Chapter II

LITERATURE REVIEW

A review of the literature is presented in this section. Self-Determination Theory and Vallerand's model of intrinsic & extrinsic motivation are described in detail. Achievement goal theory, TIMSS, and rule-space methodology are also examined. Research purpose, the proposed model, and hypotheses are shown in the last section.

Self-Determination Theory

Deci and Ryan (1985, 1991) introduced Self-Determination Theory (SDT). SDT is a theory of motivation, but combines traditional empirical methods and a theory that deals with people's internal resources for motivation (Ryan, Kuhl, & Deci, 1997; as cited in Ryan & Deci, 2000).

SDT (Deci & Ryan, 1985, 1991) proposes that people's psychological needs are the basis for their motivation. In particular, the need for autonomy (deCharms, 1968; Deci, 1975), competence (Harter, 1978; White, 1963), and relatedness (Baumeister & Leary, 1995; Reis, 1994) are essential for enhancing motivation (Reis, Sheldon, Gable, Roscoe, & Ryan, 2000; Ryan & Deci, 2000; Sheldon, Ryan, & Reis, 1996).

The need for autonomy is the need to engage in self-directed behavior (deCharms, 1968; Ryan & Grolnick, 1986). The need for competence (Deci & Ryan, 1985; Elliot & Thrash, 2002; Koestner & McClelland, 1990) is the need to experience satisfaction in improving one's abilities. The need for relatedness is the need to feel related to significant others (Levesque, Zuehlke, Stanek, & Ryan, 2004). Consequently, people engage in behaviors to support these needs (Deci & Ryan, 2000; Ryan, Couchman, & Deci, 2000; Vallerand, 1997).

Much of the research guided by SDT has supported this reasoning. For example, some researchers found that students' perceived autonomy (Grolnick & Ryan, 1987), competence (Harter, 1982), and relatedness affect their motivation (Goodnenow, 1993; Grolnick, Ryan, and Deci, 1991; Koestner & McClelland, 1990).

Self-Regulations

People can be motivated to engage in behaviors, because they value them positively (Williams, Rodin, Ryan, Grolnick, & Deci, 1998) or because they are pressured by external forces (Atkinson, 1964; Deci & Ryan, 2000; Williams, Rodin, Ryan, Grolnick, & Deci, 1998; Weiner, 1972). The issue of whether people engage in a behavior because of their values, or do it for external reasons is important in every culture (e.g., deCharms, 1968; Johnson, 1993).

SDT distinguishes between *autonomous* and *controlled regulation*s. Autonomous regulation is motivation that is controlled by internal forces, whereas controlled regulation is motivation that is controlled by external forces such as

rewards or fear (Deci & Ryan, 2000; Williams, Rodin, Ryan, Grolnick, & Deci, 1998). Autonomous regulation is also termed "*self-determined motivation,"* whereas controlled regulation is "*non-self determined motivation"* (Deci & Ryan, 1980).

An important issue for theories of motivation is the *perceived locus of causality* of events and actions in a person's life. Heider (1958) introduced the idea of perceived locus of causality, and argued that perceived locus of causality addresses how one develops his or her motives. DeCharms (1968) extended Heider's analysis, and argued that perceived locus of causality is related to the degree of autonomy of the behavior, and exists within a continuum that ranges from internal to external. Autonomous behavior is experienced as chosen and has an *internal* perceived locus of causality (deCharms, 1968), whereas controlled behavior is experienced as controlled by demands and has an *external* perceived locus of causality (Deci & Ryan, 1985). An internal locus is highly autonomous or self-determined, whereas an external locus addresses the fact that the source of one's behavior lies in an external force (deCharms, 1968). Any condition that promotes an internal perceived locus of causality increases self-determination. According to SDT, motivational needs that form a continuum ranging from internal to external comprise intrinsic motivation, extrinsic motivation, and amotivation (Deci & Ryan, 1985, 1991).

At one end of the self-determination continuum is *intrinsic motivation*, which is motivation to engage in behaviors to experience pleasure from participating in an activity (Deci & Ryan, 1985). Intrinsic motivation is highly autonomous or self-determined, and has an internal perceived locus of causality

(Deci & Ryan, 1985). For example, an individual who says, *"I participate in <physical activity> because it is fun"* shows intrinsic motivation (see Appendix A for examples of reasons defining external, introjected, identified, and intrinsic categories).

Vallerand and his colleagues (1992) propose that intrinsic motivation comprises *intrinsic motivation to know, intrinsic motivation toward accomplishments, and intrinsic motivation to experience stimulation*. Intrinsic motivation to know is motivation to engage in behaviors to experience satisfaction from understanding something new. Intrinsic motivation toward accomplishments is motivation to engage in behaviors in order to experience satisfaction from creating something new. Intrinsic motivation to experience stimulation is motivation to engage in behaviors to feel excited.

Intrinsic motivation is not the only type of autonomous, or self-determined, motivation (Deci & Ryan, 1985). Extrinsically motivated behavior can be either autonomous or controlled. Extrinsically motivated people engage in behaviors to avoid punishment, or to seek a valued outcome, whereas intrinsically motivated people engage in behaviors to feel excited (Deci & Ryan, 1981).

At the other end of the self-determination continuum is *amotivation*, which is shown when individuals do not value the activity (Ryan, 1995) or feel incompetent (Deci, 1980). Amotivated individuals are neither intrinsically nor extrinsically motivated (Standage, Duda, & Ntoumanis, 2003). According to SDT, *extrinsic motivation* covers the continuum between amoitvation and intrinsic motivation, and consists of external regulation, introjected regulation, identified regulation, and integrated regulation (Ryan & Connell, 1989; Vallerand, 1997).

The correlations between adjacent regulations (i.e., external regulation and amotivation) are assumed to be more positively correlated than those more distant (i.e., amotivation and intrinsic motivation) (Deci & Ryan, 1991).

The least autonomous form of extrinsic motivation is *external regulation*, which is motivation to engage in behaviors controlled by rewards, threats, or demand (Deci & Ryan, 1981). People demonstrate external regulation when the source of control is outside the person (deCharms, 1968). External behavior has an external perceived locus of causality (Deci & Ryan, 1991). People who show external regulation engage in behaviors to avoid punishment, to seek a reward, or to follow rules (Ryan & Connell, 1989). For example, an individual who says, "*I need at least a high school degree in order to find a high-paying job later on"* shows external regulation.

A second type of extrinsic motivation is *introjected regulation.* Through introjection, an individual takes on external regulation, but does not fully accept it as his or her own (Ryan & Deci, 2000). Introjected behavior has an external perceived locus of causality (Deci & Ryan, 1991; Ryan & Deci, 2000). Introjected regulation is relatively controlled regulation, which does not represent self-determination, because people who show it engage in behaviors to avoid guilt, anxiety, or disapproval, or to seek self-and other-approval (Deci & Ryan, 1995; Ryan & Connell, 1989). Introjection shows ego involvement, in which people are motivated to show ability to feel worth (deCharms, 1968; Nicholls, 1984; Ryan, 1982). For example, an individual who says, "*I participate in <active sports> because I will feel bad about myself if I do not"* shows introjected regulation.

A more autonomous, or self-determined, form of extrinsic motivation is *regulation through identification* (Ryan & Deci, 1990). Identification represents a valuing of a regulation, so that the action is accepted as personally important (Ryan & Deci, 1990). Identified behavior has an internal perceived locus of causality (Deci & Ryan, 1985, 1991). People who demonstrate identified regulation engage in behaviors because they value them positively (e.g., "I want"), but they don't feel excited. Actions represent a means to an end (e.g., weight loss) (Deci & Ryan, 1985, 1991). For example, an individual who says, *"I go to school because I see the importance of learning"* shows identified regulation.

The most autonomous form of extrinsic motivation is *integrated regulation* (Deci & Ryan, 1991). Integration is necessary for controlled behaviors to be autonomous (Deci & Ryan, 1985). Through integration, external regulations are experienced as one's own (Williams & Deci, 1996), however, integrated regulation is still considered extrinsic because people engage in behaviors to achieve a personal goal (Standage, Duda, & Ntoumanis, 2003). For example, an individual who says, *"I participate in <physical activity> because it is important to me"* shows integrated regulation.

Vallerand's Model of Intrinsic & Extrinsic Motivation

Working in the area of sports psychology, Vallerand (1997, 2001) proposed a motivational sequence of "social factors affecting psychological factors, which affect types of motivation, which affect consequences".

Social factors are the origin, mastery, and performance climate (Vallerand, 1997, 2001). An origin climate supports people's autonomy; mastery climates support acquiring new skills or knowledge (Ames, 1984); but performance climates support a valuing of one's ability (e.g., Dweck & Elliot, 1984).

The psychological factors examined by Vallerand (1997, 2001) are perceptions of autonomy, competence, and relatedness. Deci and Ryan (1985, 1991) proposed that the need for autonomy (e.g., deCharms, 1968), competence (e.g., Harter, 1978), and relatedness are essential for enhancing motivation (e.g., Ryan & Deci, 2000).

Consequences are the affective, cognitive, and behavioral outcomes of self-regulatory styles (Vallerand, 1997, 2001).

Achievement Goal Theory

Other research has identified different types of goal orientations among students, and proposed that these different types of goal orientations affect other aspects of motivation. For example, these goal orientations have been identified as task-involved versus ego-involved (Maehr & Nicolls, 1980; Maehr, 1983; Nicholls, 1979), as learning-oriented versus performance-oriented (Dweck, 1986, 1988; Dweck & Elliot, 1984), and as mastery-focused versus ability-focused (Ames & Archer, 1988).

Performance goals support proving one's ability, obtaining normatively high outcomes, and interpersonal comparisons (Ames & Archer, 1988; Ames,

1992; Dweck & Elliot, 1984; Elliott & Dweck, 1988). However, learning goals support developing new skills, learning, and task mastery (Grant & Dweck, 2003). With performance goals, students evaluate their competence, rather than increase it, whereas learning goals can result in increasing effort, which, in turn, leads to better performance (Ames, 1992; Elliott & Dweck, 1988; as cited in Grant & Dweck, 2003).

It has been suggested that performance goals affect motivation and achievement (Ames & Archer, 1988; Dweck & Sorich, 1999; Elliott & Dweck, 1988; Greene & Miller, 1996; Kaplan & Maehr, 1999; Meece & Holt, 1993; Midgely & Urban, 1995; Roser, Midgely, & Urban, 1996; as cited in Grant & Dweck, 2003). Empirical research has supported this stance. For example, Elliott and Dweck (1988) found that children who have performance goals and seek high competence were more likely to be mastery-oriented in the face of obstacles, but less likely to increase their skills on a task involving errors. Ames and Archer (1998) found that children who adopt performance goals in the classroom were more likely to focus on their ability, to evaluate their ability negatively, and to believe that failure is due to lack of ability. It has been found that in a performance-oriented climate, self-concept undermines a motivation. Some researchers (e.g., Barron & Harackiewicz, 2001; Elliot & Church, 1997; cf. Rawsthorne & Elliot, 1999; as cited in Grant & Dweck, 2003), however, found that children who have performance goals were more likely to show higher achievement, but less likely to show intrinsic motivation.

Some researchers (Barron & Harackiewicz, 2000; Elliot, 1999; as cited in Grant & Dweck, 2003) found that in contrast to children who adopt performance

avoidance goals[1], children who adopt performance approach goals[2] were more likely to perform well, but less likely to show intrinsic motivation. It has been found that in contrast to normative performance goals (e.g., wanting to perform better than others), nonnormative performance goals (e.g., using a perfect score) are positively related to performance, but negatively related to motivation (Barron & Harackiewicz, 2001; Grant & Dweck, 2003).

It has been suggested that learning goals affect motivation and achievement (Ames, 1992; Barron, 2001; Cury et al., 1996; Dweck & Leggett, 1988; Utman, 1997). Past research has supported this stance. For example, Noutmanis & Biddle (1999) found that students who have learning goals showed adaptive achievement patterns. Learning goals have been found to promote mastery-oriented behaviors and persistence even after negative feedback (Ames & Archer, 1988; Elliott & Dweck, 1988; Utman, 1997). Some researchers found that children who have learning goals were more likely to use effective strategies, to prefer challenging tasks, to have a positive attitude toward the class, to believe that success follows from one's effort (Ames and Archer, 1998), and to show adaptive achievement patterns (Ntoumanis & Biddle, 1999).

[1] The focus is on the avoidance of failure.
[2] The focus is on achieving success.

Needs affecting Motivation: A Self-Determination Perspective

SDT (Deci & Ryan, 1985, 1991) proposes that the needs for autonomy (e.g., deCharms, 1968), competence (e.g., White, 1963), and relatedness affect motivation.

When some researchers (Deci & Ryan, 1985; Deci, Schwartz, Sheinman, & Ryan, 1981) distinguished between autonomy supportive versus controlling environments, they hypothesized that autonomy-supportive climates would enhance intrinsic motivation, and that controlling climates would undermine intrinsic motivation. Much of the research guided by SDT has supported this reasoning. For example, some researchers found that when teachers or parents supported autonomy, children showed intrinsic motivation (Deci & Ryan, 1985, 1987; Deci, Nezleck, & Sheinman, 1981; Deci, Schwartz, Sheinman, & Ryan, 1981; Flink, Boggiano, & Barrett, 1990; Pittman, Emery, & Boggiano, 1982; Pelletier & Vallerand, 1996; Ryan & Grolnick, 1986; Williams, Freedman, & Deci, 1998).

SDT (Deci & Ryan, 1985) argues that self-concept can enhance intrinsic motivation, but it will not do so, unless accompanied by autonomy. In other words, people must feel both autonomous and competent to be intrinsically motivated. SDT also argues that relatedness, defined as the need to feel related to significant others, can enhance intrinsic motivation. Past research has supported this reasoning. For example, Anderson and his colleagues (Anderson,

Manoogian, & Reznick, 1976) found that when teachers were uncaring, students were less likely to show intrinsic motivation.

SDT argues that self-perceptions of autonomy and competence should interact to increase well-being (Deci & Ryan, 1985, 2000; Fisher, 1978; Ryan, 1982). Past research (Grolnick, Ryan, and Deci, 1991; Williams & Deci, 1996; Williams, Freedman, & Deci, 1998) showed that autonomously motivated people show greater self-concept, and that autonomous motivation and self-concept both affect behavior change (e.g., school performance).

Self-Concept and Needs

Perceived competence and self-concept are not the same thing. Perceived competence comprises self-concept and self-efficacy. Self-efficacy is belief in one's abilities to act to achieve performance outcomes (Bandura, 1997), whereas self-concept is self-perception formed through experience with the environment. In other words, self-efficacy beliefs are based on one's personal confidence of achieving certain outcomes, whereas self-concept beliefs include the assessment of personal characteristics regarding general ability (Bandura, Pastorelli, Barbaranelli, & Caprara, 1999).

There are two distinctions between these two constructs. First, Bandura and his colleagues (1999) suggested that self-efficacy theory acknowledges the diverse nature of human abilities, whereas self-concept of ability is a global self-judgment. Self-efficacy is a judgment of one's abilities to perform a specific task, whereas self-concept judgment is more global and less

context dependent, and includes beliefs of self-worth associated with one's perceived competence (Pajares & Miller, 1994).

It has been suggested that self-efficacy beliefs and self-concept beliefs are formed by asking different questions (Bandura, 1999; Pajares, 1997). For example, self-efficacy beliefs are formed by asking "can" questions (e.g., "Can I do this mathematical problem?;" "How well can you learn general math?;" "How well can you study when there are other interesting things to do?;" "How well can you concentrate on school subjects?;" Bandura, Pastorelli, Barbaranelli, & Caprara, 1999). Self-concept beliefs are formed by asking questions about "being" and "feeling" (e.g., "Am I good at mathematics?;" "How do I feel about myself as a mathematics learner?").

Second, Pajares and Schunk (2002) suggested that self-efficacy is based on prior mastery experiences, which are the most important sources of efficacy information, whereas self-concept is partially based on social comparisons.

Self-efficacy beliefs produce their effects through four major processes that operate: cognitive, motivational, affective, and selection processes (Bandura, Patorelli, Barbaranelli, & Caprara, 1999). People who have high self-efficacy are more likely to set challenging goals for themselves and to try hard to reach the goal (Pastorelli, Caprara, Barbaranelli, Rola, Rozsa, & Bandura, 2001).

Bandura and his colleagues (1999) proposed that academic self-efficacy focuses on perceived ability to achieve academic outcomes, and consists of children's beliefs in their efficacy to master academic subjects; to manage learning activities; and to achieve academic expectations. Perceived academic

efficacy affects engagement in academic pursuits and social activities (Bandura, Pastorelli, Barbaranelli, & Caprara, 1999).

Academic self-concept focuses on academic components of self-concept, and consists of children's beliefs in their characteristics regarding academic ability. Shavelson, Hubner, and Stanton (1976) introduced a hierarchical model that differentiated between general, academic, social, emotional, and physical self-concepts (as cited in Pajares & Miller, 1994). Academic self-concepts were further differentiated as English, history, science, or math self-concepts. Self-concept judgments in academic endeavors may be subject specific, but they are never item or task specific – They are not specific assessments of ability (Pajares & Miller, 1994).

Shavelson, Hubner, and Stanton (1976) proposed that academic and nonacademic components of self-concept should be separated. Past research has supported this proposal. For example, some researchers (e.g., Byrne, 1984; Hansford & Hattie, 1982; Marsh, 1986, 1987; Marsh, Byrne, & Shavelson, 1988; Shavelson & Bolus, 1982) found that academic achievement was related to academic self-concept, but unrelated to nonacademic components of self-concept.

Many researchers (e.g., Marsh & Yeung, 1997) have argued about the causal ordering of academic self-concept and academic achievement. For example, Byrne (1984) proposed that changes in academic self-concept lead to changes in subsequent academic achievement. Calsyn and Kenny (1997) contrasted the self-enhancement and skills development models of self-concept and achievement relation. The self-enhancement model proposed that self-

concept affects academic achievement. In contrast, the skill-development model proposed that academic achievement affects academic self-concept. Calsyn and Kenny (1997) attempted to evaluate causal ordering by comparing the sizes of effects of prior achievement on subsequent self-concept to effects of prior self-concept on subsequent achievement.

Marsh (1990a) argued that this comparative approach is not appropriate because both paths are significant no matter which one is larger. Marsh (1993a) argued that the size and statistical significance of the path from prior academic self-concept to subsequent achievement is important because the issue of whether prior academic achievement affects subsequent academic self-concept is generally accepted. A compromise between the self-enhancement and the skill-development models is a “reciprocal effects” model in which prior academic self-concept affects subsequent academic achievement, and prior academic achievement affects subsequent academic self-concept (Marsh & Yeung, 1997).

Research has developed to support these models. For example, some researchers (e.g., Shavelson & Bolus, 1982) reported that prior academic self-concept significantly affected subsequent academic achievement in school subjects, but prior academic achievement had no effect on subsequent academic self-concept, supporting the self-enhancement model. However, Skaalvik and Hagvet (1990) found that prior academic achievement significantly affected subsequent academic self-concept, supporting the skill development model. Some researchers (Helmke & van Aken, 1995; Marsh, 1988; Marsh & Yeung, 1997) found that prior math self-concept significantly affected subsequent math

achievement, and that prior math achievement significantly affected subsequent math self-concept, supporting a “reciprocal effects” model.

Some researchers (Marsh, 1987; Wigfield, 1994) have offered a developmental perspective on the relation between academic self-concept and academic achievement. Marsh et al. (1998) proposed that children’s self-perceptions become more realistic with age, and that academic self-concept is more highly correlated with academic achievement. Past research has supported this proposal. For example, some researchers (Skalvik & Hegvet, 1990; Helmke, 1987) found that prior self-concept significantly affected subsequent achievement for the older cohort, but there was no significant effect of prior self-concept on subsequent achievement for the younger cohort. Pietsch et al. (2003) supported the theory that older children’s math self-concept significantly affected their mathematics performance.

Achievement as a Motivational Consequence

Self-determination theory (SDT) proposed that self-determined, or autonomous, motivation (intrinsic motivation and identified regulation) is related to positive academic and emotional outcomes, whereas non-self determined motivation (amotivation and external regulation) is related to negative outcomes (Deci & Ryan, 1991).

Past research has supported this proposal. For example, some researchers found that more self-determined motivation was related to better performance (Ramserier, 1991; Miserandino, 1996), lower dropout (Vallerand &

Bissonnette, 1992; Vallerand et al., 1989, 1993), better ability to cope with failures (Ryan & Connell, 1989), and higher quality learning (Grolnick & Ryan, 1987; Grolnick et al., 1991). Other researchers have found that non-self determined motivation is related to higher dropout (Vallerand & Bissonnette, 1992), less interest, less value, and less effort toward achievement (Ryan & Connell, 1989).

In the realm of health care, some researchers found that more self-determined motivation was related to greater adherence to medications (Williams, Rodin, Ryan, Grolnick, & Deci, 1998), better long-term maintenance of weight loss (Williams, Grow, Freedman, Ryan, & Deci, 1996), and stronger psychosocial beliefs (Williams & Deci, 1996).

SDT (Deci & Ryan, 1985, 1991) proposed that the needs for autonomy (deCharms, 1968; Deci, 1975), competence (Harter, 1978; White, 1963), and relatedness (Baumeister & Leary, 1995; Reis, 1994) are essential for achievement.

Past research has supported this proposal. For example, some researchers found that students' perceived autonomy (Grolnick & Ryan, 1987), competence (Harter, 1982), and relatedness significantly affected their performance (Deci, Eghrari, Patrick, and Leone, 1994; Fortier, Vallerand, & Guay, 1995; Hardre & Reeve, 2003; Miserandino, 1996; Ray, 2003; Ryan & Deci, 1991, 2000; Ryan & Grolnick, 1986; Ryan, Mims, & Koestner, 1983; Ryan, Stiller, & Lynch, 1994), persistence in school (Hardre & Reeve, 2003; Vallerand, 1992), and teacher ratings of student competence (Grolnick, Ryan, & Deci, 1991).

In the realm of health care, some researchers found that perceived autonomy support affected autonomous motivation for engaging in a diet program

(Williams, Grow, Freedman, Ryan, and Deci, 1996), adherence in alcohol treatment (Ryan et al., 1995), maintaining weight loss (Williams, Grow, Freedman, Ryan, and Deci, 1996), adhering to medication prescriptions (Williams, Rodin, Ryan, Grolnick, & Deci, 1998), and a reduction in smoking behavior (Williams, Gegne, Ryan, & Deci, 2002).

Researchers have applied SDT to various domains, such as school learning (Deci & Ryan, 1985; Fortier & Guay, 1997; Ramserier, 1991; Ryan & Connell, 1989; Vallerand, 1997; Vallerand & Bissonnette, 1992; Vallerand, Fortier, & Guay, 1997; Vallerand & Guay, 1997, 2000), treatment programs (Ryan, Plant, & O'Malley, 1995), religion (Ryan, Rigby, & King, 1993), psychology (Ryan & Connell, 1989), exercise settings (Cadorette, Blanchad, & Vallerand, 1996; as cited in Vallerand, 1997), sports (Blanchard & Vallerand, 1996; Vallerand, 2001), physical exercise (Chatzisarantis, Biddle, & Meek, 1997), physical education (Hardre & Reeve, 2003; Standage, Duda, & Ntoumanis, 2003), political activity (Koestner, Losier, Vallerand, & Carducci, 1996), health care (Ryan, Plant, & O'Malley, 1996; Williams & Deci, 1996; Williams, Freedom, & Deci, 1998; Williams, Grow, Freedman, Ryan, and Deci, 1996; Williams, Rodin, Ryan, Grolnick, & Deci, 1998), environmental activism (Green-Demers, Pelletier, & Merard, 1997), and intimate relationships (Blais, Sabouritn, Boucher, & Vallerand, 1990), among others.

However, there is little research into this theoretical framework in mathematics learning specifically. Some recent studies have reported relevant findings. For example, Ramserier (1991) found that self-determined motivation of Swiss students was positively related to their math performance.

TIMSS

The Third International Math and Science Study, or TIMSS, assessed the mathematics and science performance of students in the U.S. and other nations in 1995 and 1999 (Mullis et al., 2000). The TIMSS-R, or Third International Mathematics and Science Study-Revised (1999) assessed the mathematics and science achievement of eighth – graders in 38 countries, and measured their attitude toward mathematics, their math self-concept, mathematics and science curricula, instruction, home contexts, and school characteristics and policies (Mullis et al., 2000).

In 1999, nine percent of U.S eighth-graders scored 616 or higher, placing them among the top 10 percent of all eighth-graders in the 38 nations (Mullis et al., 2000). In 1999, Singapore, Korea, Chinese Taipei, Hong Kong SAR, and Japan were the top performing countries.

Several recent studies have reported findings from the TIMSS assessment, concerning the effects of important demographic variables, including gender and patient's education level. Mullis et al. (2000) found that 18 percent of students had a high math self-concept, and that students in top-performing Asian countries showed low math self-concept. Mullis et al. (2000) also found that there was a significant gender difference in math self-concept internationally. Casey and her colleagues (2001) found that gender was not related to mathematics performance.

Mullis et al. (2000) found that students generally had positive attitudes towards mathematics, even though students in top-performing Asian countries showed negative attitudes towards mathematics. Mullis et al. (2000) also found that there was a significant gender difference in attitudes towards mathematics internationally.

Mullis et al. (2000) also found that parents' education was positively related to students' math achievement. The pattern across countries was that eighth-grade students whose parents had more education were also those who had higher achievement in math.

It has been suggested that students' attitudes and self-beliefs affect their math performance internationally. Past international research has supported this position. For example, Mullis et al. (2000) found that students who have positive attitudes toward math and high math self-concept were more likely to perform well internationally. House (2000) found that students in South Africa who have positive attitudes toward math were more likely to perform well. Papanastasiou (2002) found that in Cyprus, Hong Kong, and the U.S., students who like math, and think it is important to do well in math for their friends, tended to perform well. House (2003) also found that Hong Kong students' self-beliefs significantly affected their mathematics and science achievement.

Schreiber (2002, 2003) found that American students' attitudes significantly affected their score on the advanced mathematics test, and that the more students believed that natural ability caused success in mathematics, the higher their scores on the test.

It has been suggested that several teaching activities affect students' enjoyment of learning math or science. Past research has supported this proposal. For example, House (2002, 2003) found that certain teaching activities used for learning new science and math topics and in typical science and math lessons were positively related to student enjoyment for learning science and math, whereas computer use in science and math lessons did not significantly affect student enjoyment for learning science. House (2003) also found that cooperative learning activities for instructional situations significantly affected students' enjoyment for learning mathematics.

There is a need, however, for further research to develop a model of the effects of motivation on math performance, and examine how autonomy support predicts math performance by affecting the mediator of math self-concept. There is also a need to examine how math self-concept explains additional variance in math performance, after we control for the effect of motivational resources on math performance.

Rule-Space Methodology

Tatsuoka and Tatsuoka (1987) introduced the rule-space methodology (RSM) to explain the proficiency of students on large-scale tests. Some researchers (Tatuoka & Tatusoka, 1997) have applied RSM to the Test of English for International Communication (TOEIC) and the New SAT I Math Test. RSM combines item response theory (IRT) and the algebraic theory of databases and

enables us to relate traditional scale scores to classification groups, or the knowledge states (Guerrero, 2001).

RSM collects information about the knowledge, procedure, and cognitive processing skills (called “attributes”) required to solve test items, and then classifies examinees’ responses into a set of attribute patterns, each of which is associated with a knowledge state (Guerrero, 2001). RSM is a tool to test these attributes (Tatsuoka, 1997).

The first step in conducting an analysis is to test if generated hypotheses about the attributes are correct or not (Tatsuoka & Tatsuoka, 1987). The presence or absence of each attribute is coded for each item, and results in a matrix that is called the Q matrix (Guerrero, 2001). RSM confirms mastery of the attributes if the hypotheses are correct (Tatuoka, 1997). The second step is to map ideal response patterns into a space spanned with IRT theta and a person-fit index called zeta (Guerrero, 2001).

Tatsuoka and Corter (2003) identified rule space attribute mastery probabilities (e.g., knowledge, skill, and process attributes) required to answer the TIMSS 1999 math test items (see Appendix B). The hypothesized skills represented in a “Q” matrix were tested statistically via RSM (Tatsuoka, 1985).

Research Purpose

The major purposes of the present study are as follows: 1) to develop a model of the effects of motivational resources on math performance (measured by first math plausible value score), 2) to use data from the TIMSS-R study of

math performance to test major assumptions of SDT, 3) to examine whether math self-concept explains additional and significant variance in math performance, after we control for the effect of intrinsic motivation on math performance, and 4) to examine whether autonomy support in the classroom predicts math performance both directly and indirectly through the mediator of math self-concept of students.

The Proposed Model

We propose a motivational model of math performance based on SDT (Deci & Ryan, 1985, 1991). A schematic diagram summarizing our model appears in Figure 1. In developing our model of motivation, we drew upon the theoretical perspectives of Deci and Ryan (1985, 1991), Fortier, Vallerand, and Guay (1995, 1997, 2000), and Vallerand (1997, 2001). Some researchers have found that perceived autonomy support, self-concept (Byrne, 1984), and self-determined regulations affect enjoyment of school (Grolnick & Ryan, 1989), school performance (Goodnenow, 1993; Grolnick, Ryan, & Deci, 1991; Koestner & McClelland, 1990; Miserando, 1996; Ramserier, 1991; Ryan & Connell, 1989; Ryan & Deci, 2000; Ryan & Grolnick, 1986; Ryan, Mims, & Koestner, 1983; Ryan, Stiller, & Lynch, 1994), and intention to persist in school (Vallerand, 1997; Vallerand & Bissonnette, 1992; Valerand, Fortier, & Guay, 1997).

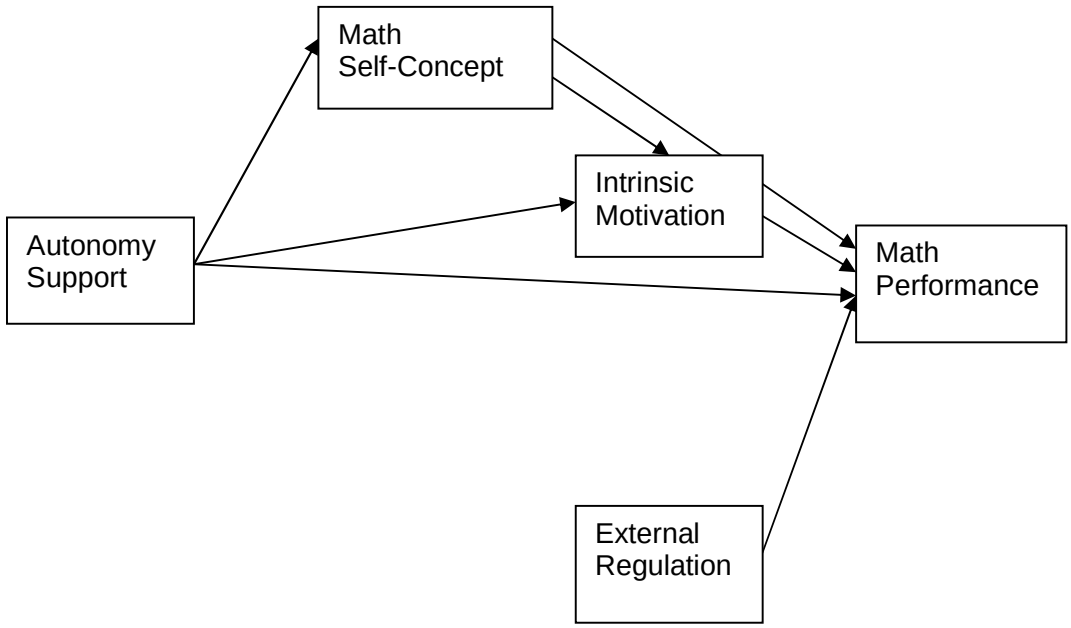
In the present model, we propose 1) that motivational resources (e.g., intrinsic motivation, external regulation) affect math performance; 2) that math self-concept affects math performance both directly and indirectly through the

mediator of intrinsic motivation; and 3) that autonomy support significantly predicts math performance both directly and indirectly through the mediator of math self-concept.

In the present model, we also add teachers' autonomy support in the classroom as a predictor of math self-concept of students. This model extends previous work (especially Vallerand, 1997, 2001) by incorporating teacher practices (autonomy support in particular) and student math self-concept, and by evaluating the effects of these factors on the criterion variable of math performance.

Figure 1

Hypothesized Motivational Model of Math Performance



Hypotheses

Based on the theoretical perspective of Deci & Ryan (1985, 1987, 1991), Fortier, Vallerand, & Guay (1995, 1997, 2000), and Vallerand (1997, 2001), and consistent with past research (Grolnick, & Deci, 1998), five hypotheses relating to motivational resources and autonomy support were incorporated in the present model, as follows:

H1a: Intrinsic motivation positively affects math performance.

H1b: External regulation negatively affects math performance.

H2: Math self-concept positively affects math performance.

H3b: Autonomy support in the classroom positively affects math self-concept.

H3c: Autonomy support in the classroom positively affects math performance.

H4: Math self-concept significantly affects math performance through the mediator of intrinsic motivation.

H5: Autonomy support in the classroom significantly affects math performance through the mediator of math self-concept.