MOTIVATIONAL CHARACTERISTIC DIFFERENCES BETWEEN PROCEDURAL AND CONCEPTUAL FRACTION LEARNERS

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Motivational Characteristic Differences between Procedural and Conceptual Fraction Learners

by

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ABSTRACT

Research concerning the ability to do fractions suggests that procedural and conceptual understanding are important for learning fractions (Hallett, Nunes, Bryant, & Thorpe, 2012; National Mathematics Advisory Panel, 2008). No research to date, however, has looked at whether conceptual or procedural knowledge are differentially related to academic motivational variables. In this study, procedural and conceptual learners were examined on three motivational variables: i) self-concept; ii) self-attribution; and iii) goal-orientation. The data suggest that the two types of learners can be differentiated based on motivations, with correlational analyses demonstrating differences in math self-concept and students' use of ability attribution when explaining math failure.

Keywords: conceptual and procedural knowledge; academic motivation; math self-concept; self-attribution; goal orientation

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Mathematical cognition researchers often discuss students' acquisition of two types of math knowledge: conceptual and procedural (e.g. Rittle-Johnson & Siegler, 1998). In its general term, conceptual knowledge is considered as a declarative type of knowledge that must be learned through thoughtful and reflective learning. Hiebert and LeFevre (1986) define conceptual knowledge "as a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information" (p. 3). This definition suggests that conceptual knowledge does not only cover the ability to meaningfully understand separate pieces of information that exists in a subject domain, but also the ability to "know that" those pieces of information are interconnected in some ways. Conceptual knowledge is often associated with meaningful and declarative learning (versus rote learning) because recognizing and creating associations between units of information promote generation of meaning and understanding in learning (Hiebert & LeFevre, 1986; Wittrock, 1989). The idea that a deeper level of information processing is involved when assessing declarative memory (e.g., memory for conceptual knowledge) is supported by neuroimaging studies. A handful of studies reveal that declarative memory relies on the medial temporal region and hippocampus area, where most memory consolidation processes take place (Squire & Wixted, 2011).

In contrast, procedural knowledge is an implicit type of knowledge that is formed by performing a set or sets of actions. Acquisition of this type of knowledge may not necessarily exist with understanding, and may be acquired through habitual or rote learning. Brain imaging studies suggest that information that is acquired through habitual learning bypasses the hippocampus and gets processed mainly in the striatum and other subcortical areas (Squire & Wixted, 2011). In the mathematics domain, procedural knowledge is interchangeably referred to as math computational skills (Hiebert & LeFevre, 1986). This skill involves "knowing how" to use mathematical symbols and to apply rules pertaining to the mathematical problems at hand. Although procedures are more susceptible to rote learning, it is possible to learn procedures with meaning. In such cases, the procedural knowledge is said to have linked with conceptual knowledge. When the two types of knowledge are related, this will then lead to effective use of procedures (Hiebert & LeFevre, 1986). For example, when solving a math problem, one's procedural knowledge will allow one to generate answers for that problem. However, if this knowledge combines with conceptual knowledge relating to that math problem, one's conceptual knowledge may be used as a mental check to determine if the procedures were executed correctly.

In addition to conceptual and procedural knowledge being different ways of thinking, recent research has suggested that there are different profiles in how people learn these types of knowledge (Hallett, Nunes, & Bryant, 2010; Hallett, Nunes, Bryant, & Thorpe, 2012; Hecht & Vagi, 2012). Some people can be classified as relying more on conceptual knowledge (hereafter called conceptual learners), while others can be classified as relying more on procedural knowledge (hereafter called procedural learners). The goal of this study is to investigate whether these two groups of learners differ in terms of their motivational characteristics. In particular, I hope to find out whether procedural and conceptual learners differ on three motivational constructs: i) self-concept: students' perceived math ability; ii) self-attribution: students' styles of assigning causal attributions to their successes and failures in mathematics; and iii) goal orientation: students' sets of values that reflect the way that they approach and engage in learning math.

Conceptual and Procedural Knowledge in Fractions

One growing interest in this area of research is the developmental pattern of conceptual and procedural knowledge acquisition (e.g. Rittle-Johnson, Siegler & Alibali, 2001). Researchers aim to examine this developmental pattern in the hope of unlocking ways to manage problems that children have in math, and to understand the processes that children employ when solving mathematical problems. Most of the research studies done on this theme tended to focus on fractions as researchers realize that the distinction between the two types of knowledge (conceptual and procedural) is most obvious in the fraction domain (e.g., Hecht, 1998; Hallett, Nunes, & Bryant, 2010). Students have to know how to add, subtract, divide, and multiply fractions (tapping into procedural knowledge), as well as having to understand what fractions represent to be able to judge if one fraction is greater or smaller than another (tapping into conceptual knowledge). Furthermore, attention given to this topic is deemed necessary as fractions are reported to be one of the most difficult topics in mathematics (NMAP, 2008).

A question that has repeatedly arisen in research examining the learning processes relating to the acquisition of conceptual and procedural knowledge in fraction is which type of knowledge should be acquired first in order to create a solid foundation for later learning (e.g. Byrnes & Wasik, 1991). Many researchers suggest that conceptual knowledge provides a strong foundation for the development of procedural knowledge, and so it should be acquired first – *concept-first view* (Byrnes & Wasik, 1991). Some researchers have challenged the former view by demonstrating instances where procedural knowledge is acquired without conceptual understanding – *procedure-first view.* For example in Peck and Jenck's (1981) study, the researchers found that 35% of their participants could successfully perform procedures without having the ability to logically reason how fractions work. However, only 10% of the researchers' sample reported having conceptual understanding of fractions when interviewed at the end of the study. To compensate for the discrepancy between the earlier views (procedure-first and concept-first), Rittle-Johnson and colleagues (2001) propose an *iterative model*, which posits that the development of conceptual and procedural knowledge mutually reinforce one another (i.e. increase in one knowledge leads to increase in another, and this leads back to an increase in the first knowledge).

However, the debate still continues, as empirical results supporting each view and model were found to differ across content domains, studies, and research participants (see review in Rittle-Johnson & Siegler, 1998). Schneider and Stern (2010) suggest that one potential reason for why such inconsistencies were found lies in the fact that measures used in previous studies have very low convergent validity (i.e. measures that were used to reflect one particular knowledge type do not purely assess that knowledge type alone). These researchers added that the choice of measures used to assess conceptual and procedural knowledge might determine the obtained empirical results in a study. It is worth noting that Schneider and Stern's (2010) argument regarding the measure validity came from their latent-factor analysis of four measures of conceptual/procedural knowledge. The low convergent validity that was found among the four measures could be the result of each measure tapping a different facet of children's knowledge about decimal fractions, and not necessarily that previous measures of knowledge types were invalid.

A recent approach by Hallett et al. (2010) attempted to resolve all three (concept-first, procedure-first, and iterative model) contradictory deductions. The researchers proposed that individual differences exist in the way that children combine conceptual and procedural knowledge. Specifically, the researchers explain that different children may take different learning pathways as they grasp fractions. Some children may rely more on conceptual knowledge, some may rely more on procedural knowledge, and some may rely equally on both. This proposition is promising given that Hiebert and LeFevre (1998) have suggested some factors that may inhibit the construction of relation between procedural and conceptual knowledge, where acquisition of one type of knowledge cannot be predicted from acquisition of the other type of knowledge. The inhibiting factors include that some children may have trouble constructing connections between multiple units of information due to certain encoding limitations (Ackerman, 1985), and some students may have a tendency to compartmentalize knowledge that they have learned (refer to Tulving, 1983, for encoding specificity theory). Hiebert and LeFevre (1986) elaborate on the latter by explaining how students often hold each math topic (e.g., fractions, algebra, decimals, geometry) as separate from each other by limiting each topic only to the context in which it was learned.

To illustrate how individual differences relating to the acquisition of conceptual and procedural fraction knowledge exist, Hallett et al. (2010) tested Grades 4 and 5 students on 10 procedural (e.g. What is 2/5 x 1/3?) and 10 conceptual (Is 1/3 larger than 4/2?) fraction questions. Students' conceptual scores were then regressed against their procedural scores in order to obtain residualized scores for each type of scale. These residualized scores represented the part of conceptual (or procedural) scale that was independent of the other knowledge type. For example, if a student had a positive conceptual residualized score, this means that the student had a higher conceptual score than would be predicted given the student's procedural score. The researchers then performed a cluster analysis using the two residualized scales to determine which subgroup of learners relied more on conceptual understanding versus procedural understanding and vice versa. From the researchers' analysis, five clusters were identified: lower than expected procedural; lower than expected conceptual; higher than expected procedural and lower than expected conceptual; higher than expected conceptual and lower than expected procedural; and higher than expected procedural as well as conceptual. Of interest, the higher conceptual-lower procedural group was found to perform better on the overall fraction measure than the higher procedural-lower conceptual group, suggesting that conceptual approaches to fraction learning may be more beneficial than procedural approaches.

A follow-up of Hallett et al.'s (2010) study with a different sample yielded similar results (Hecht & Vagi, 2012). In this study, the researchers found that a 4-cluster solution is best for the fourth graders and a 7-cluster solution is best for the fifth graders. Although the fact that they found differing number of clusters may raise questions about the reliability of these cluster analyses, it should be noted that Hecht and Vagi (2012) found some stability in cluster membership across the two grades. The consistent clusters are: lower concepts and higher procedures, higher concepts and lower procedures, and higher concepts and higher procedures. These are some of the same clusters found in Hallett et al.'s (2010) study. Hecht and Vagi (2012) also found that individuals in the cluster with a higher than expected level of both concepts and procedures performed better than the cluster with higher concepts and lower procedures, followed by the cluster with higher procedures and lower concepts, and the lower concepts cluster.

Another follow-up study with a Grade 6 sample reached a four-cluster solution (Hallett, Nunes, Bryant, & Thorpe, 2012). No new clusters emerged; instead the four clusters were identical to the ones found in previous studies. The four clusters were: lower on concepts and procedures, higher procedures, higher concepts, and higher on both concepts and procedures. For Grade 8 students, a less varied two-cluster model yielded the best fit to the data, perhaps because children's learning patterns were starting to stabilize (Hallett et al., 2012). The two clusters are the higher-than-expected procedural group (i.e. procedural learners), and the higher-than-expected conceptual group (i.e. conceptual learners). However, attempts by these researchers to find factors that differentiated the more procedural cluster from the more conceptual cluster did not bear fruit. The more conceptual and more procedural clusters did not differ in their scores on the Raven's Progressive Matrices (Raven, Raven, & Court, 1998) – a measure that reflects a general conceptual ability. Similarly, no significant differences were found between clusters on the

ABC task (Kyllonen & Stephens, 1990) – a measure that was chosen because it involves learning arbitrary procedural rules and should therefore reflect general procedural ability (Hallett et al., 2012).

This stumbling block is what leads me to pursue the current study. In particular, the aim is to recognize the characteristics that are associated with being more procedural and more conceptual. As an exploratory effort, I wish to approach this research question by going back to the rudimentary element that shapes one's academic behaviour, which is motivation (see Graham & Wiener, 1996). However, in this study, motivation will not be directly measured. Instead, motivation will be examined through three different constructs that are critical in the formation of the academic motivation framework. The three constructs are: i) self-concept; ii) self-attribution; and iii) achievement goal orientation. The measure that will be used to examine each of these constructs will be tailored to closely reflect students' belief and behaviour relating to their general math learning.

Before outlining the methodological details of the current study, all three constructs will be first reviewed. In the following sections, I will discuss how each construct may relate to being a more procedural or more conceptual learner.

Self-Concept

One's inner beliefs and thoughts are regarded as strong determinants of one's actions and behaviours (Pajares & Schunk, 2002). How individuals construe themselves can greatly influence many facets of their being: from thinking about how they should behave and react, what characteristics they should possess, what they are capable of doing, and how they are judged by others. The influence of positive self-view in promoting individuals' well-being has been reported in a variety of studies. For example, poor self-esteem has been found to relate to depression (Brown, Bifulco, Veiel, & Andrews, 1991), bullying behaviours (O'Moore & Kirkham, 2001), and anxiety-related characteristics (Rosenberg, 1962). Given its importance, many educators and psychologists have encouraged students to work on creating a positive self-regard in order to attain desirable outcomes, such as achievements and persistence in school. Various theories have been put forward (e.g. expectancy-value theory by Wigfield & Eccles, 2000) to demonstrate the influence of self-belief in students' academic engagements. Of many theories, two self-belief constructs that frequently appear in the literature are self-concept (interchangeably referred to as self-esteem – see monograph by Marsh, 2007) and self-efficacy (Bandura, 1997).

The myriad of research on self-concept and self-efficacy has made it difficult for researchers to distinguish between these two terms. The differences often do not lie within the conceptual definitions of these two constructs, but are mostly seen among the different theoretical tenets used in each construct (Bong & Skaalvik, 2003; Bong & Clark, 1999). In contrast, Pajares (1996) argued that the ambiguity in research findings on this topic was partly due to most motivational constructs (self-concept and self-efficacy alike) incorporating the same question of *competency belief* into their conceptual and operational definitions. Thus, in order to tease apart the distinction between self-concept and self-efficacy, it is helpful to briefly review the theoretical work behind these two constructs.

Early research on self-concept can be classified in two groups; one pertains to the global self (most often called self-esteem) and the other pertains to the dimensional nature of the self (one's global self-concept is made up of evaluations that one has made in multiple facets of the self, such as evaluation about one's physical or emotional aspects). The former research can be traced back to Rosenberg (1979) who defined self-concept as ". . . the totality of the individual's thoughts and feelings having reference to himself as an object" (p. 7). Shavelson and colleagues (1976) further introduce a definition that provides the theoretical foundation of self-concept research in the 1980s (see review in Marsh, 1990) by presenting seven features that are critical to the definition of self-concept. According to the researchers, "self-concept may be described as organized, multifaceted, hierarchical, stable, developmental, evaluative, and differentiable" (p. 411). At the apex, the self is viewed at a very general level and this view represents the sum of evaluations that one has made about oneself in other lower level domains, such as in academics. In general, Shavelson et al. (1976) define self-concept as one's perception and evaluation of oneself that is formed through one's experience with the environment (e.g., social interaction, success, and failures).

Research on self-concept has waxed and waned over the years because of the contentions that researchers made about the predictive power of self-concept (Baumeister, Campbell, Krueger, & Vohs, 2003; Marsh & O'Mara, 2008). While global self-concept may be a better predictor of psychological well-being, the same construct lacks predictive power of one's behaviours (Rosenberg, Schoenbach, Schooler & Rosenberg, 1995). Baumeister et al. (2003) added that even when a significant correlation is found between global self-esteem and an outcome variable, the effect size is often small and inconsequential. In Hansford and Hattie's (1982) meta-analysis study on the relation between various self-measures and performance, the researchers found that domain-specific academic self-concept offers a better prediction of academic ability (r = .42) than does the global self-concept (r = .22). Many critiques against global self-concept have lead to the refinement of self-concept measures and more emphasis on the use of a multifaceted model of self-concept (see Marsh & Shavelson, 1985). It was argued that the perception about the self cannot be understood adequately if its multidimensionality is ignored (Marsh, 1990). Nonetheless, some still question if the statistical structure of the dimensional model of self-concept truly reflects the psychological structures that are experienced by the individuals (Harter, 1990; Usher & Pajares, 2008).

Although self-concept is most frequently operationalized using competence beliefs, self-efficacy research concerns one's competency belief to attain detailed and specific outcomes in specific situations (Pajares, 1996). Bandura (1997) defines self-efficacy as an individual's confidence of his or her ability to perform a specific task successfully. As demonstrated by this definition, self-efficacy researchers focus less on the constructed schema pertinent to one's ability; instead they concentrate more on the confidence that individuals express about their skills. In terms of methodological perspective, Bong and Clark (1999) argue that while self-concept assessments probe both the cognitive ("Can I do this task?") and affective ("How well can I do this task compared to others?") judgments of one's perception, self-efficacy measures only appraise the cognitive aspect ("Can I do this task?") of one's confidence judgment. The inclusion of the affective component makes self-concept a better predictor of affective-motivational variables. For example, in the case of math self-concept, this self-report measure is highly predictive of math anxiety (e.g. Ferla, Valcke, & Cai, 2009). However, debate still continues on whether the cognitive and affective components of self-concept are empirically distinct.

In an extensive review by Bong and Skaalvik (2003), the researchers recognize features that differentiate self-concept from self-efficacy. Opposite from efficacy rating, self-concept's competence evaluation tends to be normative, past-oriented, relatively stable over time, and is not constrained to a specific context under study (see review for a more detailed discussion – Bong & Skaalvik, 2003). In most assessments, academic self-concept is gauged through items that refer to specific school subjects, and academic self-efficacy items refer to specific school tasks. Nonetheless, the two constructs' central query pertains to individuals' perceived competency and they both aim to predict motivation and performance. Even though self-efficacy is not as sensitive as self-concept towards social comparison, this type of comparison may indeed influence the judgment of both self-beliefs.

In the present study, I chose to examine students' self-concept as this construct expresses a fairly stable perception about the self (Bong & Skaalvik, 2003). Since I would want to scrutinize how this perception relates to the students' past math learning approaches, a past-oriented measure is deemed much more relevant to the research goals. For the purpose of this study, math self-concept will be defined as a person's organized perception of his or her math skills and ability, in comparison to those of peers and relative to his or her other academic abilities (Marsh, 1986). This definition arose from the internal and external frame of reference model (I/E model) of academic self-concept, which posits that perception of one's academic ability in a specific domain (e.g. English or Mathematics) is formed after socially comparing one's ability to that of others and internally comparing the same ability to ability in another academic domain.

Antecedents of Self-Concept and Their Relations to Math Self-Concept

Skaalvik (1997) identifies a few key antecedents to the formation of self-concept. As briefly mentioned above, self-concept is influenced by the frames of reference that individuals use to judge their own competency. The causal attributions that people make about their success and failures in a particular academic domain could also affect how the self-concept related to that domain is formed (see also Marsh, Cairns, Relich, Barnes, & Debus, 1984). Other antecedents include appraisal from significant others, one's own mastery experience, and the perceived importance of the ability under evaluation. Nonetheless, empirical studies often center on the frames of reference, causal attribution, and mastery experience. In fact, the rationale behind predicting how math self-concept relates to procedural/conceptual learning approach can be found in research demonstrating that mastery experience is a key antecedent to forming one's academic self-concept. Before describing some of these literatures, let me briefly review the other relevant antecedent – frames of reference. Literature on causal attribution will be reviewed in a separate section focusing on self-attribution as a characteristic that potentially distinguishes procedural from conceptual learners.

Frames of Reference

On the basis of the hierarchical and multifaceted model of self-concept, Marsh and Shavelson (1985) recognize two higher-order academic self-concepts: mathematics and verbal. Although mathematics and verbal *achievements* are strongly correlated, math and verbal *self-concepts* are nearly uncorrelated (Marsh & Shavelson, 1985; Marsh et al., 1988; for cross-cultural generalizability, refer to Marsh & Hau, 2004). The internal and external frames of reference (I/E) model offers an explanation for why a near-zero correlation was found between verbal and math self-concepts. According to this model, assessment of one's self-concept encompasses both internal and external comparisons. Internal comparison involves comparing one's ability in an academic area with one's ability in another academic area (i.e.: comparing math ability with verbal ability, and vice versa). In contrast, external comparison involves comparing one's ability with the ability of others.

Internal. The lack of a relation between math and verbal self-concept may be because, in each domain, a different internal frame is used (i.e. if a math self-concept is assessed, a verbal achievement is considered, and vice versa). As a consequence, when one is assessing one's math self-concept, high achievement in the verbal domain is more likely to produce a lower math self-concept. Conversely, a high achievement in math would foster a less favourable report of verbal self-concept. In a recent meta-analysis that was based on 69 data sets, Moller, Pohlmann, Koller and Marsh (2009) found support for the I/E model; math and verbal achievement were highly correlated (r = .67), but the correlation between math and verbal self-concepts was close to zero (r = .10).

External. Theories related to the use of the external frame derive from Festinger's (1954) theory of social comparison. According to Festinger, humans have a natural tendency to compare themselves to others when they are unable to judge their opinions and abilities on their own. This type of social comparison is made especially when there is no objective and non-social criterion that individuals can use to accurately evaluate themselves. In school classrooms, social comparison is almost unavoidable. The substantial emphasis on academic performance and achievements in schools has created an environment in which pupils are constantly bombarded with information about the grades and popularity of other students. Thus, it is no surprise that pupils' perceived academic ability (both math and verbal) would be greatly influenced by how able they think they are, compared to other students in the classroom.

Depending on who encompasses your external frame of reference, a different set of self-beliefs would be generated. These differences can partly explain the age, gender, cultural, and individual differences that have been found in relation to math self-concept (Marsh, Parker, & Barnes, 1985). In terms of gender, boys tend to report higher math self-concepts than girls, despite the lack of gender differences in math performance (see a meta-analytic review in Else-Quest, Hyde, & Linn, 2010). The gender differences in math self-concept often emerge during elementary school years and remain stable later in life (Marsh, 1989; Marsh & Yeung, 1988). In a male-stereotyped domain – Mathematics – research suggests that girls become more negative when comparing their ability to boys (Eccles, 1987). However, the effect size pertaining to these gender differences is reported to be small (Else-Quest, Hyde, & Linn, 2010).

As for age, a number of studies have demonstrated a normative decline in mathematics self-concept across middle childhood and early adolescence (Marsh, et al., 1985; Marsh, 1989; Wigfield, Eccles, Mac Iver, Reuman, & Midgley, 1991). In a study involving grade 7 to 12 students in Australia, Germany and the United States, researchers found a similar pattern of self-concept development in both males and females across all three settings (Nagy, Watt, Eccles, Trautwein, Ludtke, & Baumert, 2010). This declining trend is attributed to children's increasing cognitive ability, which leads to a more realistic approach in utilizing the internal and external frames of reference (Wigfiled, Eccles, mac Iver, Reuman & Midgley, 1991). In the mathematics domain, it is not surprising to see a decline in math self-concept as students start to learn more difficult math topics.

One of the most discussed findings concerns the cultural differences in math self-concept. In a study involving 41 participating countries, Lee (2009) found that despite Asian students' higher performance in mathematics, the students tended to report lower math self-concept. Liu and Meng (2010) found a similar result in their study comparing American and East Asians. Regardless of the American students' lower math scores, this group of pupils reported significantly higher math self-concept than students from East Asian countries. Liu and Meng (2010) reasoned that such discrepancies were found because East Asian cultures value humbleness and modest attitudes, whereas individualistic cultures value self-confidence and assertive attitudes. However, others argued that the differences could be attributed to Asian parents' higher expectations of their children's academic performance as well as the more intense peer competition among Asian students to do well in school (Lee, 2009).

The math self-concept differences that are found between East Asian and Western students can be better understood by reviewing Marsh's (1987) big fish-little pond effect (BFLPE). In essence, the BFLPE states that when the school's average is high, an equally able student would report lower academic self-concept than when the same student is placed in a school with a low average achievement level. Thus, in East Asian countries, where there are many more high math performers in the school environment, students are more likely to rate their math self-concept lower despite performing better than students in most western countries. A similar BFLPE effect is also clearly evident in studies comparing higher-ability and lower-ability schools within the same geographic location (Marsh, 1991; Marsh & Parker, 1984).

Chiu et al. (2008) conducted a study to assess the influence of math tracking – the separation of students into different classrooms on the basis of their abilities in math – on Grade 7 students' math self-concept. This study indirectly examines the type of reference group that students with varying ability level utilize. Although higher track students tended to have higher ability self-concept compared to the lower track students, Chiu et al. (2008) revealed that when the students' math achievements are controlled for, math tracking does not predict students' self-concept of their math ability. This finding seems to imply that the relation between math self-concept and math ability is only present within each tracking group, making it an internal frame of reference. Furthermore, students reported that they most frequently compare themselves to students who perform similarly to them within their own tracking group.

A review on social comparison in the classroom by Dijkstra, Kuyper, van der Werf, Buunk, and van der Zee (2008) organized empirical findings around four following themes: motives, dimensions, direction, and consequences of social comparison. The authors conclude that while younger children's – under the age of 7 – social comparison is driven by the need for self-development and identification of the classroom norms, older children are motivated to merely evaluate their performance against others. However, the second line of argument remains hypothetical, as there is still a dearth of research on older children's social comparison behaviours. Dijkstra and colleagues (2008) further conclude that students mostly prefer comparing their performance to students who performed better than them (upward comparison), but only do so when they identified themselves with that comparison target (e.g., same sex, age, and race). Though such comparison may encourage students to strive for academic self-improvement, it may also invoke negative affect and lower students' academic self-concept.

Mastery Experience

The second antecedent of interest – mastery experience – is the driving force behind the postulated link between self-concept and procedural/conceptual learners. Although self-concept researchers often do not discuss the role of mastery experience explicitly, Skaalvik (1997) suggests that this variable bears meaningful influence in the formation of a schema pertinent to the self. For example, knowing that one is able to effectively solve problems involving fractions, algebra, and geometry may provide information that one is very good at math, and thus change how an individual perceives his or her own general competence in math.

In self-concept research, mastery experience is often signified by positive academic achievements. As expected, numerous studies investigating both academic achievements and academic self-concept reported a significant positive correlation between the two variables (e.g. Marsh & Hau, 2004). However, since most of these studies are performed correlationally, the direction of the relation between the two variables is still under debate. Consistent with viewing mastery experience as an antecedent to self-concept enhancement, Byrne (1996) asserts that academic self-concept becomes more positive as academic performance improves. However, opponents of that view believe that positive academic self-concept promotes skill development that eventually leads to a more successful scholastic achievement (e.g. Shavelson & Bolus, 1982). A structural equation modeling performed by Marsh and Yeung (1997) reveal a reciprocal relation between the two variables – achievements and self-concept (also Marsh, Trautwein, Ludtke, Koller, & Baumert, 2005).

Nonetheless, a high score on a math achievement test does not give a true sense of mastery experience, as pupils may have easily obtained a high score by simply memorizing facts about the to-be-tested materials. Mastery experience differs in the way that it gives students concrete understanding of the knowledge at hand. Sense of mastery is most likely acquired through reflective, deep, and meaningful learning, which is needed for conceptual understanding (see Pintrich, Roeser, & de Groot, 1994). Hence, conceptual learners would be the group of pupils who are more likely to have rich mastery experience, and this prior experience would lead them to rate their self-concept more positively than procedural learners. In contrast, the procedural group's tendency to focus more on memorizing steps for execution of math computations may allow fewer windows of opportunities for mastery of that knowledge to occur. This situation may consequently result in the procedural group's fraction scores being positively correlated with math self-concept compared to the conceptual group's scores.

Self-Attribution

Another variable that received considerable attention in the academic motivation literature is pupils' attributional style. This line of research demonstrates the tendency to search for a causal explanation for an outcome, especially when the outcome of an event (e.g. academic performance) is unexpected and/or important to the individual (Weiner, 1972). Attribution theorists further suggest that when individuals generate explanations about why certain achievement outcomes occur, they also attach the most important causal explanation to their perceived competency (Seifert, 2004; Weiner, 1979). This claim fits well with the above-mentioned literature that introduces attribution as an antecedent of self-concept (Skaalvik, 1997; refer to self-concept section above).

In order to fully understand how the attribution-perception thought process occurs, Weiner (1972) began by outlining the types of attributions that most students often generate; the attributions include ability, mood, effort, task difficulty, teacher's bias, luck, and the help of others. The researcher claimed that each of these attributions can be arranged into three bipolar dimensions: internal-external, stable-unstable, and controllable-uncontrollable. Hence, how one perceives one's competency following an attribution will depend on where the attribution falls along each of these three dimensions. As an example, consider a situation where a student fails a math exam. If the individual claims that it was her lack of ability in math that caused the failure, her self-esteem and her confidence that she will later do better in math will deteriorate. This is because 'ability' is internal to one's being, constant in nature (i.e. less likely to change), and less difficult to control. Given these three characteristics, the student assumes responsibility within herself and may expect to fail again in the future*.

Students' patterns of attributions exhibits both situational and dispositional differences. One obvious situational difference lies in the success and failure outcomes; the typical pattern of attributions for these two outcomes is often subject to a self-serving bias (i.e., people tend to take more personal responsibility for success than failure by attributing success to internal factors, and failure to external factors; Skaalvik, 1994). Meta-analyses performed by Mezilus, Abramson, Hyde, and Hankin (2004) produced a large effect size ($d = .96$) for this bias. However, a few dispositional differences were also identified; self-serving attributional bias varied significantly with age, cultural factors, and psychopathology. In particular, children, Asians, and individuals with psychopathology (e.g. anxiety) portray smaller biases compared to older adults, Westerners, and community samples respectively. Contrary to most students, individuals who exhibit learned helplessness – the lack of persistence at tasks that realistically could be mastered – believe that both successes and failures are caused by external factors that are beyond the students' control (Dweck & Reppucci, 1973).

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* These outcomes correspond well with the expectancy-value theory of academic motivation (refer to Wigfield & Eccles, 2000).

It is also worth noting that in Weiner's attribution theory, ability and effort are distinguished; ability is internal, stable, and uncontrollable, whereas effort exemplifies an internal, unstable, and controllable attribution (Weiner, 1985). Each of these types of attribution implicates affect and motivation differently. However, there are also developmental differences when it comes to comprehending what is meant by ability or effort. In a study of children ages 5 to 15 years, the younger children appeared to conflate the meaning of effort and ability by inferring that people who are 'able' are the people who exerted the most effort (Folmer et al., 2008). The study also revealed that as children mature, ability and effort were thought to have an inversed relation (i.e. the more effort you exert, the less able you must be). Through a series of studies, Nicholls and Miller (1984) organize the developmental differences into four levels. Of interest, the distinction between ability and effort – ability as a factor that limits the influence of effort – is well understood by the time children reach 12 years or level four.

Marsh, Cairns, Relich, Barnes, and Debus (1984) conducted a study to closely examine the relation between self-attribution and self-concept using the Sydney Attribution Scale (SAS). The SAS was developed to compensate for the less reliable and valid assessments of attribution used in the past (see Stipek & Weisz, 1981). Based on the analysis, the dimensions on the SAS appear to correspond well with the dimensions on the researchers' self-concept measure – Self-Description Questionnaires (SDQ). The students' math ability attribution was found to correlate most highly with their math self-concept. However, the researchers also found that ability attribution (not effort or task difficulty attribution) is specific to math performance. This finding is inconsistent with Weiner's theory (1979), as he claims that the three dimensions described in his model are generalizable across outcomes and academic content areas.

Given that ability attribution is specific to math performance, it is not surprising why previous studies had difficulties distinguishing math effort attribution across genders (e.g. Stipek, 1984). Research looking at gender differences in math attribution often found that males and females differ in that male students are less likely to attribute math failure to lack of ability, and more likely to attribute math success to ability compared to girls (Dickhauser & Meyer, 2006; Parsons et al., 1982; Stipek, 1984). This is still true even when the boys and girls perform equally well in mathematics (Dickhauser & Meyer, 2006). In an effort to elucidate the gender differences in attribution further, Dickhauser and Meyer (2006) included two other factors that they thought might influence students' ability attributions: their teacher's *actual* evaluation of their ability, and their *perception* of their teacher's evaluation of their ability. Results from the researchers' path analyses indicate that while boys used both math grade and perceived teacher's evaluation as cues for making ability attribution, girls' ability attribution is less strongly influenced by their math grade but is heavily influenced by the girls' perceived teacher's evaluation regarding their math ability. This suggests that, for girls, the link between their perceptions of their competency and their attributional beliefs is stronger than the link between academic performance and attribution.

Between-culture attributional style comparisons produce different patterns of data. In a study comparing students' math attribution in China, Japan, and the United States, the Asian students believed that effort played a greater role in performance outcomes compared to their Western counterparts (Tuss, Zimmer, & Ho, 1995). This pattern of results is consistent with a larger cross-national study conducted by Chandler, Shama, Wolf, and Planchard (1981). In line with Western parents' cultural tendency to emphasize ability much more than effort, Western students typically made more ability attributions than effort attributions in relation to their academic performances (Kinlaw, Kurtz-Costes, & Goldman-Fraser, 2001).

From the literature above, it appears that math grades are not a strong indicator of one's attribution belief. A review by Stipek and Weisz (1981) revealed that most of the reported achievement-attribution correlations were non-significant and only a few exceeded a correlation coefficient of .40. However, the literature also indicates that attribution is more strongly related to self-concept (e.g., Marsh et al., 1984; Skaalvik, 1994). Hence, if I predict that conceptual learners would have a higher math self-concept given their richer understanding in the math domain, conceptual learners would then be more likely to make internal (specifically ability) attribution to explain their math performance. In contrast, procedural learners may perceive that the extents of their math skills are highly dependent on the type of math computations given, which are uncontrollable in nature. Thus, procedural learners would be expected to make more external than internal attribution for their math outcomes. In spite of these hypotheses, group differences between procedural and conceptual learners' attributional styles may not be found given the large effect size of a self-serving bias reported in Mezilus et al.'s (2004) meta analysis study.

Goal Orientation

The inclusion of the goal-orientation construct – individual's purposes or aims with respect to developing competence at an activity or set of activities – in this study aims to provide a broader view of the possible differences in learning approaches between conceptual and procedural learners. The traditional approach in the goal orientation framework involves categorizing achievement goals into mastery versus performance goal orientations (Ames, 1992). One's values that are relevant to a course that one is taking may drive selection of the goals (Pintrich, Roeser, & De Groot, 1994). For example, if attaining the knowledge from the course is perceived to be vital for achieving a future dream career, a mastery goal will more likely be endorsed. However, if getting an A for one's parents is the only important thing to achieve, then a performance goal will be endorsed. Several theories, including social cognitive theory (Bandura, 1997) and self-determination theory (Ryan & Deci, 2000), have also contributed to the literature on the behavioural differences between mastery- and performance-oriented learners. As a whole, research suggests that the reasons for approaching certain learning tasks, the idea of success, and the cognitive engagement in learning will differ depending on the type of goal that the students have set for themselves (Ames, 1992; Pintrich & De Groot, 1990).

In a few research reviews, mastery-oriented learners (also referred to as learning or task oriented) have been described as intrinsically motivated individuals whose main goal in academics is to increase competency and improve knowledge acquisition (Ames, 1992; Covington, 2000; Seifert, 2004). These types of individuals also view effort as an important determinant of their success, and are more likely to take blame for any poor performance. Yet, mastery-oriented learners often report positive self-statements when asked about their perceived academic ability. Additionally, this group of learners is less afraid of engaging in challenging tasks and deep strategy processing as, to them, the process of learning is much more important than the learning outcome itself (Elliott & Dweck, 1988; Pintrich, Roeser, & de Groot, 1994). The mastery goal has also been positively correlated with school grades, and these types of learners are often seen outperforming those who adopted performance goal orientation (Covington, 2000).

In contrast to research findings related to a mastery goal, those pertaining to a performance goal orientation (also referred to as ego-involved, ability-focused or competitive goal orientation) appear to be less straightforward. Although research indicates that performance-oriented learners are driven by a desire to maximize favourable evaluations of their competence, mixed results were reported in research examining some of the behavioural and cognitive patterns associated with performance goal orientation (see review in Covington, 2000). Even though performance orientation is sometimes recognized as a maladaptive motivational pattern that is vulnerable to learned helplessness, performance goal orientation may also result in a high course grade (Elliott & Church, 1997) and a high academic self-efficacy (Midgley & Urdan, 1995).

Researchers, such as Elliot and Harackiewicz (1996), suggest that the conflicting results seen with performance goal orientation originate in past researchers' failure to distinguish between performance-approach and performance-avoidance goals. Later work reveals that unlike individuals who adopt the latter goal orientation, performance-approach learners strive to demonstrate competency by investing considerable effort in learning

(Elliott & Dweck, 1988; Elliott & Church, 1997). In contrast, performance-avoidant learners avoid performance of tasks so that their competency will not be truly tested and they will not be viewed as incompetent. If performance-avoidant learners achieved a poor grade in math, the actual action of avoiding learning math itself could be used as an excuse for having done poorly. In fact, most maladaptive responses (e.g.: helplessness, boredom), which were previously linked to performance goal orientation, are typically evident in the performance-avoidant learners more so than performance-approach learners (e.g. Jarvis & Seifert, 2002).

Despite the differences that are found among the three goal orientations mentioned above, Pintrich (2000) suggests that an individual may indeed exhibit multiple goals at once. For example, a student may be motivated to improve his or her skills in math (mastery), but at the same time may wish to flaunt their ability status to other individuals in their social circle (performance-approach). Several studies have suggested how the three types of goal orientations could be related (e.g. Midgley et al., 1998). The correlations seem to vary slightly across studies because of the use of differing questionnaires. For example, Nicholls and colleagues (1990) have found a negative correlation between mastery and performance goals, but a significant positive correlation was found between performance-approach and -avoidance goals. Using a measure called Pattern of Adaptive Learning Scales (PALS) – the first measure to include the approach-avoidance distinction – Midgley and colleagues reported no link between mastery and any of the performance goals. However, the same positive correlation was found between performance-approach and -avoidance goals (r = .56). While it is not clear-cut how mastery goals may relate to performance goals, these findings suggest that people who endorsed a performance-approach goal have a high tendency to also endorse work-avoidance performance (refer also to Middleton, Kaplan, & Midgley, 2004).

Concerning the relation between goal orientation and self-concept, there are only a few articles that briefly discuss this topic. The literature suggests that self-concept of ability plays a bigger role in performance-oriented learners' achievement-related behaviours than in mastery-oriented learners' behavioural patterns (e.g., Dweck, 1986; Elliott & Dweck, 1988). When performance goal orientation is adopted, learners become increasingly vigilant about how their performance compares with others', which, in turn, has a strong influence on their self-concept. Once self-concept is low, the pattern of responses seems to reflect a performance-avoidance orientation, and once self-concept is high, the response pattern fits with performance-approach orientation (Elliott & Dweck, 1988). For mastery-oriented learners, the drive to increase competency often overrides how one thinks about one's ability. Research by Nicholls (1990), where approach-avoidance was collapsed into one performance goal, yielded a different result: level of perceived ability did not seem to correlate with either performance or mastery orientation. The researcher concluded that pupils may opt for different goal orientations (mastery or performance) even when their level of perceived ability is the same (high or low self-concept), and vice versa.

Nonetheless, the main reason why I think that goal orientation may be related to conceptual/procedural knowledge lies within the idea that mastery- and performance-oriented learners differ in their strategy use. The depth of information processing utilized by mastery-oriented learners was said to be deeper and more meaningful compared to performance-oriented learners who sought shallower strategies that could yield a quick pay-off (Pintrich et al., 1994). The differences in strategy use could be especially marked in mathematics, as this academic subject has been associated with cognitively demanding tasks. Furthermore, as acquisition of procedural knowledge can be obtained through rote memorization and may exist independent of meaning (i.e., not necessarily understanding why a procedure is carried out in a particular manner), it is possible that high dependence on procedural knowledge is related to performance-oriented goals. More specifically, procedural knowledge would be more likely related to performance-avoidant learners because performance-approach learners' choice of strategies can be as sophisticated as mastery-oriented learners (Elliott & Dweck, 1988). Conceptual knowledge, on the other hand, may be more strongly related to mastery goal orientation because the intrinsic drive in mastery-oriented learners may lead them to seek in-depth strategies that would benefit their knowledge gain.

The Current Study

Reviews on each of the motivational variables above plausibly suggest that motivational orientations could have different effects on students' processing of procedural and conceptual types of knowledge, and thus simultaneously affect students' learning profiles. This proposition bodes well for the aim of the current study, which is to demonstrate that procedural and conceptual learners could have dissimilar motivational attributes. Findings from this study may provide an improved understanding of the individual differences that exist in the way that students rely on both conceptual and procedural knowledge. In addition, if procedural and conceptual learners differ in their motivational characteristics, this would validate the cluster analysis approach of grouping individuals based on their relative success on the two types of knowledge measures.

In this study, two types of major analyses will be performed. First, I wish to run a similar two-cluster analysis as was performed with grade-eight students in Hallett et al.'s (2012) study. This analysis would determine if the current data produce the same two types of group memberships as in Hallett et al.'s (2012) study – a more procedural and a more conceptual group. Second, using regression analyses, the procedural learners will be compared with the conceptual learners on the degree to which their procedural/conceptual scores relate to their scores on the math self-concept, self-attribution, and goal-orientation measures. The influence of gender will also be controlled because previous studies have reported a few gender differences relating to academic self-concept and attributional style.

Because of its exploratory nature, this study investigated the influence of learning style with a range of motivational variables. Nevertheless, some tentative hypotheses can be made about how conceptual and procedural learners may vary in regards to specific variables. Considering that in-depth conceptual understanding about the underlying mechanisms behind a math problem signifies a better grasp of that math topic (Hiebert & Lefevre, 1986), I surmise that this advantage would provide the impetus for forming a more positive view about mathematics in general. Figures 1 and 2 below have been included to summarize the main hypotheses of interest. The solid lines represent the correlations that have been demonstrated in previous studies. The dotted lines represent the main correlations that will be tested in this study. Bearing in mind findings from past literatures, I hypothesized that conceptual learners' fraction scores would relate highly positively with math self-concept score, mastery goal orientation, attributing math success to ability, but relate negatively with attributing math failure to external factors (see Figure 1). In contrast, procedural learners' fraction scores are predicted to have lower positive associations with math self-concept, relate positively with performance goal orientation, and relate positively with attributing math success to external factors, and math failures to a lack of ability (see Figure 2). However, for procedural learners, I anticipate finding more complex results given the approach-avoidance dimension that is found within the performance goal orientation framework. To simplify Figure 1 and 2, relations between fractions scores and failure attributions are not included. However, the hypothesized relations can be found above.

Figure 1 and 2 are separately presented to illustrate that I expect to see different pattern of correlations between procedural/conceptual scores and each of the motivational variables for the procedural and conceptual learners. Those differences in correlations will be examined through regression analyses, focusing specifically on possible interactions. Although the specific variables mentioned in the hypotheses above are of particular interest, the analyses will also investigate differences between conceptual and procedural learner regarding the other motivational variables measured in this study.

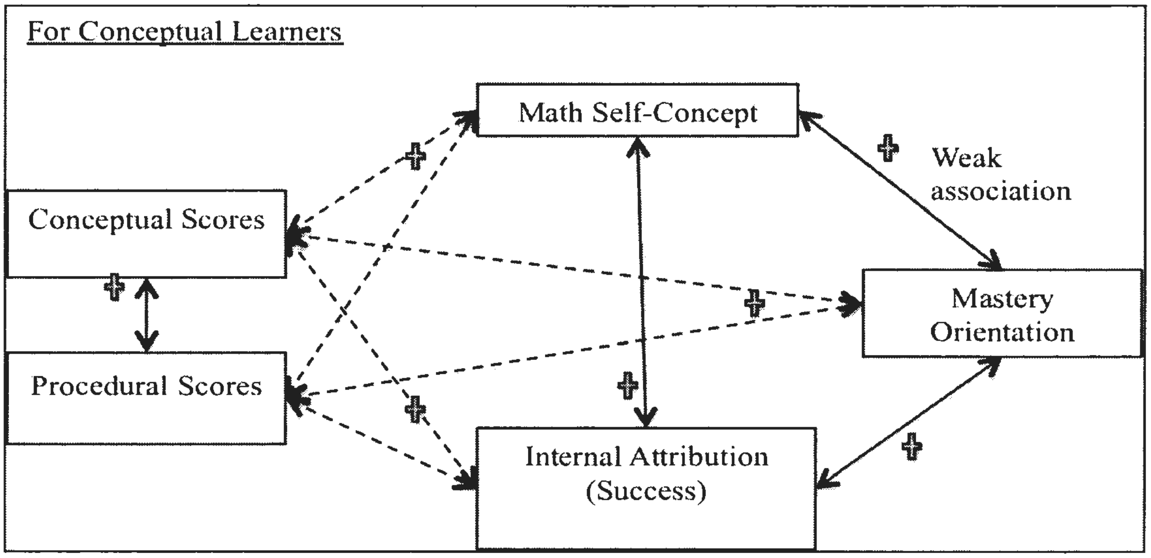

Figure 1. The links between conceptual learners' conceptual/procedural scores and other motivational variables, with dashed arrows representing hypothesized links.

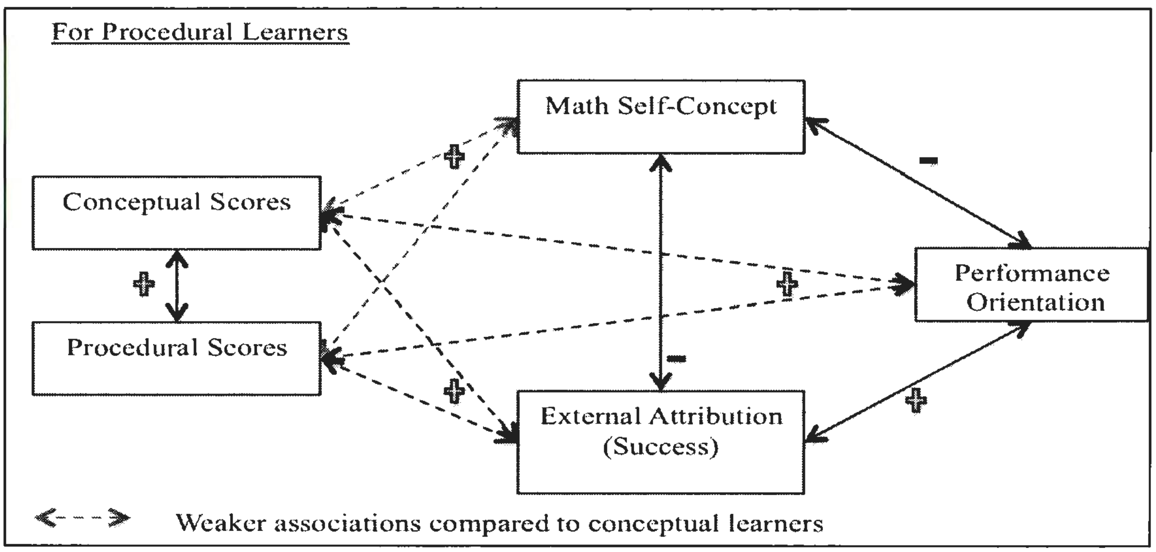

Figure 2. The links between procedural learners' conceptual/procedural scores and other motivational variables, with dashed arrows representing hypothesized links.

Method

Participants

A total of 61 (34 males and 27 females) Grade-8 students were recruited from five schools in the Eastern School District of Newfoundland, Canada. Two students (1 male and 1 female) were excluded from the analyses because of attrition, and one male student was excluded for merely circling the responses without reading the items on the motivation measure. The final sample contained 58 students (33 males and 25 females), with the mean age of 13.67 (*SD* = .38). In terms of ethnic background, 86% were Caucasians and 14% were from other racial groups (e.g., East Asian, Middle-Eastern, Hispanic).

This age group was chosen because previous work by Hallett and colleagues (2012) found that the procedural and conceptual measure (used in this study) was appropriate for clustering Grade 8 students into more procedural and more conceptual learners. From previous research, the importance of motivation during adolescence should be noted, as this is a critical period when motivation begins to decline (Wigfield et al., 1991). Hence, if there exists any motivational characteristic differences between conceptual and procedural learners, the differences should be readily detectible in adolescent participants.

Measures

Procedural and Conceptual Fraction Measure (Hallett et al., 2010). This 24-item paper and pencil instrument measures Grade 8 students' procedural and conceptual ability in fraction solving. Twelve of the items were procedural questions, and the other 12 were conceptual questions. Given that some of the items had sub-questions, the total marks for each subscale did not yield to the number of items on the scale. The procedural subscale was marked out of 14, and the conceptual subscale was marked out of 24. Most of the items on this measure were taken from the Chelsea Diagnostic Mathematics Fraction Tests (Brown, Hart, & Küchemann, 1984). The chosen conceptual items assessed understanding of equivalency (e.g. 2/4 = 4/8), the ability to judge whether one fraction is larger than another, or knowledge of other characteristics associated with the meaning or concept of fractions. The procedural items required students to solve a problem using a series of computational steps they had learned previously in school. Refer to Appendix A for example items on the measure.

Math and Verbal Self-Concept Subscales (Marsh et al., 1985). The math and verbal self-concept subscales were obtained from the Self-Description Questionnaire II (SDQ-II) designed to be appropriate for students from Grade 7 to Grade 12. The full measure has 102 items measuring 11 different factors of self-description, and each factor can be tested on its own. The 11 factors included three areas of academic self-concept: verbal, math and school in general; two areas of non-academic self-concept: physical appearance, physical ability; three areas of relationship self-concept: parent relationships, same-sex and opposite sex peer relationships; two other important areas of self-concept: honesty/trustworthiness and emotional stability; and one general self-esteem scale derived from Rosenberg (1979).

For the purpose of this research, I only assessed students' verbal and math self-concept. Thus, a total of 20 items were used – 10 from each math and verbal factor. For each item, participants were required to respond on a six-point Likert scale, with 1 being

"False" and 6 being "True." The items were both positively and negatively worded. The negatively worded items were reverse scored during data analysis. A high score (a maximum score of 60, and a minimum score of 6) on this scale reflected a more positive self-concept, and vice versa. For examples of items on the subscales, refer to Appendix B. Instructions for administering and scoring the items were obtained from a manual compiled by Marsh (1992).

Although I was primarily interested in the math self-concept reports, I felt that it might be worth examining the relation between participants' math and verbal self-concepts, and to see if that relation confirms Marsh's (1986) I/E model. Moreover, since verbal abilities have been used as a possible explanation for a better performance on a conceptual measure (e.g., Schneider & Stern, 2010), there may be a positive correlation between verbal self-concept and conceptual scores, especially for the conceptual learners.

Sydney Attribution Scale (Marsh et al., 1984). The main purpose of the SAS was to measure students' perception of the causes of their academic success and failure. The wording on this scale was not modified to fit Canadian English (i.e. changing the word "maths" to math). I assumed that this minor change would not have an influence on Canadian students' responses, and thus it was best to leave the measure in its original form. This scale included 24 items (6 items for 4 different outcomes) with three Likert-type responses on each item. The three responses were designed to reflect causal attributions that are loaded on ability, effort or external factor (e.g.: luck, task difficulty, or teacher influence), which meant that there were three separate causes for each one of these outcomes: math-failure, math-success, reading-failure, and reading-success. The Likert scale on this measure ranged from 1 = "False," to 5 = "True." On each subscale, students could attain a maximum score of 30 and a minimum score of 5. A few examples of items on this scale are included in Appendix C. Although the measure includes both reading and math attribution scales, the scores on the reading domain were not included in the data analyses, as they were not relevant to my primary interest.

Personal Achievement Goal Orientation Subscale (Midgley et al., 2000). This subscale was adopted from the original Patterns of Adaptive Learning Scales (PALS). The complete version of PALS could be broken down into two scales: one for students and the other for teachers. Other measures on the student scale include: students' perception of teacher's goals; perception of classroom goals; academic-related perceptions, beliefs, and strategies; and perception of parents, home life and neighborhood. The PALS was chosen over other goal orientation measures, because previous research – comparing the psychometric properties between PALS, Motivation Orientation Scales, and Learning and Performance Scales – revealed that the PALS generally scored the best in terms of factorial and construct validity (Jagacsinki & Duda, 2001). The alpha coefficients for each of the measured goals were reported to be in the range of .75 to .89 (Midgely et al., 2000). The goal-orientation scales on the PALS were based on research showing a differential emphasis on mastery, performance-approach, and performance-avoidance goals. In this study, the items will be rephrased to reflect goals that were specific to the math domain. This was performed following the most recent test manual provided by the scale developers – Midgely and colleagues (2000). A five-point Likert scale was used to collect responses for each item on the measure. The responses were anchored at 1 = "Not at all true, 3 = “Somewhat true”, and 5 = “Very true.” Example items on this scale are included in Appendix D, where they are grouped by subscale. In the actual measure, the order of the items was randomized without identification of a specific goal orientation, but the end result was three separate subscales indicating the level of agreement for each individual with each goal orientation.

Procedure

A total of 13 Junior High Schools in St. John’s and the greater area were contacted by post mail and telephone calls to inquire about their willingness to participate in this study. Only 38% of the contacted schools agreed to allow students participation. Upon approval from the school principal, teachers were asked to distribute information letters and consent forms for parents of the students to review and sign.

Data collection involved two testing sessions. In the first session, students with a returned parental-consent form were asked if they were willing to participate. Once students’ consents were obtained, they were asked to complete a measure of fraction understanding. This measure was given to students in groups during a 45-minute class period. One may speculate that group administration may affect performance of students who were conscious about how they perform surrounding their peers (i.e. performance-oriented learners). However, I suspect doing the first session in groups would have minimal impact on such students because students were repeatedly told that they would not be graded on this test and students were warned not to look at their neighbours’ answers, but they were encouraged to do the best that they could on the fraction test. Students were told that the researcher was interested in knowing how comfortable the students were with fractions, and that they were not allowed to use calculators.

For the second session, the classroom was divided into a few smaller groups and students' seats were positioned so that their peers were not visually present. This was done because some of the questions included in this session were sensitive to social comparisons. For example, when the questionnaire item asked a student to report how he or she feels about their math ability, the person's self-concept could be higher when sitting next to a less able student than when sitting next to a more able student. To avoid this influence, exposure to peers was minimized. In this second session, students were asked to complete all three motivational measures: i) the math and verbal self-concept scale; ii) the Sydney attribution scale; and iii) the personal achievement goal-orientation scale. Students were reminded that their responses were anonymous and that there were no right or wrong answers for these types of questions. Students were simply encouraged to be honest with their answers. The order of the three measures was counterbalanced across participants, using a Latin-Square ordering, to control for order effects (i.e. each participant received one out of six possible test orders). A total time of 30 minutes was allocated for this portion of data collection. Also, depending on the school facility, small-group testing was sometimes carried out in a school library or an empty classroom. At the end of the second session, each individual was given $10 in cash for participating.

The order of test administrations was not counter-balanced because, with group administration, this could have introduced differences in order between schools. Moreover, the amount of time between the two sessions was thought to be long enough to minimize any influence of the earlier session on the later one.

Results

Cluster Analysis

As performed in Hallett and colleagues' (2012) study, I regressed the conceptual and procedural scales against each other to generate residualized conceptual and procedural scores. In Hallett and colleagues' (2012) study, the researchers used a few criteria (e.g., looking for highest score on the *C(g)*, a test that measures the ratio of the variance between clusters compared with the variance within clusters) to search for the best cluster solution for their Grade 8 students' residualized scores. A two-cluster solution proved to explain the researchers' data the best. The two clusters were the more procedural (higher-than-expected procedural and lower-than-expected conceptual) and more conceptual (higher-than-expected conceptual and lower-than-expected procedural) groups. In my study, a k-means cluster analysis was performed using the residualized scores by assigning a k value of 2. The number of iterations needed for this cluster solution was three. The two-cluster solution yielded the same pattern of clusters for Grade 8 that was reported in Hallett et al.'s (2012) study, and is presented graphically in Figure 3. Of the 58 students, 30 of them (males = 17; females = 13) were classified as more conceptual (having positive residualized conceptual scores and negative residualized procedural scores), and 28 of them (males = 16; females = 12) were classified as more procedural (having positive residualized procedural scores and negative residualized conceptual scores). A goodness-of-fit chi-square analysis indicated that the frequencies of the two categories were not significantly different, $X^2(1) = .069$, $p = .80$.

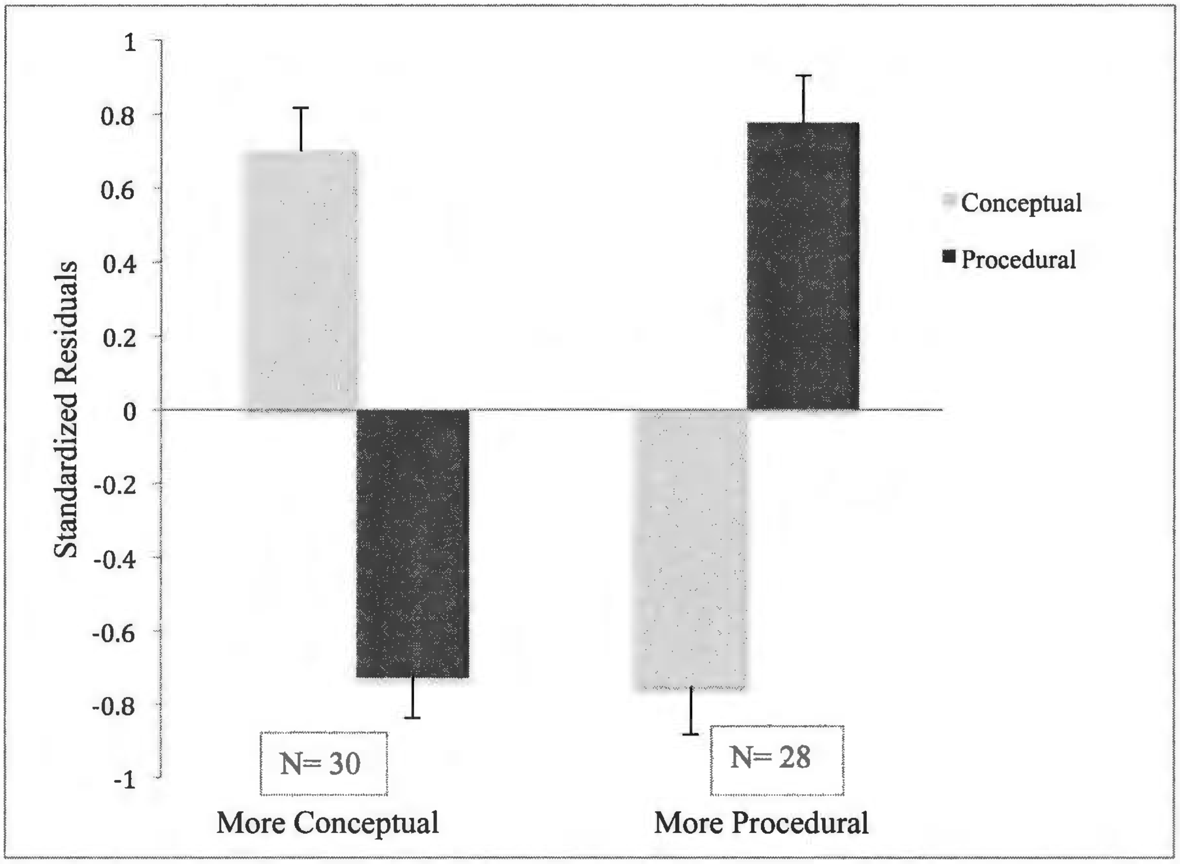

Figure 3. Cluster solution for residualized conceptual and procedural scores. Error bars represent standard errors of the means.

Regression Analyses

Given the nature of how the clustering was done, I decided to examine the group differences using relational analyses instead of using mean-difference (t-test) analyses. The clustering was done in such a way that it reflected students' relative ability on one scale compared with the other scale. Hence, it is quite possible to find both low- and high-achievers in one cluster, and this may result in having no significant differences in the mean score between the two clusters. Furthermore, the study hypotheses were not concerned with mean differences between conceptual and procedural learners, but with differences between these two groups of learners in the relations between achievement and motivation.

Table 1 presents the zero-order correlations between the motivational variables and the procedural/conceptual scores. The means and standard deviations for all scales are reported in Table 2.

Table 1. *Correlation Matrix*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Conceptual	-	.71**	.95**	.56**	.22	.42**	.29*	.02	-.52**	-.16	.12	.12	.08	-.02
2. Procedural	-	-	.90**	.65**	.31*	.43**	.17	.06	-.60**	-.22	-.01	.04	-.17	-.24
3. Overall Fractions	-	-	-	.65**	.27*	.46**	.26	.04	-.60**	-.20	.07	.09	-.03	-.12
4. Math SC	-	-	-	-	.22	.78**	.47**	-.02	-.79**	-.22	-.09	.30*	.10	-.01
5. Verbal SC	-	-	-	-	-	.07	.10	-.11	-.42**	-.44**	-.15	.32*	-.02	-.08
6. MSuccAbility	-	-	-	-	-	-	.62**	.07	-.61**	-.07	.00	.33*	.30*	.09
7. MSuccEffort	-	-	-	-	-	-	-	.06	-.31*	-.14	.07	.50**	.26	.20
8. MSuccExt	-	-	-	-	-	-	-	-	.01	.14	.34**	-.09	.26*	.44**
9. MFailAbility	-	-	-	-	-	-	-	-	-	.37**	.12	-.29*	-.16	-.02
10. MFailEffort	-	-	-	-	-	-	-	-	-	-	-.04	.02	.01	.05
11. MFailExt	-	-	-	-	-	-	-	-	-	-	-	.04	.24	.18
12. Mastery	-	-	-	-	-	-	-	-	-	-	-	-	.16	.02
13. PerApproach	-	-	-	-	-	-	-	-	-	-	-	-	-	.69**
14. PerAvoid	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Notes: * p < .05. ** p <.01. Math SC is Math Self-Concept, Verbal SC is Verbal Self-Concept, MSuccAbility is Ability Attribution for Math Success, MSuccEffort is Effort Attribution for Math Success, MSuccExt is External Attribution for Math Success, MFailAbility is Ability Attribution for Math Failure, MFailEffort is Effort Attribution for Math Failure, MFailExt is External Attribution for Math Failure, PerApproach is Performance Approach, and PerAvoid is Performance Avoidance*

Table 2. *Means and Standard Deviations for Each Scale*

Scale	Mean	Standard Deviation
1. Total Conceptual (N=58, marks out of 24)	12.74	4.69
2. Total Procedural (N=58, marks out of 14)	5.26	3.52
3. Total Fraction (N=58, marks out of 38)	18.00	7.60
4. Math Self-Concept (N=58, marks out of 60)	39.60	11.90
5. Verbal Self-Concept (N=58, marks out of 60)	45.29	9.42
6. Math Success Ability (N=58, marks out of 30)	18.96	6.21
7. Math Success Effort (N=58, marks out of 30)	21.72	4.83
8. Math Success External (N=58, marks out of 30)	17.64	4.59
9. Math Failure Ability (N=58, marks out of 30)	14.26	5.76
10. Math Failure Effort (N=58, marks out of 30)	18.38	4.24
11. Math Failure External (N=58, marks out of 30)	16.74	4.17
12. Mastery Goal (N=57, marks out of 25)	19.89	3.37
13. Performance Approach (N=57, marks out of 25)	12.60	5.52
14. Performance Avoidance (N=57, marks out of 20)	10.84	4.48

In the regression analyses, I was interested in the predictive power of three major variables: motivation, cluster membership (learner types), and gender. These three types of variables were used to predict students' conceptual and procedural scores separately. Hence, for each type of motivational scale, two separate regression analyses were performed: one predicting procedural scores and one predicting conceptual scores.

Aside from examining the main effects produced by each of the three variables (motivation, cluster membership, and gender), I was fundamentally interested in examining if motivation interacted with cluster, although I was also interested in interactions with gender or if all three variables interacted with each other. The analyses were performed in a backward manner, where I began by entering motivation, cluster membership, gender in the analyses along with two-way interactions and the three-way interaction as predictors. In cases where the three-way interaction was significant, the full model was preserved. However, when the three-way interaction was not significant, it was removed from the model and each two-way interaction was then examined. Any two-way interactions that were significant remained in the model. If no interactions (two- or three-way) were significant, only motivation, cluster-membership, and gender were used as the predictor variables. In the end, the main objective was to present the simplest model that explained the influence of each type of motivational variables, cluster membership, and gender on students' conceptual and procedural scores. Results from these analyses are summarized in Table 3 and 4.

Table 3: *Regression Analyses Predicting Conceptual Scores*

	Mot β	Cluster β	Gender β	Mot x Cluster β	Cluster x Gender β	Mot x Gender β	Mot x Cluster x Gender β
Motivation (Mot) Scale							
Math Self-Concept	1.45**	.647**	.173	-.742*	-.198	-.636	.541*
Verbal Self-Concept	.221	.306*	-.163	-	-	-	-
Ability Attribution for Math Success	.459**	.370**	-.234*	-	-	-	-
Effort Attribution for Math Success	.290*	.270*	-.225	-	-	-	-
External Attribution for Math Success	.013	.279*	-.211	-	-	-	-
Ability Attribution for Math Failure	-.572**	.374**	-.049	-	-	-	-
Effort Attribution for Math Failure	-.153	.301*	-.159	-	-	-	-
External Attribution for Math Failure	.017	.275*	-.209	-	-	-	-
Mastery Orientation	.146	.265*	-.239	-	-	-	-
Performance Approach Orientation	.029	.259	-.224	-	-	-	-
Performance Avoidance Orientation	-.059	.277*	-.220	-	-	-	-

Note: ** $p < .01$, * $p < .05$. *Beta coefficients reflect the degree of correlation with conceptual scores. Codes for cluster membership: 1 = conceptual, 0 = procedural. Codes for gender: 1 = males, 0 = females.*

Table 4: *Regression Analyses Predicting Procedural Scores*

	Mot β	Cluster β	Gender β	Mot x Cluster β	Cluster x Gender β	Mot x Gender β	Mot x Cluster x Gender β
Motivation (Mot) Scale							
Math Self-Concept	.591**	-.219*	-.071	-	-	-	-
Verbal Self-Concept	.226	-.603**	-.395*	-	.458*	-	-
Ability Attribution for Math Success	.379**	-.559**	-.460*	-	.456*	-	-
Effort Attribution for Math Success	.219	-.674**	-.488**	-	.517*	-	-
External Attribution for Math Success	.047	-.644**	-.455*	-	.482*	-	-
Ability Attribution for Math Failure	-.855**	-.244*	-.018	.389*	-	-	-
Effort Attribution for Math Failure	-.114	-.623**	-.414*	-	.473*	-	-
External Attribution for Math Failure	.052	-.655**	-.447*	-	.477*	-	-
Mastery Orientation	.032	-.638**	-.456*	-	.482*	-	-
Performance Approach Orientation	-.073	-.624**	-.449*	-	.031*	-	-
Performance Avoidance Orientation	-.199	-.616**	-.459*	-	.502*	-	-

Note: ** $p < .01$, * $p < .05$. *Beta coefficients reflect the degree of correlation with conceptual scores. Codes for cluster membership: 1 = conceptual, 0 = procedural. Codes for gender: 1 = males, 0 = females.*

Predicting Conceptual Scores

Before scrutinizing the effects and interactions that were specific to certain types of motivational scales, it is worth identifying a pattern of results that was consistent across all types of motivational constructs. In reference to Table 3, where conceptual score was placed as the criterion variable, cluster membership significantly predicts conceptual scores across all regression analyses. This outcome was not surprising, as I would expect more conceptual learners to have, on average, higher conceptual scores.

In addition to the above general pattern, a significant three-way interaction between math self-concept, gender, and cluster membership was observed. After controlling for gender and cluster membership, math self-concept appeared to have a significant influence on students' conceptual scores, in which a more positive perception about one's math ability relates to an improved performance on the conceptual measure. This relation seemed to change depending on which group of clusters the students were in, and whether they were male or female. Surprisingly, the beta coefficient showed that the relation between math self-concept and conceptual scores was more positive for procedural learners than it was for conceptual learners (refer to Figure 4). However, a significant three-way interaction clarified that the interaction between math self-concept and cluster differed at the level of gender. In particular, for males, both procedural (R^2 = .429) and conceptual (R^2 = .385) learners' scores on the conceptual measure similarly improved as a linear function of math self-concept. For females, those who were in the procedural group (R^2 = .724) had a larger positive change in their conceptual scores than those in the conceptual group (R^2 = .260), as the students viewed their math ability positively. This three-way interaction is depicted in Figure 4.

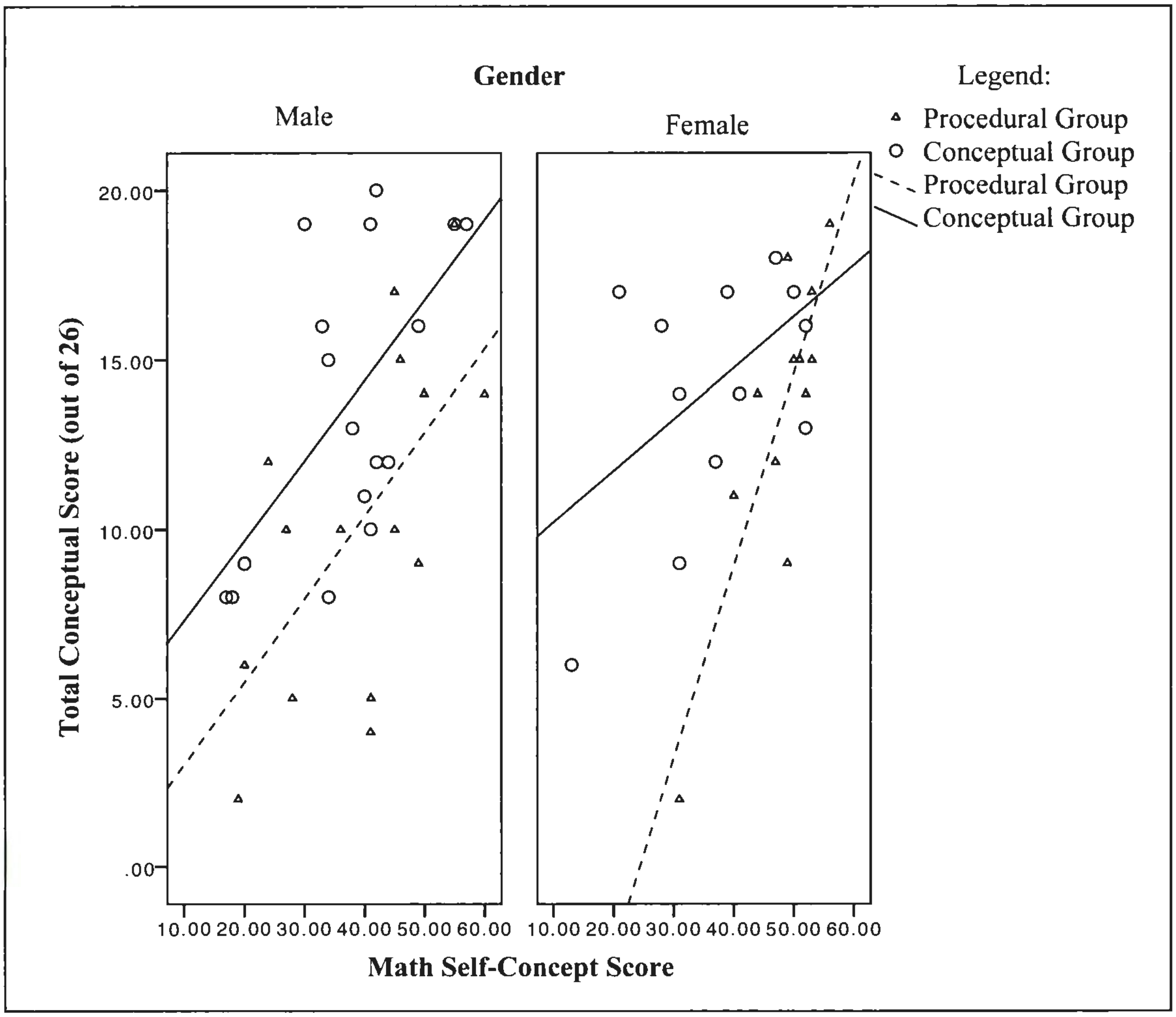

Figure 4. Three-way interaction between math self-concept, cluster membership, and gender with conceptual score being the dependent variable.

Additionally, the data indicated that students' attributional styles relating to their performance on the conceptual measure was subjected to self-serving bias. In general, as students performed better on the conceptual scale, they were more likely to attribute their math success to ability but were also more likely to agree that inability was not the cause of their math failures. Moreover, although ability attribution was often shown to be exclusive to the math domain (e.g., Marsh et al., 1984), Grade 8 students in this sample were shown to be using the effort attribution as well when explaining their math success. Unlike math failures, the smarter students were more inclined to use the other internal causal factor (i.e. effort) by attributing their math success to the amount of effort they exerted in studying math. However, these associations were not dependent on type of learner or gender, so they were not relevant to the current study's hypothesis. The final type of attribution (external factors) failed to explain the distribution of students' conceptual scores in both failure and success outcomes. Verbal self-concept also failed to predict any variance in students' conceptual scores. As for goal orientation, none of the achievement goals was related to students' conceptual scores.

Predicting Procedural Scores

Given that procedural and conceptual scores tended to explain certain math performance differently in previous studies (e.g. Schneider, Rittle-Johnson, & Star, 2011), I performed a separate set of regression analyses to examine variables that are informative in explaining the variance in students' procedural scores – refer to Table 4. Cluster membership was predictive of students' procedural scores demonstrating that the procedural learners were more likely to have higher procedural scores, which is to be expected. More interestingly, with the exception of math self-concept and ability attribution for math failure, there appeared to be a gender difference in procedural scores when other motivational variables and cluster membership were controlled for. Gender and cluster membership almost always significantly interacted, suggesting that the relation between cluster and procedural scores differed for males and females – see Figure 5. Note that Figure 5 represents the gender by cluster membership interaction without the influence of any of the motivational variables. For simplicity reasons, the unadjusted means were used here to illustrate this two-way interaction because this same pattern of means was prevalent in all these models even after accounting for the motivational variables in question. As depicted in Figure 5, male students in the procedural and conceptual groups performed similarly well on the procedural scale. Females in the procedural group, on the other hand, appeared to have higher success with the procedural items than females in the conceptual group, who performed just as well as the males from both groups. In other words, the expected difference between conceptual and procedural learners on procedural scores is only evident in females and not in males. Still, it is worth reiterating that the cluster analysis was performed based on students' residualized scores. It may be intuitive for readers to assume that students in the procedural group would have higher procedural scores than students in the conceptual group but this is not necessarily the case for subgroups within these groups. If a group of procedural learners happen to be on the lower end of achievement, then they will not necessarily outperform conceptual learners on the upper end on achievement, even in regards to procedural knowledge. Looking at Figure 5, this seems to be what is happening for the males in the sample. While the females are showing the expected advantage of procedural knowledge for the procedural group, males from the conceptual group are performing equally well on the procedural knowledge measure as males from the procedural group. The implication is that males in the conceptual group are generally of higher ability than males in the procedural group, although this is not true of females.

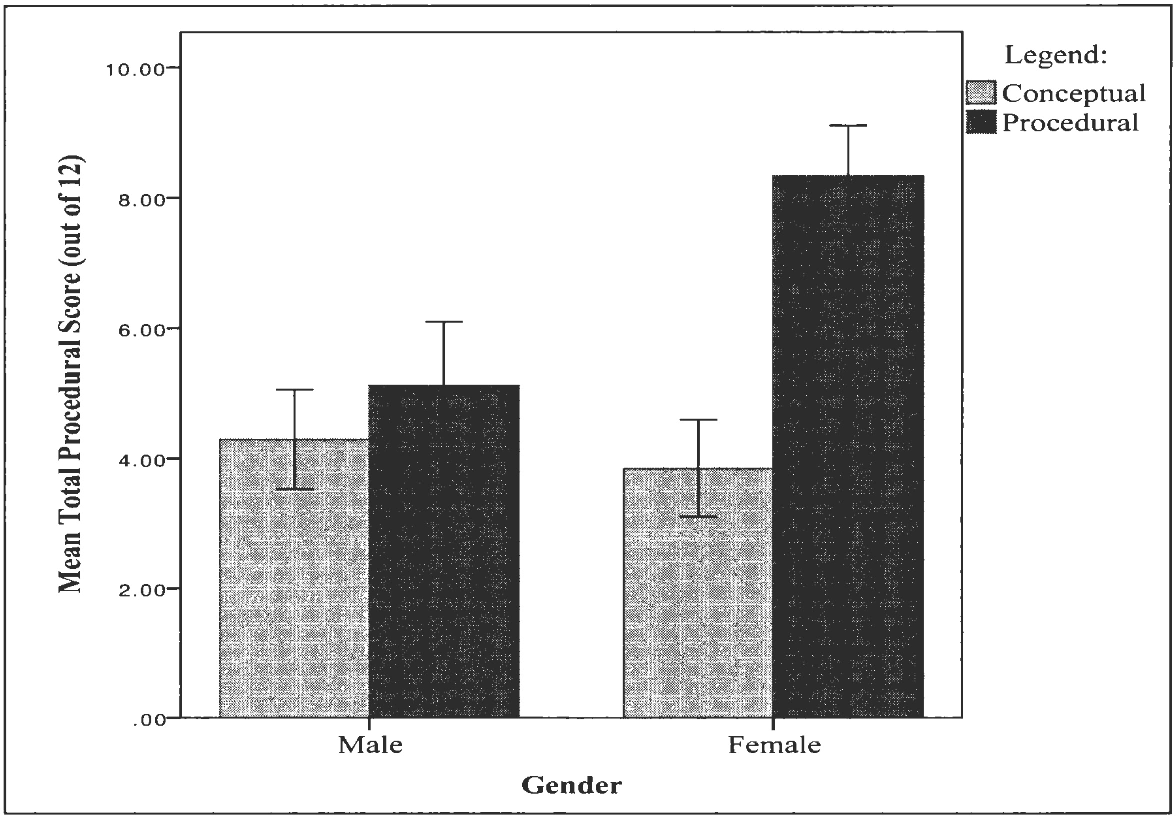

Figure 5. Interaction between gender and cluster membership on raw procedural scores, with dark bars representing procedural group and light bars representing conceptual groups. Error bars represent standard errors of the means.

Aside from this general pattern of gender by cluster interactions, there were three effects with the procedural measure that were related to the motivational variables. The first concerned math self-concept. In contrast to the conceptual scale, the model of prediction for procedural scores relating to math self-concept was much simpler in this section of analysis. None of the interaction terms proved to be significant. However, students' math self-concept was highly predictive of their procedural scores: a more favourable math-ability perception was related to an increased performance on the procedural measure.

The other two effects involved the attribution of both math success and math failure to ability. Students' attributional styles once again were subjected to a self-serving bias. As students' performance on the procedural scale improved, ability was more likely favoured to be the causal factor of their success. When failures were considered, the students tended to deny that their failures were caused by their lack of ability in math. In fact, students' ability attribution scores on the math failure outcome were highly negatively correlated with the students' scores on the procedural scale, β coefficient = -.855, $p < .001$. A significant interaction between believing that math failure was unrelated to ability and cluster membership indicated that, as procedural scores increased, procedural learners (R^2 = .568) were much more likely to attribute lack of ability as a reason for math failure compared to their conceptual counterpart (R^2 = .174). Figure 6 visually represents this two-way interaction. Effort and external attribution used for explaining math success and failure proved to have no significant influence on students' procedural scores.

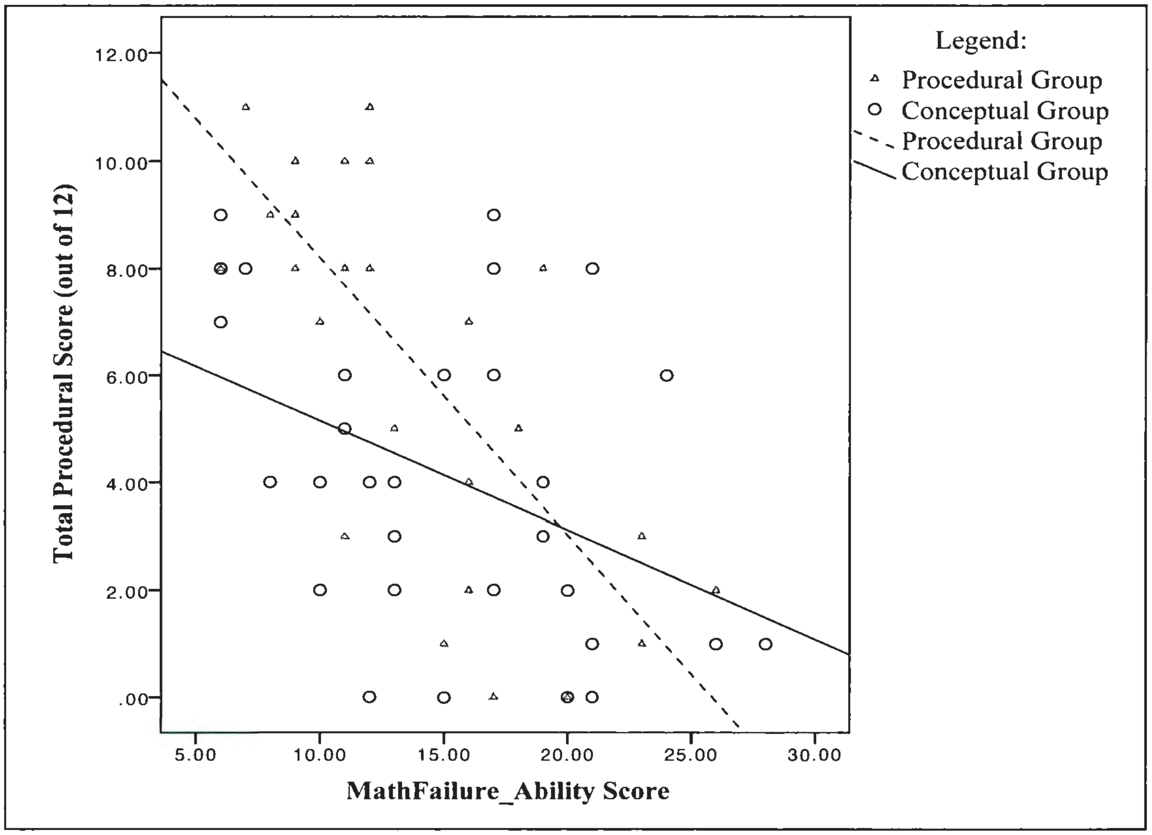

Figure 6. Interaction between ability attribution score of math failure and cluster membership, with procedural scores being the dependent variable. Higher score on the x-axis means having stronger belief that one failed because one has low math ability.

Again, none of the achievement goal orientations were related to either conceptual or procedural scores, and the non-significant relation did not interact with cluster membership or gender. Consistent with the earlier analysis (in predicting conceptual scores section), verbal self-concept also failed to predict students' procedural scores.

Summary from Models Predicting Conceptual and Procedural Scores

In reference to the hypotheses shown in Figure 3 and 4, I have summarized the significant interactions that were found in this study in Figure 7 below. For the most part, I did not find many significant motivational characteristic differences. Goal orientation was removed from the figure because it did not seem to have any influence on students' procedural and conceptual performances. As depicted, math self-concept scores of the girls in the procedural group have a larger influence on their conceptual performance compared to other groups of students. In terms of attribution, procedural learners tended to believe much more that lack of ability was not the cause of their math failures in comparison to the conceptual learners.

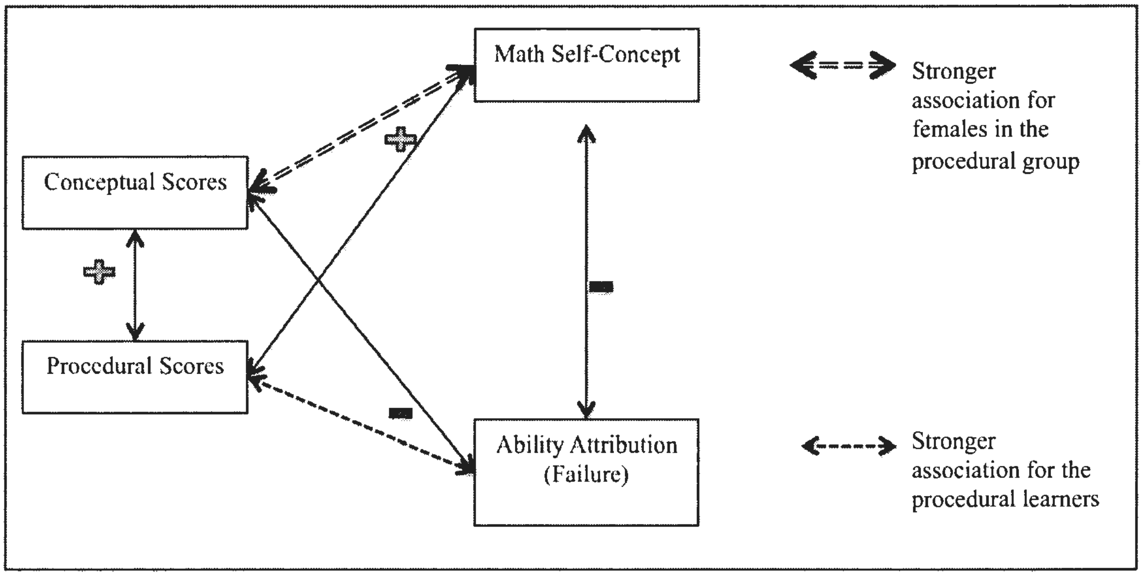

Figure 7. Summary of the significant interactions. The positive association between conceptual scores and math self-concept is stronger for females in the procedural group. The negative association between procedural scores and attributing math failure to lack of ability is stronger for the procedural learners.

Relation between Motivational Constructs

It is worthwhile to mention a few interesting findings that paralleled previous research on academic motivation. For example, math self-concept was found to correlate positively with students making more internal attributions. Specifically, as students' perceived math ability became more positive, they tended to take more personal responsibilities for their math success by attributing the outcome to their ability ($r_{(56)} = .78$, $p < .001$) and effort ($r_{(56)} = .47$, $p < .001$). However, when asked to consider their math failure, a high math self-concept made the students more likely to believe that ability has nothing to do with their failure, $r_{(56)} = -.79$, $p < .001$. As demonstrated in preceding sections, students' attribution styles seem to fit well with the self-serving bias, which posits that people tend to take more personal responsibilities for positive outcomes and not for negative outcomes.

Interestingly, students who highly value mastery experience in their learning tended to report a more positive perception of their math ability ($r_{(55)} = .30$, $p = .02$), and tended to attribute their math success to ability ($r_{(56)} = .33$, $p = .01$) as well as having exerted more effort ($r_{(56)} = .50$, $p < .001$). The positive correlation between mastery orientation and effort attribution was no surprise because Ames and Archer (1988) have suggested that students who emphasis mastery goal have a stronger belief that success follows one's effort. The latter two correlations (in relation to attribution) indicated that when mastery orientation was adopted, the causal explanation that was chosen was internal in nature. Yet, when it came to failure, only the stable and uncontrollable attribution (i.e. lack of ability) was more likely favoured as sense of mastery goal increased, $r_{(55)} = -.29$, $p = .03$.

As I have alluded to earlier in the introduction section, in comparison with mastery-orientation, performance-orientation is often associated with attributing academic outcomes to external factors. This sample of students was no exception; the more performance-oriented the students were, the more likely they were to attribute their math success to external factors (performance-approach, $r_{(55)} = .26$, $p = .04$; and performance-avoidant, $r_{(55)} = .44$, $p < .001$). Although both were significant, it is worth noting that degree of correlation was much higher with performance-avoidant orientation than with performance-approach orientation.

Discussion

The goal of this study is to find out whether procedural and conceptual learners differ on three motivational constructs: self-concept, self-attribution, and goal orientation. The results above demonstrate that procedural and conceptual learners can be differentiated on the basis of a few but not all of the motivational variables. Procedural and conceptual learners are different particularly in the way they perceive their math ability and the way they use ability attribution to explain their failure in mathematics. However, the motivational differences between the two types of learners can further depend on gender (i.e., whether there are differences between procedural and conceptual learners is contingent on being male or female).

Aside from the differences between conceptual and procedural groups, conceptual and procedural scales generate different sets of predictions when differing motivational variables are considered. For example, only ability attribution for a success outcome is predictive of students' procedural scores, but the same ability and effort attributions are able to explain the variance in students' conceptual scores. This line of evidence suggests that although the procedural and conceptual scales are correlated, the types of motivation that are important to one type of knowledge (procedural or conceptual) might not be important to another. As most researchers in the math cognition field have suggested, procedural and conceptual knowledge, albeit having an influence on one another, contribute differently to the type of performance under investigation (e.g., Rittle-Johnson & Star, 2007; in the researchers' study the performance under investigation was procedural flexibility). In the following attempt to elucidate the findings in this study further, I will examine the differences between procedural and conceptual prediction models by considering each motivational construct independently.

First, findings in the self-concept portion revealed that math self-concept influenced male students' scores on the conceptual measure in a similar fashion, regardless of the students' cluster membership. However, female students who were classified as more procedural were more prone to an ability-perception change as their conceptual scores improved. One factor that could help explain this finding stems from the cues carried by conceptual questions that could be effective in changing students' views of their math potential. Specifically, knowing how to solve conceptual questions may signal that one has a deep understanding in math and, overall, must have an excellent math ability. These results seem to suggest that females in the procedural group tend to rely on this signal (much more than males or females in the conceptual group) in the evaluation of their math ability. Seeing how ability-perception and performance function in a cyclical manner (Marsh & Yeung, 1997), a more favourable perception of math ability may then result in having a higher score on the conceptual measure, especially for females in the procedural group. In contrast, although math self-concept is predictive of performance on the procedural scale, no specific group or gender tends to weight success on procedural questions higher than other groups or gender.

One reason the verbal self-concept measure was included was to investigate if a high evaluation of perceived verbal ability would be associated with performing well on the conceptual measure. This query was partly driven by previous researchers' suggestions (e.g., Schneider, Rittle-Johnson, & Star, 2011), which postulates that individuals with high verbal abilities are at an advantage to perform well on conceptual questions because they involve a verbal explanation task. In my research, students' verbal ability was not directly measured. However, as far as self-perception is concerned, the findings indicate that procedural and conceptual learners are not different in how well they think they perform in the verbal domain. Verbal self-concept itself failed to predict students' scores on the conceptual and procedural measures. It is also worth mentioning that, consistent with Marsh's (1986) Internal and External (I/E) model of academic self-concept, students' verbal self-concept has almost no correlation with their math self-concept. Perceiving one's verbal ability highly does not mean that the same person would perceive his or her math ability highly as well. As explained by Marsh (1986), students often think of themselves as being either more of a verbal person or more of a math person, but not both.

Turning to self-attribution, previous research repeatedly affirms that ability attribution is specific to the math domain (e.g., Marsh et al., 1984; Stipek, 1984). Conforming to this claim, the current findings also reveal that ability plays a role in distinguishing conceptual from procedural learners. For example, when failure outcome is being evaluated, inclination to avoid lack-of-ability as an explanation of failure is predictive of the students' performance on the procedural scale. However, compared to conceptual learners, procedural learners' tendency to believe that their ability does not influence their failure appears to be much more indicative of performing well on the procedural scale. One possible explanation as to why this difference occurs comes from how it may be surmised that procedural learners are typically more performance-oriented and conceptual learners are typically more mastery-oriented. As discussed in a review by Covington (2000), failures threaten the ego of performance-oriented learners because they are often concerned about how others perceive their aptitude (see also Ames & Archer, 1988). Hence, it would not be surprising to observe that the smarter students in the procedural group fervently disprove of inability as being the causal explanation of their math failures, more so than their more conceptual peers. This is especially so when taking into account the procedural students' performance in the area that they are normally good at (procedural questions) versus an area that they are worse at (conceptual questions). However, this explanation remains speculative as, correlationally, no differences in goal orientation among the procedural and conceptual learners were found.

In line with many previous studies (e.g., Dickhauser & Meyer, 2006), it is not uncommon for students to attribute their success on math performance to their own ability, especially when they become proficient in the math knowledge. In particular for this study, the better the students were on the conceptual and procedural scale, the more likely they believed that their positive achievements in math were due to their ability. However, it is only on the conceptual scale (not procedural) that effort attribution seems to matter as well. This finding suggests that when students give more weight to effort as being one of the important determinants of success, the students' performance on the conceptual measure may tend to improve. Considering that conceptual questions tend to be processed at a deeper cognitive level in comparison to procedural questions (Hiebert & LeFevre, 1986), it is not surprising that effort emerges as an important contributor for success on the conceptual measure but not for procedural measure.

As presented in the results section, achievement goal orientations not only failed to explain students' performance on the procedural and conceptual scales, but also were not predictive of any differences between procedural and conceptual learners. The data may suggest the Grade 8 students do not have a specific inclination to favour one goal versus the other, and thus the adoption of multiple goals decreases the predictive power of goal orientation on procedural/conceptual performance. As described by Pintrich (2000), it is undoubtedly possible for pupils to adopt multiple goals at one time. This is especially probable given the approach of the present-day, where performance orientation is almost always emphasized by the education system. Grades assignment, for example, compels students to constantly compare themselves with their classmates. Consequently, the existence of the classroom's salient goal orientation (to focus on performance) may likely coexist with the student's own goal to focus on mastering the subject. Given that classroom and teacher's goal orientation can be influential on students' leaning approach as well (Ames, 1992), future studies should directly examine the degree to which students feel intrinsically or extrinsically motivated to learn math (refer to self-determination theory in

Ryan & Deci, 2000). Perhaps self-determination would be more closely related to being a more procedural or more conceptual learner than goal orientation itself.

In addition to the above reasoning, it is intuitive to deem that the lack of explanatory power of goal-orientation could also be attributed to students' lack of concern with what their learning goal should be. However, Nicholls (1990) has found that both mastery and performance goals are evident as early as second grade. Furthermore, Middleton and colleagues (2004) have also demonstrated that students' goal-orientations are moderately stable during junior high school. The researchers found that sixth graders' performance-approach goal positively predicted the likelihood of adopting a performance-avoidance goal in the seventh grade. In light of this evidence, the argument that assumes that Grade 8 students ignored their learning goals seems less compelling.

Apart from the three motivational constructs (self-concept, self-attribution, and goal orientation), the notable influence of gender in this study warrants further investigation. In Steffens, Jelenec, and Noack's (2010) study, the researchers demonstrated how some Grade 4, 7, and 9 students implicitly concurred with the stereotype that the math domain belongs to boys and the verbal domain belongs to girls. Despite the lack of gender difference in students' math grade, the study showed no sign of math-gender stereotype in boys at all grade levels, but revealed a strong implicit (not explicit) math-gender stereotype in adolescent girls. Further, the researchers found that the stereotype (though it had a small effect on boys) significantly predicted students' math achievements, where a high endorsement of such stereotype was associated with poorer math achievements in girls but better math achievements in boys. Taking this research into account, I suspect that the degree to which a person implicitly believes in a math-gender stereotype can potentially mediate the influence of gender on being a more procedural or a more conceptual learner. It may also mediate the influence of gender on procedural and conceptual performance. Perhaps females who hold strong math-gender stereotype may be more likely classified as a procedural learner, more so than a conceptual learner, because that stereotype could have interfered with learning math in a deeper manner.

Related to the issue of gender, unlike the girls, conceptual males in this sample tend to be of higher ability as they were found to have higher conceptual scores but not lower procedural scores compared to the procedural males. Given this situation, we may note that the male students' ability distribution did not parallel the female students' ability distribution, at least in regards to procedural knowledge. As the gender by cluster interactions for the procedural measure demonstrated, females in the procedural group demonstrated more procedural competence than the males in the procedural group, but this same gap was not evident in the conceptual group. One may argue that this discrepancy reflects an overall performance difference between males and females in the procedural group, and it could be the reason why we found gender differences in the way procedural learners perceived their math ability in association with their conceptual performance.

It is also worth noting that students' overall performance on the procedural sub-scale (37%) appeared to be lower than on the conceptual sub-scale (53%). It is intuitive to think that the procedural questions may be more difficult to solve than the conceptual questions. However, upon inspection of the data and students' raw answers, the students seemed to have made many calculation errors especially with multiplication facts. In one particular school, the math teacher informed me that her students could not quite complete some of the fraction questions without heavily relying on their times table. I was also informed that the current education system no longer advised math teachers to make their students memorized multiplication facts as those facts can be easily retrieved from calculators and times table. If we allow students to use times table, this may not reflect students' true ability to do the procedural questions. This is a limitation that is beyond the researcher's control. The low procedural scores that are found within this sample also resulted in a low variability of procedural scores between individuals. If students' procedural scores were much more varied, cluster membership may have stronger predictive ability.

Above all, the findings reported here should be received with caution. This is because the data analyses were based on relatively small number of participants and there was a potential Type-1 error in effect. As I have tested multiple hypotheses, a family-wise error rate dictates that one or more of the significant tests are bound to result in a Type 1 Error. One of the significant interactions that were found above was not part of my original hypotheses. Prior to the test, the procedural learners were expected to attribute their math failures to internal factor, specifically to lack of ability. However, a negative significant correlation was instead found. The procedural learners appeared to be more likely to deny lack of ability as an explanation for failure than their conceptual counterpart. Hence, this significant finding must be received with caution, as it may be a result of a Type-1 Error. Additional participants will be needed for future study to provide a more cogent explanation of the differences between procedural and conceptual learners, and careful attention to Type-1 error should also be considered.

Additionally, through my observation while conducting this research, I came across one individual who appeared to be answering the motivational questions in a random manner without properly reading the items on the measure. It is possible that there were other students who answered in a similar manner. However, precise detection of such acts across all students was beyond the research team's control given the procedure that was used in this study. Although challenging to implement, perhaps a preemptive strategy to mitigate the influence of such behaviour (answering without reading) would be to individually test each participant.

Nonetheless, based on the findings with this small sample, and taking gender differences into account, procedural and conceptual learners appear to be different in the way that their perceived math ability and ability-attribution belief influence their performance on the fraction questions. The motivational differences among clusters that were found here provide support for the cluster analysis method of grouping procedural and conceptual learners that was performed in this and previous studies (Hallett et al., 2010; Hallett et al., 2012; Hecht & Vagi, 2012). The cluster analysis appears not to be just a mere product of statistical grouping. Instead, there seem to be some motivating factors for someone to be more procedural or more conceptual in his or her approaches to fraction learning. However, the motivation characteristic differences that were found here are not intended to demonstrate that the conceptual group generally has more positive self-views compared to the procedural group. Rather, I am suggesting that the self-doubt that one has in one's ability might hinder procedural learners in their attempts to learn math (or fractions specifically) in a more in-depth manner. This hindrance might eventually create barriers that could prevent that person from ever forming a strong conceptual understanding of that math topic.

Although the data analysis was presented in a one-directional manner (motivations predicting procedural and conceptual performance), it is important to note that motivation itself is malleable and dynamic (Bandura, 1986; Graham & Weiner, 1996). Any new information relating to a person's success on conceptual and procedural questions may alter that person's ability belief, and this alteration may then have some influence on the pupil's future task engagements when learning mathematics. Hence, educators should take into account students' inner beliefs and self-motivations relating to math learning when teaching both procedural and conceptual types of knowledge, and not merely focus on whether students can solve procedural or conceptual questions. Ultimately, as educators, we want our pupils to be able to master both procedural and conceptual questions well because proficiency in both types of knowledge may create the best outcome for a student's math performance.

Conclusion

Overall, the study presents a few motivational characteristic differences between procedural and conceptual learners, especially in the students' ability beliefs. Gender plays an important role in these differences; girls are seen to be much more sensitive than boys to their self-views pertaining to math ability. Future studies are needed to examine the effects of motivation and gender on procedural and conceptual performance further. The current study only measured three types of motivational constructs – self-concept, self-attribution, and goal orientation. Perhaps there are other types of motivational constructs (e.g., self-determination) that are more closely related to being more procedural or more conceptual fraction learners. Further investigation of this line of inquiry would benefit the work of forming an improved model describing the motivational characteristic differences between procedural and conceptual learners. Consequently, information provided by this model could assist educators and the education system in their ongoing search for a refinement of the math curricula that balances the teaching of procedural skills and conceptual understanding (CBC News, 2012). In devising these math curricula, the motivation of students should also be considered because, as this research shows, individuals differ in the way that they rely on conceptual and procedural knowledge and their motivational characteristics appear to have an influence on these differences.

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Appendices

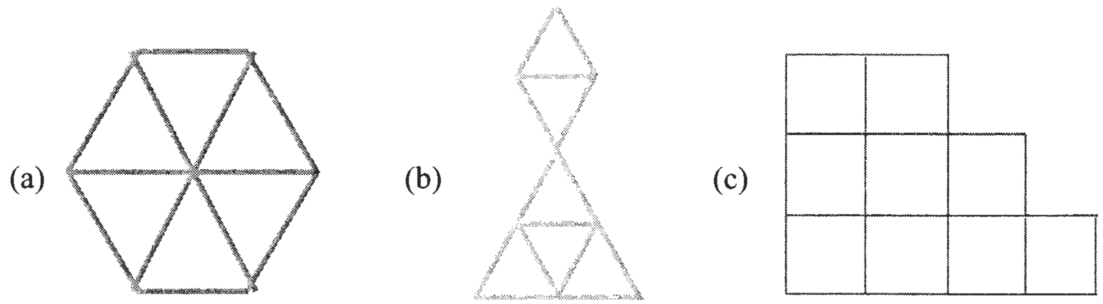
Appendix A

Procedural and Conceptual Fraction Measure

Example of a conceptual item:

1. Shade in two-thirds of each of these shapes:

(a) (b) (c)



Example of a procedural item:

2. Please solve this and show your workings:

$$\frac{4}{7} + \frac{9}{14} =$$

Appendix B

Self-Concept Measure

Likert scale used for all items on the Math and Verbal Self-Concept scales:

1	2	3	4	5	6
False Not like me at all; it isn't like me at all	Mostly false	More false than true	More true than false	Mostly true	True This statement describes me well; it is very much like me

Example of Math Self-Concept question:

1. I have always done well in Mathematics

Example of Verbal Self-Concept question:

2. I do badly on tests that need a lot of reading ability

Appendix C

Sydney Attribution Scale

Example question for math failure outcome:

1. Suppose you get a maths question wrong in class. It is probably because:	False	Mostly False	Sometimes False, Sometimes True	Mostly True	True
a) you often have trouble in maths	☐	☐	☐	☐	☐
b) the question was hard	☐	☐	☐	☐	☐
c) you never pay any attention in maths lessons...	☐	☐	☐	☐	☐

Example question for math success outcome:

2. Suppose you are chosen from your school to take part in a state maths competition. This is probably because:					
a) you will try your best...........................	☐	☐	☐	☐	☐
b) you were lucky	☐	☐	☐	☐	☐
c) you are good at maths..........................	☐	☐	☐	☐	☐

Appendix D

Personal Achievement Goal Orientation

Num.	Items	Not at all True		Somewh at True		Very True
	Mastery-Oriented					
1.	Learning a lot of new things is what is important to me in math.	1	2	3	4	5
	Performance-Approach					
1.	In math, doing better than other students is important to me.	1	2	3	4	5
	Performance-Avoidant					
1.	It is important to me that I don't look stupid in math class.	1	2	3	4	5