts that students who have spatial strengths and weak verbal skills often struggle in the traditional classroom. Visual-spatial abilities have been found to be an important factor in science and mathematical thinking (Lohman, 1996). Research (Hegarty & Kozhevnikov, 1999; Lohman, 1996; Solano & Presmeg, 1995) has shown a relationship between spatial ability and mathematical problem solving. To achieve success within the classroom context, students with a preference for visual-spatial learning require teaching strategies that match their preferred learning style. The revised 8-item version of the VSLQ will facilitate the identification of VSL in secondary schools so that appropriate educational programs can be provided for these students. Identifying students with spatial strengths is a critical step in the development of an appropriate educational program for these students. Silverman and Freed (2003) claim that the visual-spatial learning style is often not addressed in schools. Mann (2001) and Silverman (2002) have identified a number of teaching strategies that are effective with students who have a preference for visual-spatial learning. They include increasing the level of difficulty, encouraging visualization, teaching holistically, using humour, colour, mnemonics, and using manipulates. "Although less research has been conducted on visual learning than on verbal learning, there are many indications of the power of visual instructional aids" (Mandl & Levin, 1989; Winn, 1991). Without intervention, students with a preference for visual-spatial learning in secondary schools may not achieve their full potential.

Limitations of Study

There are five limitations of this research project. Firstly, the participants in all three studies were secondary school students. As such, it can only be argued that the instrument is applicable for use with this age group of students. During Study 1, four items loaded onto two factors. By loading onto two factors these items may have negatively affected the internal reliability of the 8-item version of the VSLQ. These items were loaded onto the dominant factor in Study 2 for analysis purposes. Conducting a rotation of the factor structure may have maximised the high loadings and minimised the low loadings so that the simplest possible structure was achieved.

During Study 3 the data collected using Silverman's (2000) VSI was found to be extremely highly skewed. This may be attributed to the different target populations of Silverman's (2000) VSI and the 8-item version of the VSLQ. Silverman's (2000) VSI was developed to measure preferences for visual-spatial learning in primary school students. In contrast, the 8-item version of the VSLQ was designed for implementation with secondary school students. To facilitate a correlational analysis of the underlying factors on the three instruments (VSLQ, VSI, and SAT) the data was subjected to dichotomization. Although the process of converting the data to binary code allowed the data to be analysed, it also may have discarded any of the information about individual differences in the original data (MacCallum et al., 2002). This may had affected the results of the correlational analysis, as a strong negative correlation was found between the factors underlying Newton and Bristoll's (2009) SAT and the spatial awareness factor on the revised 8-item version of the VSLQ. The use of a third verbally anchored, self-report instrument for measuring typical performance in relation to spatial ability (e.g. Vividness of Visual Imagery Questionnaire) that involved a 5-point Likert scale may have improved the correlational analysis.

The statistical significance in the three studies may have been the direct function of the small sample sizes, Study 1 (n = 125), Study 2 (n = 227), and Study 3 (n = 300). This is supported by the research of Marsh and Balla (1986) that found 10 of the 12 goodness-of-fit indices are influenced by sample size. They found that sample effect size was substantial when sample sizes are small. The amount of random variance is inversely related to sample size (Marsh & Balla, 1986). Ellis and Steyn (2003) support this position arguing that smaller *p*-values are obtained as the size of the data sets increase.

The statistical analysis of the VSLQ requires further examination. The completed VSLQs during each of the three studies were subsumed into one cohort for data analysis. The learning experiences, knowledge, and cognitive maturity of students in Years 8 to 12 are not comparable. As such, a factorial invariance analysis should have been conducted to determine the notion of equivalency (Phan & Ngu, 2014; Zeegers, 2001). A factorial invariance analysis would have allowed the researcher to determine if the 8-item version of the VSLQ is reliable and valid across genders, social groups, and educational levels.

Directions for Future Research

Further statistical analysis could be conducted on the 8-item version of the VSLQ. Data collected using the 8-item version of the VSLQ could be be divided into subgroups (Year 8, Year 9, Year 10, Year 11, and Year 12) and subjected to a factorial invariance analysis (Phan & Ngu, 2014; Zeegers, 2001). This would determine if the instrument is more effective in identifying preferences for visual-spatial learning in a specific age group. Alternatively, the sample could be split into two distinctive groups: junior secondary (Years 8, 9, and 10) versus upper secondary (Years 11 and 12). A configural model could be compared against an alternative model.

There are very few instruments currently available for measuring preferences for visual-spatial learning in secondary school students. Silverman's (2000) VSI, discussed in this research, is the most commonly used instrument for identifying VSL. Although widely used in primary school classrooms, the reliability and validity of the instrument is questionable. Another instrument developed to identify VSL is Mann's (2006) My Thinking Style Questionnaire. However, the focus of this instrument is gifted students who display a preference for visual-spatial learning. The limited focus of this questionnaire made it inappropriate for the current study.

Traditional "objective" spatial tests that involve the manipulation of geometric shapes are not appropriate for identifying VSL. These instruments are measures of maximal performance and focus on the mental manipulation of two-dimensional and three-dimensional shapes (Weckbacher, 2007). This study demonstrated that there is not a clear relationship between verbally anchored measures of preferences for visual-spatial learning and "objective" spatial ability tests. This is supported by Burton and Fogarty's (2003) claim that no relationship has been established between these two different test formats. Visual-spatial learning is a preference for using images, pictures, colours, and maps to organise and communicate ideas (Silverman, 2005). As such, "objective" instruments for measuring visual-spatial ability are not reliable at identifying students who have a preference for visual-spatial learning. Researchers (Guion, 1991; DuBois et al., 1993; Marcus et al., 2007; Sackett et al., 1988; Vance et al., 1988) claim that there is low correlation between measures of typical performance (8-item version of the VSLQ) and maximum performance ("objective" spatial ability tests). Future research needs to focus on providing further evidence of the reliability and validity of the 8-item version of the VSLQ. The current study has provided some evidence to support the claim that the instrument has reliability and validity. The 8-item version of the VSLQ should be tested against the results of other verbally anchored instruments designed to measure typical performance associated with visual-spatial ability and preferences for visual-spatial learning.

The validity of the 8-item version of the VSLQ could also be further demonstrated by comparing the results on the 8-item version of the VSLQ against curriculum based content tests and examinations. Throughout the literature there have been significant references to the mathematical (Campbell, 1993; Clements, 1998; Clements & Battista, 1992; Mann, 2005; Van Garderen & Montague, 2003) and scientific ability (Humphreys et al., 1993; Shea et al., 2001) of students with high visual-spatial abilities and a preference for visual-spatial learning. Participants could be asked to complete the 8-item version of the VSLQ and a standardised mathematics or science test. A high score on the 8-item version of the VSLQ, and a standardised mathematics or science test could provide further evidence of the construct validity of the instrument. Alternatively, a secondary school students demonstration of the Achievement Standards in the Australian Curriculum (Mathematics and Science) could be examined and compared against his/her results on the 8-item version of the VSLQ. This would allow for the testing of the structural validity of the questionnaire. The results of the 8-item version of the VSLQ, VSI, and SAT could be regressed against educational outcomes (see Figure 6.1). This statistical approach would provide information regarding the predictive effects of the identified latent factors.

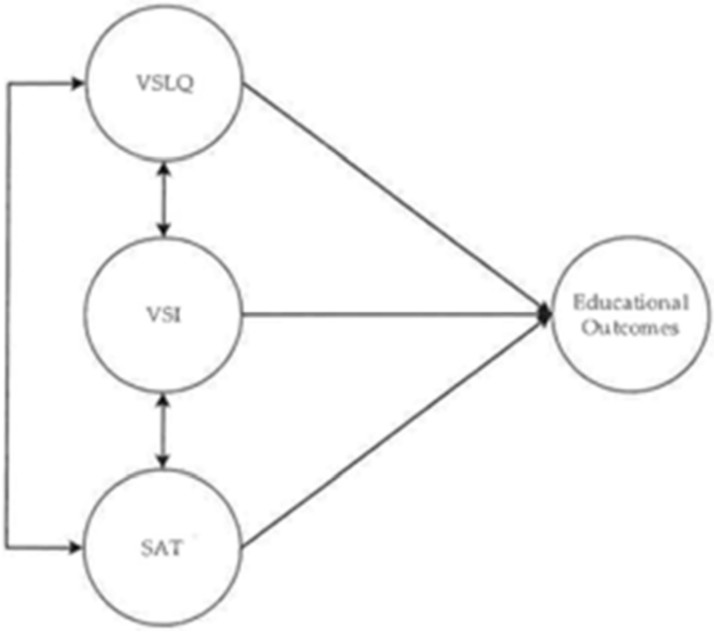


Figure 6.1. Structural Validity of the 8-Item Version of the VSLQ (Examiner 3, personal communication, February 4, 2016)

By comparing the results of the 8-item version of the VSLQ and a standardised mathematics or science test this may also contribute to the literature on establishing the relationship between typical performance and maximal performance. However, to date there has been no clear relationship shown between measures of typical performance, like the 8-item version of the VSLQ, and measures of maximal performance, like mathematics and science tests (Guion, 1991; DuBois et al., 1993; Marcus et al., 2007; Sackett et al., 1988; Vance et al., 1988.

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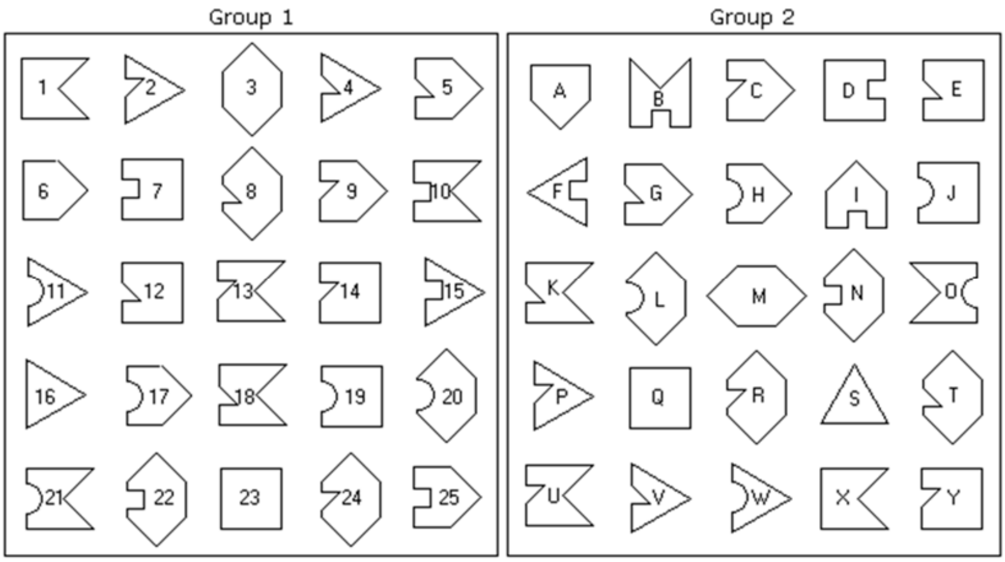
Appendix A

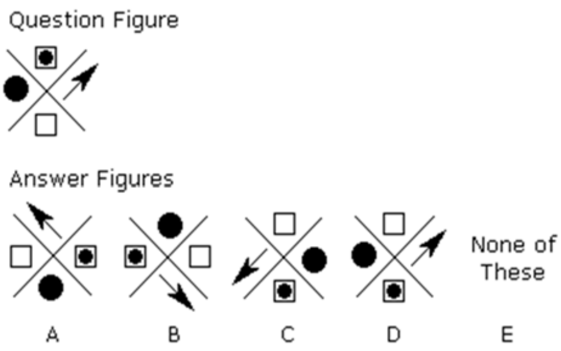
Items on Newton and Bristoll's (2009) SAT

1. Which shape in Group 2 corresponds to the shape in Group 1?

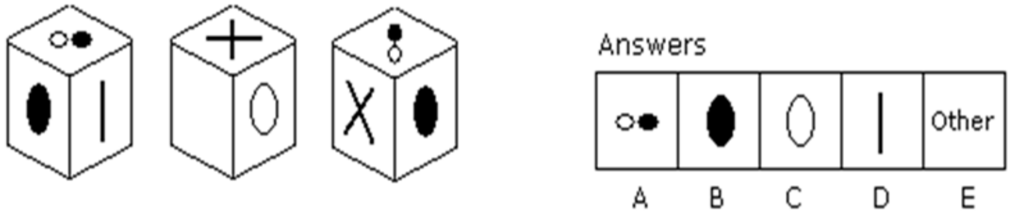


1.	2.	3.	4.	5.
6.	7.	8.	9.	10.
11.	12.	13.	14.	15.
16.	17.	18.	19.	20.
21.	22.	23.	24.	25

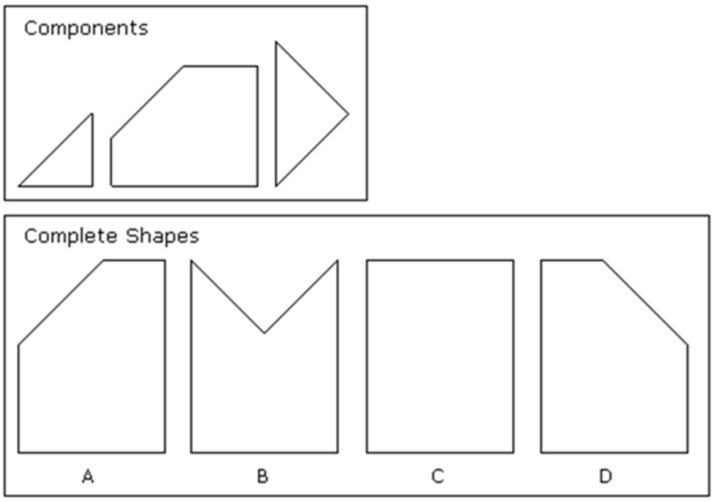
26. Which of the Answer Figures is a rotation of the Question Figure?



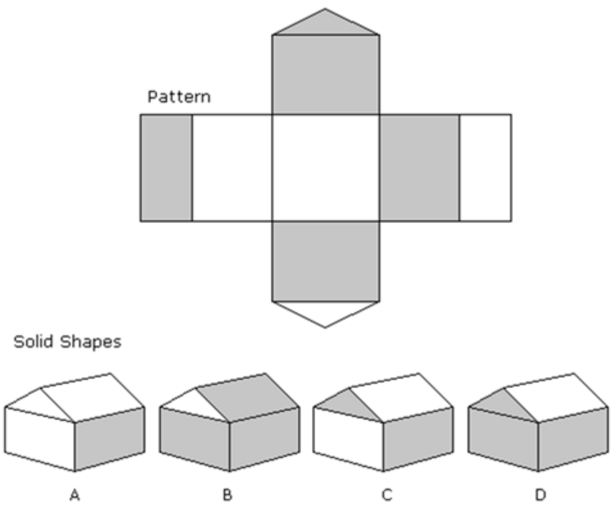
27. Three views of the same cube are shown below. Which symbol is opposite the X?

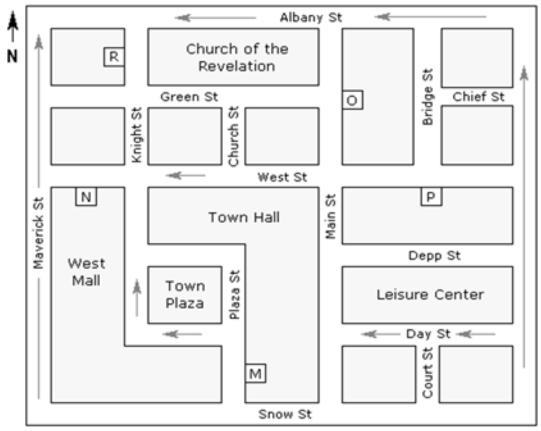


28. Which of the complete shapes below can be made from the components shown?



29. Which of the sold shapes shown could be made from the pattern below?





30. Officer Wilkinson is in Depp Street and can see the Town Hall to her right. What direction is she facing?

A	B	C	D
North	South	East	West

31. She turns and walks to the junction with Main Street. She turns and proceeds two blocks before turning right, then taking the next right, and walking half a block. Which direction is nearest to her current position?

A	B	C	D
M	N	R	P

32. Officer Garcia starts from location ‘N’ and proceeds as follows: right onto West Street – heading East, fourth left – heading North, first right – heading East, first right – heading South, third right – heading West. He proceeds West for one block. Where is location ‘P’ in relation to his current position?

A	B	C	D
North	South East	North East	North West

Appendix B

Items on Capp's (2006) VSLQ

Item	Content
1	When I am trying to study for a test I find it easier to remember pictures and diagrams rather than words I have read
2	I am not very good at getting to class on time, handing assignments in by the due date and getting to appointments on time
3	My bedroom is very neat
4	I prefer my teacher to give me an overview of a topic before exploring elements of it in depth
5	My classmates are jealous that I seem to understand complex material easily
6	I find it easy to identify the connections and relationships between the ideas my teacher explains
7	When I walk into a room I generally notice everything
8	I have neat handwriting
9	I am good at reading maps
10	I find problem solving questions in mathematics more interesting than regular equations
11	When I am learning a new word I prefer to visualize the whole word in my head rather than sounding it out
12	Most people think I am very disorganized. However, I have my own system of organization.
13	When I am doing mathematics the answers to the questions tend to just come to me
14	I am very good at remembering things that I have seen
15	When I learn something I never forget it
16	I generally find my own methods of solving problems rather than using the ones my teacher suggests
17	I hate it when my teacher is upset or angry
18	People think I come up with strange solutions to problems
19	My grades/results at school are all over the place
20	I hate studying algebra in mathematics
21	I love studying chemistry in science
22	I find it difficult to learn languages other than English in class
23	I think that I am getting better at school as I get older
24	When I am interested in something I can concentrate on it for a long time
25	I believe that being compassionate to other people is the most important thing someone can do
26	Everything I do has to be perfect
27	I can't understand why people do immoral things
28	I want to know everything; I am very curious
29	If I am interested in something I won't stop until it is finished
30	I am always full of energy
31	I have trouble with spelling

32	I love doing times tables
33	Most of my friends are older than me or adults
34	I have a wide range of interests both at school and outside of school
35	I think that I have a good sense of humour
36	I love reading
37	I hate when people are treated unfairly
38	I can’t understand why some people my age make immature judgments
39	I seem to notice everything around me
40	I like to daydream
41	When I am doing something I like to be as creative as possible
42	I am very well organized. I have a routine for everything
43	I am good at Jigsaws
44	I prefer to type my assignments rather than write them by hand
45	I find it easier to understand what I have read than what I have seen in a diagram or picture
46	I am very good at meeting deadlines
47	I find it difficult to understand my teacher if he/she does not go step by step through the information or skill
48	My friends seem to understand complex information presented by the teacher but I find it difficult to understand
49	I find it easy to follow directions when they are told to me
50	One of my favourite subjects at school is either art or music
51	I find it difficult to read maps. I prefer that someone gives me verbal or written directions to a location.
52	I am good at mathematics questions that I have been shown how to do; however, I find problem solving questions difficult
53	When I am trying to remember how to spell a word, I like to sound it out
54	If I disagree with something I have to speak up and tell everyone
55	My teachers tell me I have poor or messy handwriting
56	I always show my working when completing problems in mathematics
57	I find it easy to learn something if I repeat it a few times
58	I am able to easily follow verbal instructions given by the teacher
59	I can remember how to get to a location after I have been there only once
60	I generally do very well in all my subjects at school
61	I enjoy studying algebra in mathematics
62	I hate studying geometry (shapes and angles) in mathematics
63	My teachers say that I am academically talented
64	I hate listening to my teacher talk and give instructions
65	The easiest way for me to learn a language is in a class
66	I generally find it difficult to get my work finished in class
67	I enjoy playing computer games and watching television
68	My parents always complain that my bedroom is messy
69	My friends would say that I am funny
70	I always put 100% effort into everything that I do