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EVALUATING STUDENTS' MOTIVATION IN PREDICTING MATHEMATICS AND SCIENCE PERFORMANCE: A DEVELOPMENTAL PERSPECTIVE

By

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ABSTRACT

EVALUATING STUDENTS' MOTIVATION IN PREDICTING MATHEMATICS AND SCIENCE PERFORMANCE: A DEVELOPMENTAL PERSPECTIVE

By

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This study employs concepts associated with a general expectancy - value model of motivation to explore students' motivation within a developmental perspective. It examines how specific aspects of motivation, i.e., interest, importance, career relevance, perceived competence, and success attributions to natural talent and hard work, are related to students' achievement in mathematics and science. The present study had two main goals: 1) to examine the relationships among students' subject matter interest, importance, career relevance, perceived competence, and success attributions at three developmental levels, and 2) to evaluate the usefulness of these aspects of motivation in predicting students' performance on a mathematics and science achievement test. The study employs structural equation modeling to evaluate the usefulness of these motivational constructs in predicting students' performance as a function of students' developmental level and the academic domain assessed.

For my father.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION AND BACKGROUND

Introduction

In a recent conversation, an eighth grader indicated that very few of his peers thought that school was important. When asked what he thought was important to his peers he said, "friends and other activities like sports." His comment, while not particularly surprising, did seem to be a rather unusual description for a class that had developed a reputation among the school's staff, students, and parents for being academically oriented and motivated. The student mused further that some students didn't seem to be trying as hard or doing as well in school as they had in earlier years. When prodded as to why he thought that might be, he paused and considered, "Perhaps they aren't trying because they don't think it's that important...there are other things they're more interested in. Or maybe they've just gotten tired of trying and not doing as well as they'd like. I guess they aren't trying as hard or doing as well as they could."

These comments from an eighth grader illustrate the role that motivational issues often play in efforts to understand and explain students' academic achievement behavior. While it is a human trait for people to attempt to understand the behavior of others (Bruner, 1990), educators and policy makers are professionally motivated as well in attempting to make sense of students' academic achievement. Educators and policy makers are interested in understanding the factors that affect students' academic achievement so that they might improve student learning.

Those interested in students' motivation have sought explanations of students' achievement behavior at the individual, classroom, and system levels (Thomas, 1993; Brown, 1993; McCaslin & Murdoch, 1991). Although researchers and educators alike acknowledge the strategic and important role that motivation has in students' cognitive and academic development, assessment of aspects of students' motivation are typically not a part of academic achievement tests (Scarr, 1981; Paris, 1991). The prevailing view that students' academic motivation plays an important role in their achievement behavior is supported by a considerable amount of research. The vast majority of this research has related students' motivation to specific strategies, classroom grades, short tests for research purposes, and future curricular/course-taking decisions – not to achievement tests.

Many achievement tests have become "high stakes" assessments which have major implications for educational policy and curriculum if not for an individual student's immediate educational future. However, assessing students' motivation and relating this to their performance on this type of "high stakes" assessment is rare. The important role students' motivation has in achievement and the importance afforded achievement tests has prompted one set of researchers to argue that,

> Tests should measure more than what students know; they should assess students' perceptions of their abilities, their own effort and goals, their interests in the material, their relative satisfaction with their own performance, and their preparation for the tests. Personal control, efficacy, ownership, and self-regulation are critical constructs for achievement and deserve to be assessed. (Paris et al, p. 18)

A distinguishing feature of the present study is that it examines students' motivation in relation to their performance on a "high stakes" achievement test.

Embedded in the student's comments noted earlier are references to two motivational constructs, expectancies and values, that are the basis of a general model of motivation which has informed many productive research programs (e.g., Eccles, 1983; Grolnick & Ryan, 1987; Harter, 1983; Nichols, Cobb, Wood, Yackel, & Patashnick, 1990; Pintrich & DeGroot, 1990). Inherent in his comments is the idea that, not only do students' behaviors change over time, but what they expect from themselves (they're "tired of trying and not doing as well as they'd like) and their underlying reasons ("there are other things they're more interested in") may also change. Thus, a students' academic behavior may be understood in terms of her evaluation of her personal resources relevant to the task (expectancies) and her evaluations of the task (values) – all of which are subject to change as the student grows and matures.

The current study focuses upon the way different aspects of students' expectancies and values are interrelated and relate to their performance on a specific achievement test. This study draws upon concepts associated with a general expectancy-value model of motivation to address the two main purposes of this study: 1) to examine the interrelationships among students' subject matter interest, importance, career relevance, perceived competence, and success attributions at three developmental levels with respect to two academic domains (e.g., mathematics and science), and 2) to evaluate the usefulness of these aspects of motivation in predicting their performance on an achievement test in mathematics and science.

Background

Motivation

Weiner (1989) notes that there have been two traditional perspectives on human motivation and behavior: behavior generality and behavior specificity. Theorists who favor *behavior generality* tend to view individual's behavior as a function of internal states or drives which are expressed in a relatively invariant manner over time and across settings. According to this view, motivation is considered an aspect of personality, a stable attribute that functions in an essentially consistent and predictable manner across all situations or contexts.

In contrast, theorists who hold a *behavior specificity* perspective regard an individual's internal states or drives as temporary states that are a function of the specific situation or context. According to this view, an individual's motivation is a function of both the individual's personality and the specific context. For example, Rotter (1954) claimed that the proper focus of investigation in matters of personality and motivation was "the interaction of the individual and his meaningful environment" (p. 85).

Rotter's emphasis upon the interaction between the individual and the environment is compatible with more recent cognitive and socio-psychological conceptions of motivation. These perspectives emphasize an individual's motivation and behavior as an adaptive response on the part of an individual to specific situations in which personal resources are flexibly applied (Bandura, 1986; Maehr & Braskamp, 1986; McCaslin & Murdock, 1991). This emphasis has emerged as a corollary to the recognition of the fundamental social nature of human thought and development. Humans are uniquely social and strive to make sense out of their surroundings and interactions (Bruner, 1990; Kozulin, 1990). The aspects of motivation employed in this study may be viewed as cognitive constructs employed by individuals as they attempt to understand themselves and their environment.

The specific aspects of motivation employed in this study are associated with a general expectancy-value motivational model. Rotter (1954) originally proposed the general principle that the potential for any behavior could be viewed as a function of an individual's expectancy of a reward associated with the anticipated behavior and the value assigned by the individual to the expected result or goal of the behavior. He broadly defined expectancy as the "probability held by the individual that a particular reinforcement will occur as a function of a specific behavior on his part in a specific situation" (Rotter, 1954, p. 107).

About the same time, Atkinson and his colleagues employed the concepts of expectancy and value more specifically to understanding and explaining achievement behavior (Eccles, 1983; Weiner, 1992; Wigfield, 1994). Subsequently, these two basic motivational components have been expanded and refined by researchers investigating motivation for a variety of behaviors in many different settings.

In general, the expectancy component of the model addresses the question, "Can I do this task?" This involves issues such as how well one is likely to do the task, evaluations of one's competence for the task, and one's ideas (attribution) about what it would take to do well on a task (Harter, 1981; Bandura, 1986; Pintrich & DeGroot, 1990; Weiner, 1992). The value component concerns the question, "Why am I doing this task?" Investigators have conceptualized this motivational component as one's intrinsic interest in the task, one's evaluations and estimations of the task's utility and importance, and one's goals or purposes for engaging in the task (Eccles, 1983; Pintrich & DeGroot, 1990; Weiner, 1992; Wigfield, 1994).

A sizable body of research has demonstrated that motivation plays a critical role in determining the level of an individual's performance (Eccles, 1983; Pintrich & DeGroot, 1990; Weiner, 1992; Wigfield, 1994). Independent of a person's ability, one's motivation has been shown to determine to what extent, if at all, effort will be expended in a task applying whatever abilities one may have. The expectancies and values held by the individual, historically elaborated and operationalized as one's perceptions of competence, success attributions, interest in and value afforded the task, and one's long-range and short-range reasons for engaging in the task (achievement goals), are all likely to be critical considerations in deciding how to apply and expend the efforts, strategies, and knowledge one has with respect to any considered task.

Motivation and Development

As children grow and mature many changes may be observed in a variety of domains including their physical appearance, interests, values, and behaviors. Any of these changes may be associated with development. But change over time is not all that is typically meant by development. Development is usually associated with a particular kind of change that occurs over time; changes that result in an increased ability, capacity, or competence to accomplish tasks, make decisions and distinctions, and to understand and interpret various situations.

Harter (1983) presents a perspective on the individual's developing self concept as a social construct that emerges and differentiates. This development proceeds on the basis of both increased competencies and changing social contexts and interactions. Motivation is considered an important aspect of one's personality or self-concept (Harter, 1978). Many different aspects of one's self-concept may also be considered from a motivational perspective such as one's self-descriptions, likes, dislikes, values and priorities as well as one's knowledge about the self as an active agent – the reasons and purposes leading to specific decisions, choices, and behaviors.

Harter (1983) reasons that, in so far as motivation is a function of the self, we should expect to find developmental changes in the differentiation, strength, and structure of various aspects of motivation as the self grows and matures. A complete model of motivation must, therefore, be a developmental model which includes some description of the changes in motivation over time.

The following section identifies several key aspects of students' motivation and discusses the importance of considering motivation from a developmental perspective and with respect to a specific context (i.e., subject matter).

Interests and Values

As children grow and develop their interests and activities change. A four year old who is very interested in art and spends a great deal of time engaging in various artistic endeavors may become a soccer fanatic by age 9 and completely engrossed in computers and mathematics by age 14. This sort of scenario illustrates the common sense connection between one's interests, values, and behavior. One might reason that one would tend to value and pursue through activities those endeavors that represent one's interests. Accordingly, with reference to particular school subjects, one would expect to find a close relationship between student interest, perceived value of the subject, and subject-matter-specific achievement behavior. It would appear reasonable that students would invest themselves, their time, energy, and cognitive efforts, in those subjects that they both valued and were interested in.

Stipek (1984), for example, found that both students' interest in and the value afforded a particular subject, e.g., math or reading, decreased from upper elementary through middle or junior high. However, this close connection between interests and values has not always been found. Wigfield (1994) reports that for another group of students, their interest in mathematics did not decrease over a three year period, from fifth to eighth grade, despite a decrease in the importance students' assigned to it.

Competence

Closely related to one's interest in and perceived value for a subject is one's self-evaluation of competence. Harter has documented the changing nature of perceived competence, from preschool age through adolescence

(Harter, 1981; Harter, Whitesell, & Kowalski, 1992). Harter found that even children as young as four and five make a distinction between being competent socially and being competent in sports. As children grow, their competence beliefs become even more differentiated so that their self-perception regarding mathematics is distinct from the competence beliefs about reading, music, and other domains (Harter, 1983).

In addition, there is a developmental trend in the strength of students' competence beliefs as they move through elementary school and into middle school or junior high. Young children tend to maintain relatively high competence beliefs even in the face of failure but these competency beliefs tend to decline from early elementary into middle school or junior high (Dweck, 1989; Stipek, 1984; Wigfield, 1994). This decrease in students' perceived competence has been explained, in part, by their increased capacity for considering information from several sources, i.e., their own performance and the performance of others, and by their increased ability to form more realistic evaluations of what they have done. The changing classroom environment from early elementary to middle school has also been thought to play a role in students' decreasing evaluations of their competence. In early elementary, students are often praised and rewarded for whatever effort they may put forth without regard for the quality or product of that effort. As the student advances through elementary school and into middle or junior high, the quality and product of the student's effort becomes more and more the focus of reward and evaluation (Eccles & Midgley, 1989).

The corresponding decrease in students' perceived competence and their valuing of a specific subject matter has been explained by the idea that what one is good at, one values. Thus, if a student is good at math, she will place a high value on math but if she is not good at reading, she will not highly value reading. Such changes in the relationship among mean levels of students' subject-matter interest, importance afforded the subject, and their subject-matter-specific perceived competence suggests that the role these motivational aspects play in predicting subject-matter-specific behavior may not be the same at every developmental level. If students do tend to value what they are good at and choose those activities over others, it would follow that the value aspects of motivation would become more predictive of behavior as students are able to make choices in their activities.

Success Attributions

Eccles has also considered motivation within a developmental framework. Referring specifically to the role attributions play in motivation she hypothesized that their influence "may well become an epiphenomenon rather than a causal influence on subsequent expectations and performance" once a stable self-concept has been formed (Eccles, et al, 1983, p. 87). These attributions have to do with how one interprets the causal connections between one's own effort, ability, and achievement performance (Eccles, 1983; Gentile & Monaco, 1988; Schunk, 1991; Weiner, 1989; Weiner, 1992).

Recently, two different orientations have been linked with students' achievement behavior that involves students' attribution of success to either effort or ability (Ames, 1992; Cobb, Wood, Yackel, Nichols, Wheatley, Trigatti, & Perlwitz, 1991; Dweck & Bempechat, 1983; Eccles & Midgley, 1989; Ginsburg & Asmussen, 1988; McCaslin & Murdock, 1991; Nichols et al., 1990; Pintrich & DeGroot, 1990). The defining characteristic of one orientation, referred to as a mastery goal (Ames, 1992), learning goal (Dweck & Bempechat, 1983) or task-involved orientation (Nichols et al., 1990), is an attribution of success to effort. The other orientation involved an attribution of success to ability. This is one of the main characteristics of those who endorse a performance goal (Ames, 1992; Dweck & Bempechat, 1983) or an ego-involved task orientation (Nichols et al., 1990).

Developmental differences in these types of attributions have also been reported. For example, Stipek (1984) found that students in early elementary school were more likely to attribute success to effort while older students were more likely to attribute success to ability. These developmental changes in success attributions parallel the developmental changes regarding a student's competence beliefs. The proposed reasons for why students' competence beliefs decrease is that they become more aware of their relative performance in the classroom and that their efforts are more critically evaluated. These developmental changes in students' cognitive skills and in the nature of their educational environments may also be the basis for the shift in students' success attributions from effort to ability. Part of the reason may be that younger students do not readily differentiate between competence beliefs and success attributions since both are based primarily upon the effort they expend.

Career Relevance

A fundamental assumption in career development theory is that individuals desire to implement their self concept, that is their knowledge of themselves, their interests, values, and competencies, in their vocation or career in a congruent manner (Holland, 1973; Gottfredson, 1981; Super, 1990). In other words, people desire to have specific positions and to develop careers that explicitly or implicitly endorse, or at least are compatible with, their own most prized interests, values, and abilities. Someone who loves to read, for example, but despises working with numbers would be more likely to seek employment as a writer, editor, or bookstore clerk than as a bookkeeper, bank teller, or engineer. Similarly, someone who enjoys science and highly values the sanctity of human life would be more likely to pursue a career in prosthetics research and design, hospice care, or environmental management than one in weapons development and manufacture or with a health care corporation known for a "bottom line" orientation and seemingly little regard for the people involved.

However, people do not typically wait until they are ready to look for their first career-related employment position to "implement" their self-concept. In fact, one's self-concept is a dynamic concept formed along the way through life experiences. Some of these formative life experiences include making decisions about which subjects to study, how much time and effort to invest in schooling and academics, and which types of employment positions are feasible to pursue. These issues of self-concept, identity and career, are major developmental themes for adolescents and young adults (Erikson, 1963; Marcia, 1980). For example, Montemayor and Eisen (1977) found a significant increase from age 10 to age eighteen in the number of subjects who used some reference to an occupational role in responding to the question, "Who am I?" In addition, one British study reported that 14 year-old students rated "usefulness for a job" as the single most important factor in determining their school subject choices (Kelly, 1988).

One of the motivational questions examined in this study is, "Why am I doing this task?" One way this motivational component has been assessed is by looking at the goals or reasons one has for engaging in specific behaviors (Ames, 1992; Bereiter & Scardamalia, 1989; Carr, Borkowski, & Maxwell, 1991; Cobb et al., 1991; Nichols et al., 1990; Schunk, 1991). Eccles' (1983) identified two types of achievement goals, long range and short range, associated with this aspect of motivation. These achievement goals were conceptualized as broad life goals, such as career plans or the desire to act in a particular manner relative to specific gender-role considerations. These reflect the purposes one has for learning and doing different activities. Considerations of gender role stereotypes and sex differences in achievement have dominated the research on these types of goals (Wigfield, 1994). In this study, students' perception of a specific subject's relevance to their future career is assessed as an achievement goal.

This type of achievement goal may be considerably more important for older students than younger ones. Issues of vocational or occupational concerns are more prominent and immediate in their thinking about themselves and their future so that career relevance could be expected to demonstrate a stronger relationship with their achievement in the relevant subject matter than that for younger students. In addition, as career issues become more salient as students move from elementary to high school, one might expect students' subject matter career relevance to demonstrate an increasing relationship with other aspects of the motivation, most notably indications of their interest in and value afford the relevant subject.

Subject Matter Specificity

Earlier, motivation was defined as one's adaptive response to specific situations in which personal resources are flexibly applied. In contrast to a trait theory of motivation where an individual has a certain level of motivation that is brought to bear in all situations and domains, the flexible and adaptive theory suggests that one's motivation for mathematics and for science would not necessarily look the same. Consistent with this flexible and adaptive conception, Harter (1983), as mentioned previously, has found that children's perceived self-competence demonstrates an increasing differentiation among domains with increasing age. Young children discriminate between the academic and social areas while older children begin to discriminate among academic subjects in their competence assessments. Wigfield (1994) reports that in a series of studies conducted with students as early as first grade, factor analyses revealed students' competence beliefs formed distinct factors for the domains of math, reading, music and sports activities.

However, the implications of these studies for the differentiation of students' motivation with respect to mathematics and science remains unclear. Mathematics and science may be more closely associated than, for example, math, reading, music and sports. Mathematics and science are often located within the same department or college in educational institutions while reading (language arts, literature, English), music and sports are not. The fact that the advanced sciences require a certain degree of facility with advanced mathematics emphasizes the close relationship between the academic pursuit of the two domains.

Given this close association between mathematics and science it is interesting to note that high school mathematics and science teachers have significantly different views of their respective subjects. Mathematics teachers view their subject as considerably more defined, sequential and static (unchanging) than do science teachers (Stodolsky & Grossman, 1995). Therefore, one might expect students to differentiate their motivation for mathematics and science to the extent that these were viewed as different subjects. Older students who have had more exposure to the two disciplines may be more likely to have been socialized into their teachers' academic perspective and make a distinction in their motivation for the two subjects than younger students.

In a longitudinal follow up to an earlier investigation of children's interest in and beliefs about the value of math, reading, instrumental music, and sports, Eccles and her colleagues found that the children's beliefs about the usefulness and importance of all subjects decreased over 3 years. However, only the children's interest in reading and instrumental music demonstrated the same decrease; children's interest in math and sports did not decrease (Wigfield, 1994). Self-efficacy and perceived self-competence, two measures of expectancy, also demonstrate differences as a function of academic domain (Bandura, 1986; Harter, 1983). These results suggest that not only may the different aspects of students' motivation demonstrate different developmental trends from one another, but the developmental trend may not be the same with respect to the two domains of mathematics and science.

Assessing Achievement

Students take many different kinds of tests which serve a variety of purposes. Resnick & Resnick (1992) identify three main classes of educational assessments that serve different purposes: tests for public accountability and program evaluation, tests for student selection and certification, and tests for instructional management and monitoring. Students are probably most familiar with this last type – quizzes and tests given in classrooms by teachers. They are developed and administered by teachers to diagnose and monitor student learning and to inform and guide teachers as they plan and evaluate their instruction. These may also be used by teachers as a basis for informal and formal evaluations and reports of students' learning. This type of assessment is commonly developed and evaluated at the discretion of the individual teacher.

A second type of test students may take is one that is given to evaluate students for selection into or out of particular educational programs and opportunities. This type may also be administered by classroom teachers but is probably less common in the overall experiences of students. Examples of this type of assessment include assessments of student "readiness" for entrance into first grade, mastery of basic mathematics skills and "readiness" to study algebra, mastery of specific curricular content upon which specific kinds of certification, recognition, or credit may be awarded. The items and the recognition criteria for this type of assessment are not typically determined at the classroom level by individual teachers but by some group of educators who work to develop a commonly recognized standard for student performance.

The third type involves tests that students take in order to obtain an indicator of some aspect of the education system or process. These might involve an indicator of the effectiveness of a particular instructional approach or a particular curriculum. In some instances, this type of assessment may be used to generate indicators to inform educators, policy makers, and the public about the general state of the education system. The items, scoring, and evaluation criteria for these assessments are always the responsibility of a single organization that most likely has little if any affiliation with individual teachers, classrooms, schools or school districts. While this type of test may have a rather "high profile" in the public arena and may be spoken of in classrooms as very important, these are probably relatively infrequent for students. Since these assessments are given to generate indicators for some level of the education system, such as the state, school district or school, rather than indicators of individual student achievement, the immediate effect and consequence for students is less clear that with the other types. The assessment employed in the present study is of this last type.

Recently there has been a great deal of discussion about the need for "alternative" forms of assessment. At least one researcher has attributed this dissatisfaction to the inappropriate use or misuse of the assessments that have commonly been employed (Taylor, 1994). Dissatisfaction, confusion and frustration have arisen when assessments of one type have been forced to serve the purposes of another type of assessment. Discussions in everyday language about the "fairness" of a test often stem from such inappropriate application of assessment results. Examples of the misuse of assessments would be the attempt to use the results of a student selection or credential exam as an evaluation of a general education program or the use of an assessment designed to create a program evaluation indicator as an indicator of individual student achievement.

Dissatisfaction with commonly employed assessments have stemmed from a failure to interpret results appropriately and from overgeneralizations. This form of misuse or misinterpretation is related more to the nature or content of the test rather than the purpose or type of the test. The source of dissatisfaction comes from the use of test results to draw conclusions about constructs or issues not actually measured by the test (Resnick & Resnick, 1992). In such instances, there is often a mismatch between what the assessment is measuring and what has been taught. This problem is not necessarily inherent in the quality or type of the assessment tool employed but has to do with what is valued within a system. In their discussion of this phenomena Resnick and Resnick conclude that "(t)he problem of assessment is really a problem of curriculum and of educational goals" (pp. 59-60).

The achievement assessments employed in this study were designed as a part of an international investigation of curriculum, educational goals, and the teaching and learning of mathematics and the sciences. Assessment topics and items were identified through international consensus regarding what would be appropriate to include in measuring student achievement at specific student levels. The assessments and the research have been designed to create country level or regional indicators of student achievement but not indicators of individual student performance.

While individual indicators of achievement and motivation are generated and employed in analyses for this study, they are not interpreted at this level; that is, scores are not reported for specific individuals. Indicators of students' motivation and achievement in the areas of mathematics and the sciences are described, modeled and interpreted at an aggregate level according to students' grade level. This use is consistent with the nature and purpose for which the assessment instruments have been designed.

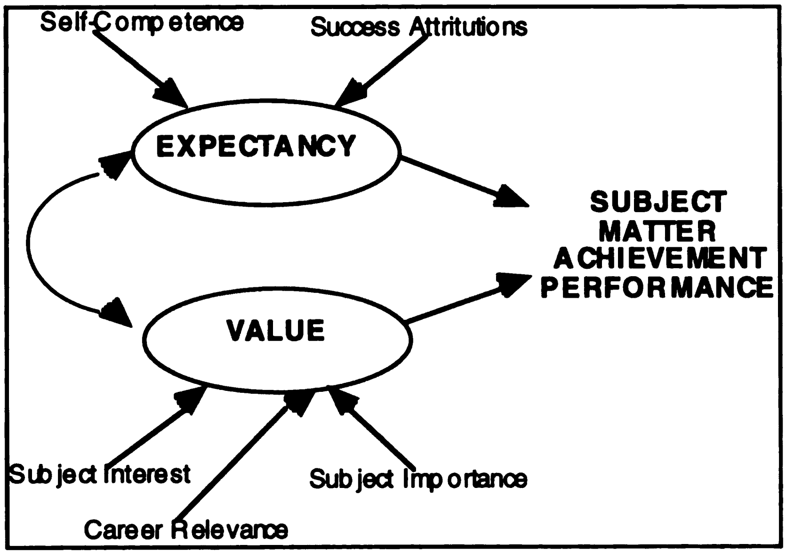
Motivation Related to Achievement

As a general framework for understanding students' achievement motivation and behavior, Eccles' (1983) comprehensive model of achievement performance and choice includes the origins and the causal relationships among students' expectancies and values. Subsequent research by Eccles and her colleagues has yielded empirical support for many parts of the model. For example, using confirmatory factor analysis on data from first through twelfth graders, they found that a two factor model involving expectancy and value had significantly better fit indices than the single factor model. They interpreted this to mean that even first graders made a distinction between their beliefs about what they may be good at (expectancy) and their ideas about what is important (value) with respect to the domains of math, reading, and sport.

Much of the work by Eccles and her colleagues has examined the relationships among aspects of students' expectancies and values and how these relate to students' course selection and persistence in studying mathematics. Other studies have examined the effect of specific aspects of motivation, such as self-efficacy or self-concept and intrinsic value on students' achievement behavior as measured by classroom grades. As previously noted, the relationship between students' motivation and their achievement behavior as assessed by an achievement test has rarely been examined. In addition, the developmental changes in the mean level and structure of many aspects of students' motivation suggests that the relationship between students' motivation and achievement would not be a static one. The developmental changes previously noted in students' interests, competence, and career considerations suggest that the relationship between these motivational aspects to their achievement would differ as well.

The current study examines the relationship between students' motivation and their performance on an achievement test as a function of their developmental level and the subject matter domain. This involves examining the interrelationship among the same aspects of motivation at the three developmental levels as well as the way these motivation factors relate to subject-matter-specific achievement at the different levels. Figure 1 illustrates how the specific aspects of motivation measured relate to achievement according to the generalized expectancy-value model.

Figure 1 – Aspects of Motivation Related to Achievement



Research Questions and Hypotheses

This study employs concepts associated with a general expectancy - value model of motivation to explore students' motivation and how these aspects of motivation are related to their performance on a mathematics and science achievement test. These are described and explored as a function of students' developmental level. In particular, this study addresses two main questions:

1. How does students' motivation differ as a function of their developmental level and the relevant subject matter? More specifically, do students' interest, importance, and perceived competence with respect to mathematics and science decrease across the three developmental levels

assessed? How do students' success attributions differ at these three developmental levels? How do students' perception of subject matter career relevance change? Does the relationship between students' motivation in mathematics and science change as a function of students' developmental level?

Hypothesis 1: Students' interest, importance, and perceived competence for both mathematics and science will decrease across the three developmental levels assessed.

Hypothesis 2 Elementary students will attribute success in both mathematics and science more to hard work than to talent while older students will attribute success in both subjects more to talent than hard work.

Hypothesis 3 Perceived competence and success attributions (i.e., to natural talent/ability and to hard work/effort) will not be differentiated in elementary students but will be differentiated in older students.

Hypothesis 4: Students' subject matter related career interest will show an increasing relationship with other motivational concepts from middle elementary to middle school to high school.

Hypothesis 5: The relationship between students' mathematics and science motivation will decrease across the three developmental levels, i.e., from middle elementary to middle school to high school.

2. How does students' motivation relate to their achievement test performance? Is this relationship the same at each developmental level for both mathematics and science? More specifically, does the relationship

between students' subject matter career relevance and their achievement differ over the three developmental levels assessed?

Hypothesis 6: The relationship between students' interest, importance, and perceived competence with their achievement will increase across the three developmental levels assessed.

Hypothesis 7: Subject matter career relevance will demonstrate a stronger relationship with achievement for twelfth grade students compared to younger students.

Hypothesis 8: The relationships between motivation and achievement will be different in the two domains of mathematics and science.

CHAPTER 2: METHODOLOGY

Research Design

This study represents a secondary analysis of data gathered as a part of the Third International Mathematics and Science Study (TIMSS) in the United States. Sponsored by the International Association for the Evaluation of Educational Achievement (IEA), TIMSS is a comparative study of education in mathematics and the sciences conducted in 50 educational systems on five continents. The goal of TIMSS is to measure student achievement in mathematics and science in participating countries and to assess some of the curricular and classroom factors that influence student learning in these subjects. TIMSS will provide educators and policy makers with an unparalleled and multidimensional perspective on mathematics and science curricula; their implementation; the nature of student performance in mathematics and science; and the social, economic, and educational context in which these occur. The study employs a cross-sectional design to assess student motivation and background and a randomized block design to assess student achievement.

The present study employs descriptive, correlational and structural equation analyses to investigate student motivation and to evaluate the usefulness of an expectancy-value model of motivation in explaining students' performance on a large scale, multinational achievement test. This large-scale survey was designed to obtain measures of educational achievement representative of students in the United States at three different age levels. The descriptive part of the study involves characterizing students' motivation as assessed in the TIMSS Student Background Questionnaire.

MANOVA and correlational analyses are employed to create a description of the relationship among the motivational constructs as a function of subject matter and students' grade level. In these analyses, subject matter is a within subjects variable while grade level is a between subjects variable. Structural equations are employed to test the equivalence of the expectancy-value model of motivation in predicting students' achievement test performance in the two different subject matters at each of the three student grade levels. In the structural equation analyses, subject matter and grade level are both between subjects variables. The exception to this is subject matter for grade 12 students where all students took a single test that assessed both mathematics and science.

Sample

The TIMSS involved obtaining measures of students' mathematics and science achievement at three different developmental levels. The international definitions for these three student populations are the two grade levels containing most 9-year-old students (population 1), the two grade levels containing most 13-year-old students (population 2), and those in the last year, i.e., the highest level offered, of secondary education (population 3). In the United States, the grade levels associated with these student population definitions are grades three and four for population one, grades seven and eight for population two, and grade twelve for population three.

TIMSS examined students in two adjacent grade levels at the two younger student populations to obtain a pseudo-longitudinal measure of students' learning in the upper of the two adjacent grade levels. In TIMSS, the focus of all data collection and analyses is upon the upper grade of these two student populations. The same test, intended to be appropriate for the upper grades' curriculum, is administered to students in the two adjacent grades so that the lower grade students' achievement may be used as a pseudo-pretest for upper grade students' achievement. However, since the focus of this study is on investigating the relationship between students' motivation and their achievement, rather than an investigation of any curriculum effect, this study employs data only from the upper grades for the younger two student populations.

This study focuses solely upon data collected from students in grades four, eight, and twelve. Since the same test is used with the two adjacent grades, this design avoids confounding the curriculum effect on students' achievement due to the rather large differences in the learning opportunities found in the curricula of the two adjacent grade levels with differences in achievement that may be explained by their motivation. Focusing solely upon the upper grades for the younger student populations also reduces variation that may be due to developmental changes across the two adjacent grades of populations one and two and increases the interpretability of differences that may be found across the three different grade levels.

Since the goal of TIMSS is to obtain a nationally representative sample of student achievement, geographical primary sampling units (PSUs) were identified and a stratified random sampling of the PSUs was made to obtain a sample representative of the U.S. Schools were selected from each geographical PSU and mathematics classrooms were then randomly selected from these schools for participation in the educational survey. Students in the selected mathematics classrooms participated in the mathematics and science assessments. In this way the student sample is considered to be representative of the entire U. S. student population at the sampled grade levels. For the two younger student populations, a total of 26 schools, twelve schools for student population one and fourteen schools for population two, were selected from seven states. This school sample consisted primarily of public schools except for two private schools, one at each of the two student populations. In addition, four of the student population two schools were considered magnet schools with advanced placement programs. For student population three, 18 schools were selected from eight states. Three states but no schools or school districts were the same between the student populations one and two sample and the student population three sample.

A total of 1510 students, 778 girls and 732 boys, in grades four, eight, and twelve participated in the educational survey. There were 516 in grade four, 266 girls and 250 boys, 702 in grade eight, 374 girls and 228 boys, and 292 in grade twelve, 154 girls and 138 boys. Because administration of the various instruments could occur on two separate days, some students did not complete all parts of both the achievement instrument and the background questionnaire. In addition, only those grade twelve students currently taking science courses completed all the questions pertaining to science on the background questionnaire. Only those students who had valid responses to all the motivation items and the relevant achievement items were included in the analyses reported here. Exclusion of cases having missing or incomplete data yielded a total of 377 grade four students, 603 grade eight students and 114 grade twelve students. Descriptions of the student sample are summarized and presented in Table 1.

Table 1 – Description of Student Sample by Grade

Variable	Grade 4	Grade 8	Grade 12
Mean age in years	10.00 (*SD* = 0.42)	13.85 (*SD* = 0.46)	17.88 (*SD* = 0.53)
Sex of students			
Female	49.3 %	55.9 %	59.3 %
Male	50.7 %	44.1 %	40.7 %
Books in the home			
None	0.3 %	–	–
Very few (1-10)	2.4 %	1.0 %	1.8 %
One shelf (11-25)	8.1 %	6.6 %	5.3 %
One bookcase (26-100)	30.5 %	32.5 %	27.4 %
More than one bookcase (>100)	58.8 %	60.0 %	65.5 %
English spoken at home			
almost never	1.6 %	0.5 %	2.7 %
some of the time	5.1 %	4.9 %	5.4 %
most of the time	12.2 %	14.0 %	6.3 %
always	81.1 %	80.5 %	85.6 %
Patents' education level			
Don't know	61.3 %	31.2 %	14.9 %
Some school	1.1 %	2.0 %	5.3 %
High school graduate	2.7 %	6.8 %	9.6 %
Some college	8.0 %	12.8 %	13.2 %
College graduate	27.1 %	47.3 %	57.0 %

Instruments

Student Background Questionnaire

The Student Background Questionnaire contained items providing information about student's general background, i.e., age, country of birth, the frequency with which English is spoken at home, the family's cultural and economic capitol, student's time use outside of school, student's motivation and interest in mathematics and the sciences, and an indication of the frequency with which specific instructional activities occur during mathematics and science lessons. Items that addressed these concepts were either adopted from previous IEA studies or were crafted specifically for TIMSS through the activities of the Survey of Mathematics and Science Opportunities (SMSO) project (see Survey of Mathematics and Science Opportunities, 1993 for more detail).

Initially, all the items on the Student Background Questionnaire were the same for all three student populations. However, during the development phase of the questionnaire, many expressed concern over the response burden this placed on the youngest students. Consequently, the SMSO eliminated a few items from the population one student questionnaire to shorten the length of the background questionnaire and the amount of time it would take the younger students to complete it (Schmidt & Cogan, in press).

Another difference between the versions of the background questionnaire for students at the three different population levels was necessitated by the differentiation of the sciences. While mathematics courses have different titles and address different branches of mathematics, there is a greater perceived consistency and relationship between branches of mathematics than branches of science (see, for example, Stodolsky & Grossman, 1995). At the college level, mathematics is usually a single major while teachers and others who major in the sciences usually concentrate on a single branch of science such as biology, chemistry, or physics. During the development phase of the Student Background Questionnaire, SMSO found strong evidence internationally that this greater differentiation among the sciences is often established in students' experiences and the curriculum as early as the population two student level. For this reason, most of the science motivation items were asked successively with respect to biology, earth science, and physical science or biology, chemistry, earth science, and physics.

In the version of the Student Background Questionnaire employed in the United States, multiple science versions of the motivation items were asked only of grade twelve students. Since the achievement test contained items from all areas of science (as is explained more fully in the next section), students' responses to the motivation items for multiple sciences were combined for analyses. If items were asked four separate times, once each for biology, chemistry, earth science, and physics, students were to respond only to those items having to do with the sciences they were currently taking. The mean of the multiple responses by grade twelve students to more than one science was employed in analyses for comparability with the responses of population one and two students. The specific items used to assess students' science motivation along with the multiple science options for grade twelve are listed in Appendix 2.

The motivation constructs employed in the analyses in this study include students' subject matter Interest, Importance, Career interest, Perceived competence, and Success Attributions. Students responded to each item that assessed these constructs using a 4-point Likert scale. Parallel items were included concerning motivation in mathematics and science. Interest, Importance, Career interest, and Perceived Competence for both mathematics and science were assessed with more than one item. A single item assessed students' attribution of success to ability and another single item assessed students' attribution of success to hard work. Students' Interest in the subject matter (i.e., mathematics or science) and their rating of the subject matter's Importance were both measured by three items. Students' subject-specific Perceived Competence and subject-specific Career Interest were both measured by two items. The respective reliabilities, calculated according to Cronbach's alpha, for the mathematics scales were .83 (Interest), .71 (Importance), .40 (Perceived competence), and .70 (Career Interest). The corresponding science scales had reliabilities of .76 (Interest), .72 (Importance), .32 (Perceived competence), and .82 (Career Interest). Due to the shortening of the grade four Student Background Questionnaire, the Career Interest and Importance scales had one less item each. This reduced the Career Interest scale to a single item for students at this grade level and therefore, no reliability is reported. The two item Importance scale for grade four students had reliabilities of .63 and .62 for mathematics and science respectively. Appendix 1 identifies all the items for mathematics motivation constructs from the Student Background Questionnaire together with their associated reliabilities. Appendix 2 contains the same information for all the science constructs from the Student Background Questionnaire employed in the analyses.

Achievement Tests

The work behind the development of the items included on the TIMSS student assessments involves a number of individuals from different countries and disciplines reflecting a genuine desire to create the most appropriate and fair assessments that have yet been employed in a multi-national comparative educational survey (Garden & Orpwood, in press). This process began with the development of the curricular frameworks for mathematics and the sciences. The frameworks were developed to provide a language system that would accurately describe the mathematics and science curricula across the many varied education systems internationally. Such a language system makes possible meaningful comparisons across a system's intended (i.e., system-level curricular guides), implemented (i.e., topics actually taught in classrooms) and attained (i.e., what students have learned) curricula as well as comparisons of these curricular elements across education systems.

The items finally selected to be included in the achievement tests were chosen to meet specific curricular specifications and to address key curricular topics of interest at each of the three grade levels. The tests were designed to balance assessment of appropriate curricular breadth as well as in-depth assessment of key focal topics for each of the three student levels. Discussions were conducted with representatives from many different countries to obtain a description of the range of topics that could be considered appropriate for students at each level. The mathematics and science frameworks embody the result of much of this discussion (Robitaille, et. al., 1993).

Item development began with the formation of an international item bank. The bank originally contained items from two previous IEA studies, the Second International Mathematics Study (SIMS) and the Second International Science Study (SISS), as well as from national assessments such as the National Assessment of Educational Progress (NAEP) from the United States. Specialists in mathematics and the sciences from a variety of countries formed the TIMSS' Subject Matter Advisory Committee (SMAC) who worked together with educational measurement specialists to review, write, rewrite, and select items for the achievement tests. Each item was critically reviewed by subject matter experts from each of the TIMSS' participating countries and were piloted with students in a number of countries before being selected for inclusion on the assessments (Garden & Orpwood, in press).

Additionally, three item types were included in the student assessments: multiple choice, short answer, and extended response. The vast majority of the items were traditional multiple choice with four or five options presented. Short answer questions were designed to be answered with a few well chosen words, a phrase, or one or two sentences. Extended response items were constructed to require a more detailed and descriptive response that would require students to write a brief paragraph of three or four sentences or present a problem solution and then briefly explain it.

The TIMSS Field Trial student assessment booklets, used in the analyses reported here, consisted of a total of eight different booklets for students in grades four and eight. Each booklet contained all three item types. Four booklets assessed students' learning in mathematics and four assessed students' learning in the sciences. Each of the grade four mathematics booklets contained between 50 and 55 multiple choice items, 3-7 short answer items, and between 4 and 8 extended response items. The grade four science booklets contained between 39 and 44 multiple choice items, 3-7 short answer items, and between 4 and 8 extended response items. At the grade eight level, mathematics booklets contained between 42 and 63 multiple choice items, 3-7 short answer items, and between 4 and 8 extended response items while the science booklets contained between 33 and 43 multiple choice items, 3-7 short answer items, and between 4 and 8 extended response items.

Grade four booklets addressed seven different mathematics topic areas: whole numbers, fractions and decimals, estimation and number sense, measurement, geometry, ratios and proportions, functions relations, and patterns, and data representation, probability and statistics. Grade eight booklets assessed all of these same topic areas except whole numbers which was not considered an appropriate topic for students at this grade level. In science, the grade four topic areas were earth science, life science, physical science, and science and technology. Grade eight topic areas were earth science, life science, chemistry, and physics.

There were three test booklets for students at the twelfth grade level. Each booklet contained either 48 or 49 items assessing both mathematics and the sciences. These booklets were designed for the general student population at this grade level which includes both students who have little coursework in either mathematics or the sciences as well as students who have advanced coursework in either mathematics or the sciences at the secondary level. For this reason, the items were designed to measure what experts considered an acceptable 'literacy' level in mathematics and the sciences (Survey of Mathematics and Science Opportunities, 1993). Each of the three booklets contained a mixture of mathematics and science items presented in the three different formats, multiple choice, short answer, and extended response. Between 20 and 25 items assessed the mathematics topics of fractions and decimals, functions and relations, measurement, estimation and number sense, and data representation, probability, and statistics. Science topics addressed by between 23 and 25 items included earth sciences, life sciences, physical sciences, and science and technology. Appendix 3 presents a table that details the number of each type of item that addressed each topic for each of the booklets used in the study.

Mathematics and science achievement scores were constructed in the same manner. Two achievement scores, multiple choice and short answer, were constructed for all students. Multiple choice items were scored either right ('1") or wrong ('0"). The mathematics or science multiple choice score for each student was the mean of the student's scores on all the mathematics or science multiple choice items contained in the student's booklet. Short answer items were also scored either right ('1") or wrong ('0"). International coding rubrics had been developed for the extended response items identifying between two and five levels of correct response for each item. For the analyses reported here, the most correct response was assigned a value of "1", the second most correct response assigned a value of "0.9", the third most correct response assigned a value of "0.8", fourth "0.7", and fifth "0.6". Incorrect or unintelligible responses were assigned a value of "0". The mathematics or science short answer score was the mean of all the scores assigned to the mathematics or science short answer and extended response items contained in each students' test booklet. Finally, students' mean scores were standardized within each assessment booklet using the *T*-scale which has a mean of 50 and a standard deviation of 10. Standardized scores define an individual student's score relative to the mean. The use of standard scores permits the comparison and aggregation of covariation of students' achievement scores with background variables across achievement booklets that may have different raw mean scores.

Data Collection

Data were collected during March, April and May of 1994. Students in grades four and eight completed assessment instruments during the later part of March and the first part of April. Grade twelve students completed their assessments during the early part of May. Test administrators had been recruited and trained early in 1994 by a professional research corporation retained by the United States government to conduct all data gathering and data entry procedures for U.S. participation in TIMSS. These trained test administrators conducted all the sessions in the selected schools and classrooms in which students completed the assessment instruments.

At grades four and eight, students completed one of eight different achievement test booklets. Each achievement test booklet contained only mathematics problems or science problems and consisted of two parts, Part A and Part B. Thus students in grades four and eight completed either a mathematics test booklet or a science test booklet. No student in these grades completed booklets for both mathematics and science. For students in these grades, administration of parts A and B of the booklets was separated by a break of at least 20 minutes. Grade four students were given 30 minutes to complete each of the two parts of the test booklet. Grade eight students were given 45 minutes to complete each of the two test booklet parts. Thus the total achievement testing time was 60 minutes for grade four students and 90 minutes for grade eight students.

Twelfth grade students each completed one of three different assessment booklets that contained both mathematics and science items. Mathematics and science items were intermingled throughout the test booklets which were not divided into sections or parts. Grade twelve students were allotted one 90 minute session to complete the test booklet with no break during the testing session. At all three grade levels, achievement test booklets were randomly distributed to the students in the mathematics class that had been randomly selected within the school as previously described above.

A Student Background Questionnaire was completed by students in all three grades. Administration of the background questionnaire always occurred in a separate and subsequent session to those in which students completed the achievement assessment. In some instances, it was possible for students to complete the background questionnaire later the same day as the assessment instrument. In many instances, however, particularly for twelfth grade students, it was necessary to hold the Student Background Questionnaire session on the day following the achievement testing in order to refrain from a gross disruption of schools' schedules. This in part explains the relatively large number of twelfth grade students that completed assessment booklets but did not complete the Student Background Questionnaire.

Students in all three grades were given at least 20 minutes to complete the Student Background Questionnaire. The Student Background Questionnaire contained items that assessed students' motivation in both mathematics and the sciences. For those students in grades four and eight, students completed an achievement test for either mathematics or science and then completed the Student Background Questionnaire that assessed their motivation in both mathematics and science. Grade twelve students completed one achievement instrument that assessed both mathematics and the sciences. They then completed the Student Background Questionnaire that assessed their motivation in both mathematics and the sciences.

CHAPTER 3: RESULTS

This study has two main components. The first component describes students' motivation in mathematics and science, how aspects of motivation relate to one another, and how students' motivation differs across grades four, eight, and twelve. The second component relates students' motivation to their performance on a mathematics and/or science achievement test. The first five hypotheses pertain to issues related to the descriptive component while the last three hypotheses pertain to the relationship between students' motivation and their achievement.

Three different types of analyses were carried out to address the specific questions and hypotheses pertaining to the study's two main components. Multivariate analyses of variance and correlational analyses were employed to address the questions and hypotheses of the descriptive component. Those pertaining to the second main component, the relationship between motivation and achievement, were examined through correlational analyses and structural equation modeling.

Describing Student Motivation

The main objective of this component entails describing the relationship among the mathematics and science motivation variables at each developmental level assessed. Table 2 presents the means and standard deviations for the six motivation variables for both subjects for students in fourth, eighth, and twelfth grades.

Table 2 – Motivation Means (Std Dev) by Grade Level and Subject

	Grade 4 $n = 377$		Grade 8 $n = 603$		Grade 12 $n = 114$	
	Math	Science	Math	Science	Math	Science
Interest	3.2 (0.7)	3.1 (0.7)	2.8 (0.7)	2.8 (0.7)	2.8 (0.8)	2.9 (0.6)
Importance	3.5 (0.6)	3.4 (0.6)	3.4 (0.5)	3.4 (0.5)	3.2 (0.6)	3.1 (0.6)
Career Relevance	3.3 (0.8)	3.3 (0.8)	2.8 (0.7)	3.1 (0.8)	2.7 (0.9	2.5 (0.9)
Perceived Competence	2.9 (0.6)	2.9 (0.6)	2.7 (0.6)	2.7 (0.6)	2.6 (0.6)	2.6 (0.5)
Talent	2.9 (0.9)	2.8 (0.9)	2.3 (0.8)	2.2 (0.9)	2.5 (0.7)	2.4 (0.7)
Hard Work	3.5 (0.7)	3.5 (0.7)	3.4 (0.6)	3.5 (0.6)	3.3 (0.6)	3.4 (0.7)

Since the motivation variables measured are conceptually related, a single two-factor multivariate analysis of variance (MANOVA) was used to examine the effect of subject and grade level on students' motivation. MANOVA evaluates the effect of one or more independent factors on the mean levels of two or more related dependent variables. The rationale for employing a single MANOVA rather than a series of ANOVAs is analogous to the rationale for using one ANOVA rather than a series of paired *t*-tests to examine the effect of one or more independent factors upon a single dependent measure. ANOVA enables a more precise control of the probability of a type-I error than multiple *t*-tests reducing the likelihood that the null hypothesis, that there is no difference between group(s) means, is incorrectly rejected (Glass & Hopkins, 1984). Similarly, MANOVA more precisely controls the probability of a type-I error than a series of ANOVAs preventing the unwarranted identification of differences between the means of two or more dependent measures across two or more groups.

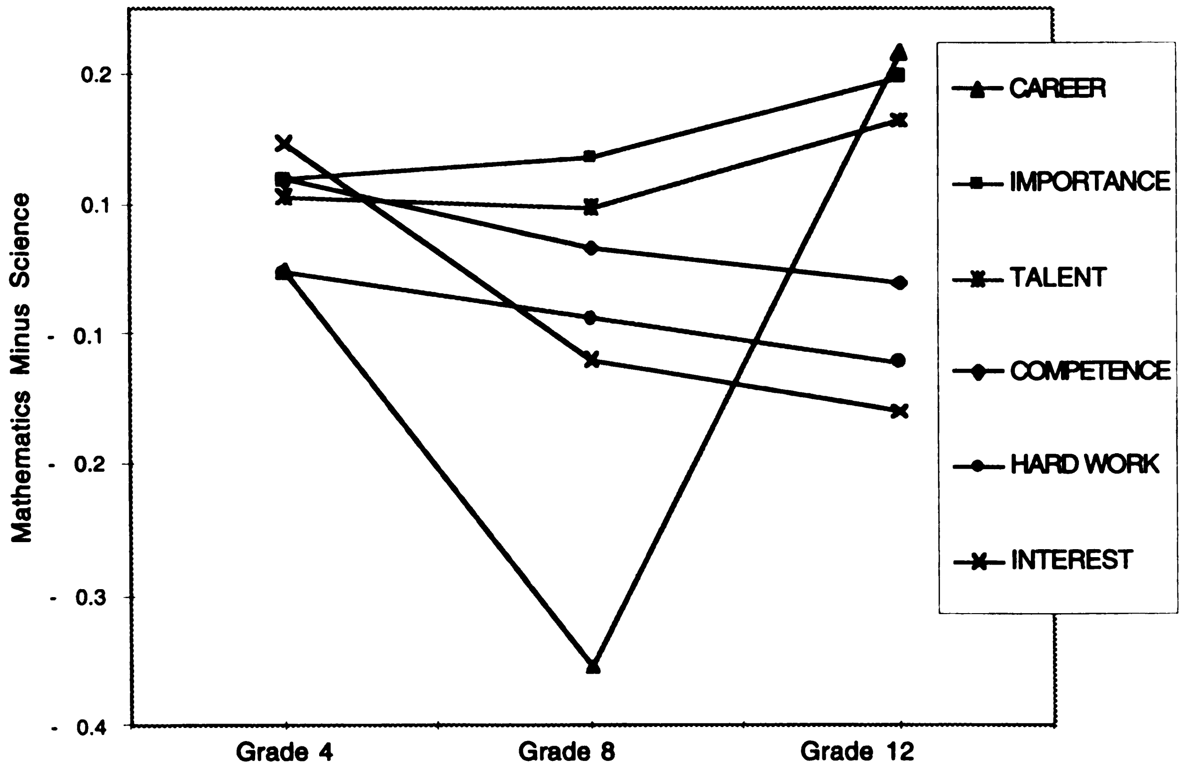
A repeated measures two factor MANOVA was conducted using the mathematics and science motivation variables as the dependent measures. Subject matter (i.e., mathematics and science) was a within-subjects factor and grade level was a between subjects factor. This analysis provided a test for the main effect of grade level and subject matter as well as the interaction between the two. MANOVA holds the effect of one factor constant to examine the effect of another factor. Accordingly, the *difference* between students' mathematics and science motivation was employed to evaluate the effect of subject matter while the *mean* of students' mathematics and science motivation was used to evaluate the grade level effect. Furthermore, the effect of grade level was examined by partitioning the grade level effect into the linear and quadratic components. The intent of this analysis was not to test specific hypotheses about the type of grade level effect but rather to provide a full description of the difference in students' motivation across the three grade levels. A complete summary of all the multivariate effects together with the corresponding univariate results is presented in Table 3.

Table 3 – Summary of MANOVA on Students' Motivation

Multivariate Effect Univariate Effect for Motivation Variables	F	df	Significance
Subject	12.87	6, 1086	.00
Interest	0.68	1, 1091	.41
Importance	33.13	1, 1091	.00
Career Relevance	6.06	1, 1091	.01
Perceived Competence	1.09	1, 1091	.30
Talent	12.33	1, 1091	.00
Hard Work	4.58	1, 1091	.03
Linear Grade	15.61	6, 1086	.00
Interest	25.83	1, 1091	.00
Importance	34.45	1, 1091	.00
Career Relevance	68.45	1, 1091	.00
Perceived Competence	24.38	1, 1091	.00
Talent	15.48	1, 1091	.00
Hard Work	5.15	1, 1091	.02
Quadratic Grade	24.66	6, 1086	.00
Interest	30.49	1, 1091	.00
Importance	9.80	1, 1091	.00
Career Relevance	0.43	1, 1091	.51
Perceived Competence	0.18	1, 1091	.67
Talent	51.68	1, 1091	.00
Hard Work	1.68	1, 1091	.20
Subject by Linear Grade	5.08	6, 1086	.00
Interest	5.16	1, 1091	.02
Importance	2.57	1, 1091	.11
Career Relevance	10.30	1, 1091	.00
Perceived Competence	1.02	1, 1091	.31
Talent	1.01	1, 1091	.31
Hard Work	2.00	1, 1091	.16
Subject by Quadratic Grade	24.66	6, 1086	.00
Interest	1.22	1, 1091	.27
Importance	0.52	1, 1091	.47
Career Relevance	140.47	1, 1091	.00
Perceived Competence	0.12	1, 1091	.73
Talent	1.02	1, 1091	.31
Hard Work	0.00	1, 1091	1.00

The two factor MANOVA on students' motivation (i.e., Interest, Importance, Career Relevance, Perceived Competence, success attributions to natural Talent and Hard Work) revealed a significant linear grade level by subject interaction, $F\ (6, 1086) = 5.08$, $p < .001$ as well as a significant quadratic grade level by subject interaction, $F\ (6, 1086) = 24.66$, $p < .001$. Figure 2 graphically represents the interaction of subject matter and grade level by showing the *difference* between mathematics and science motivation means at each of the three grades.

Figure 2 – Differences Between Mathematics and Science Motivation Means by Grade

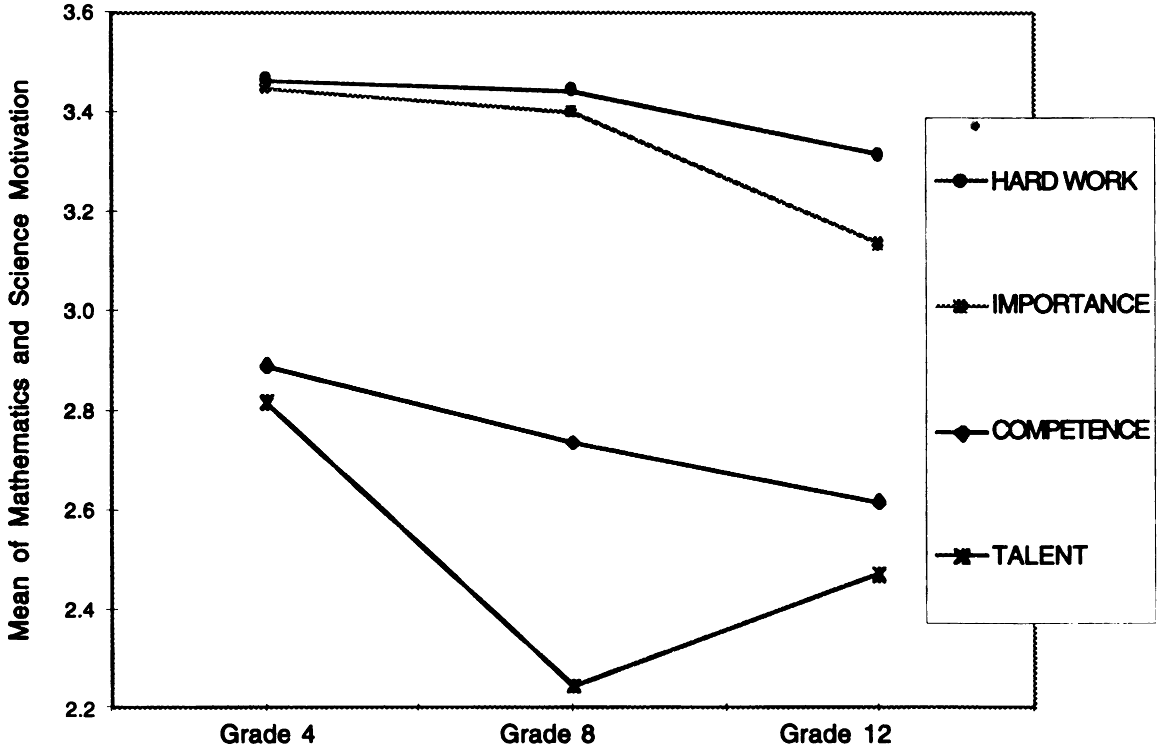


As shown in Table 3, univariate tests of these subject by grade level interactions revealed a significant linear grade level effect for the difference between students' mathematics and science motivation for two of the six motivation variables: Interest, F (1, 1091) = 5.16, $\rho < .05$, and Career Relevance, F (1, 1091) = 10.30, $\rho < .01$. Career relevance was also the only variable to demonstrate a significant interaction of subject matter and quadratic grade level effect: F (1, 1091) = 140.47, $\rho < .001$. These results mean that grade 4 students' mean interest in mathematics was greater than their interest in science but that students in grades 8 and 12 demonstrated a greater mean interest in science than mathematics. Grade 4 students expressed no difference in their perception of the career relevance of mathematics and science but differences were observed among older students. Grade 8 students perceived science to be more relevant to their future career than mathematics but grade 12 students expressed the opposite.

In addition to the significant interactions, the MANOVA also yielded significant main effects for grade level, F (6, 1086) = 15.61, $\rho < .001$ for the linear effect and F (6, 1086) = 24.66, $\rho < .001$ for the quadratic effect, and subject matter, F (6, 1086) = 12.87, $\rho < .001$. Univariate tests yielded a significant linear grade level effect for each of the four motivation variables that did not demonstrate a significant interaction: Importance, F (1, 1091) = 34.45, $\rho < .001$; Perceived Competence, F (1, 1091) = 24.38, $\rho < .001$; and success attributions to

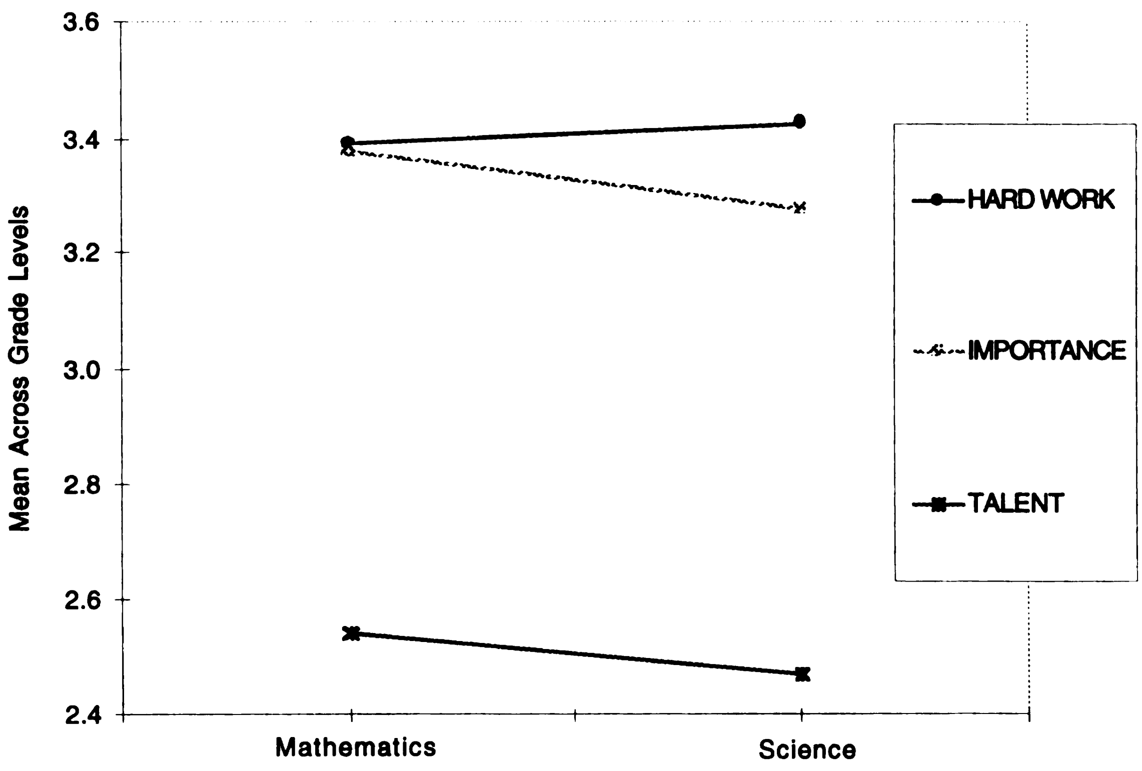
Talent, F (1, 1091) = 15.48, $\rho < .001$, and Hard Work, F (1, 1091) = 5.15, $\rho < .05$. Univariate tests also yielded significant quadratic grade level effects for students' Importance, F (1, 1091) = 9.80, $\rho < .001$ and success attribution to Talent, F (1, 1091) = 51.68, $\rho < .001$. These grade level effects are illustrated graphically in Figure 3.

Figure 3 – Mean of Mathematics and Science Motivation Variables by Grade



As can be seen in Figure 3, the quadratic effects reveal that the mean Importance of subject-matter is quite similar and relatively high for students in grades 4 and 8 but drops for students in grade 12. Students' mean attribution to natural Talent for subject-matter success reveals a different pattern: students in grades 4 and 12 endorse Talent as important for doing well to a greater extent than do students in grade 8. The linear effect seen in Figure 3 shows that students' mean subject-matter Perceived Competence is greater among grade 4 students than among grade 8 students and is even less for students in grade 12. A similar pattern is observed with students' mean attribution of subject-matter success to Hard Work. Nonetheless, this mean is consistently the largest among the six motivation variables measured in this study.

Figure 4 –Motivation Means for Mathematics and Science



Univariate tests of the subject matter effect revealed a significant difference between students' mathematics and science motivation for three of the four motivation variables that did not demonstrate a significant interaction: Importance, $F(1,1091) = 33.13$, $p < .001$ and success attributions to natural Talent, $F(1,1091) = 12.33$, $p < .001$ as well as to Hard Work, $F(1,1091) = 4.58$, $p < .05$. These differences are graphically presented in Figure 4. As can be seen from Figure 4, students in general endorsed Hard Work as a reason for doing well in science more than in mathematics. However, they endorsed natural Talent as a reason for doing well in mathematics to a greater extent than they did with respect to science. Students' mean subject-matter Importance was also greater for mathematics than for science.

Hypothesis 1: Decreasing Motivational Means

Hypothesis one predicted that students' interest, importance, and perceived competence in both mathematics and science would demonstrate a decrease across the three developmental levels. The means presented in Table 2 and graphically represented in Figure 3 are, for the most part, consistent with this hypothesis. The significant interaction of grade level and subject-matter for students' interest suggests that the hypothesized decreasing trend is dependent upon the specific subject-matter considered. The hypothesized trend appears to hold for student interest in mathematics but not for students' interest in science. The significant multivariate effect of grade together with the subsequent significant univariate grade level effects reported from the two-factor MANOVA support the hypothesis of a

decreasing trend among students' subject-matter Importance and Perceived Competence.

Hypothesis 2: Attributions to Hard Work and Talent

Hypothesis two predicted that only elementary students would attribute success in both mathematics and science more to hard work than to talent; older students would attribute success in both domains more to talent that to hard work. As may be surmised from Table 2 and the representations of students mathematics and science motivation in Figure 3, this hypothesis is not supported by the data. A second MANOVA was performed with students' mathematics and science motivation measures to obtain specific contrasts between their success attributions to Hard Work and Talent. The MANOVA has a significant multivariate grade level effect, F (24, 2162) = 18.75, $\rho < .001$, together with significant univariate tests of the difference between Hard Work and Talent both in mathematics, F (2, 1091) = 11.80, $\rho <$ .001, and science, F (2, 1091) = 35.27, $\rho < .001$, across grades 4, 8, and 12. This means that, on average, students endorsed hard Work as a reason for doing well in a subject to a greater extent than they did natural Talent. Contrary to the hypothesis, this is true for students at all three grade levels and with respect to both mathematics and science. In fact, at all three grade levels and with respect to both mathematics and science, students' mean level attribution of success to Hard Work was either the highest or second highest

of the six motivation means while their mean level attribution of success to natural Talent was the lowest.

Hypothesis 3: Perceived Competence and Success Attributions

Hypothesis 3 addresses the relationship between students' perceived competence and their success attributions (i.e., to either talent or hard work) predicting that these would not be differentiated in elementary students but would be differentiated in older students. Table 4 presents the correlations among these variables in both mathematics and science at each of the three grade levels.

Table 4 – Correlations Between Perceived Competence and Success Attributions by Subject and Grade

	Mathematics			Science		
	Talent	Hd Wrk	Comp	Talent	Hd Wrk	Comp
Grade 4						
Talent	1.00			1.00		
Hard Work	.35**	1.00		.26**	1.00	
Competence	.13*	.17*	1.00	.03	.14*	1.00
Grade 8						
Talent	1.00			1.00		
Hard Work	.04	1.00		.05	1.00	
Competence	- .03	- .04	1.00	- .05	- .02	1.00
Grade 12						
Talent	1.00			1.00		
Hard Work	- .15	1.00		.01	1.00	
Competence	- .13	- .27*	1.00	- .03	.00	1.00

two-tailed significance * $p < .01$ ** $p < .001$

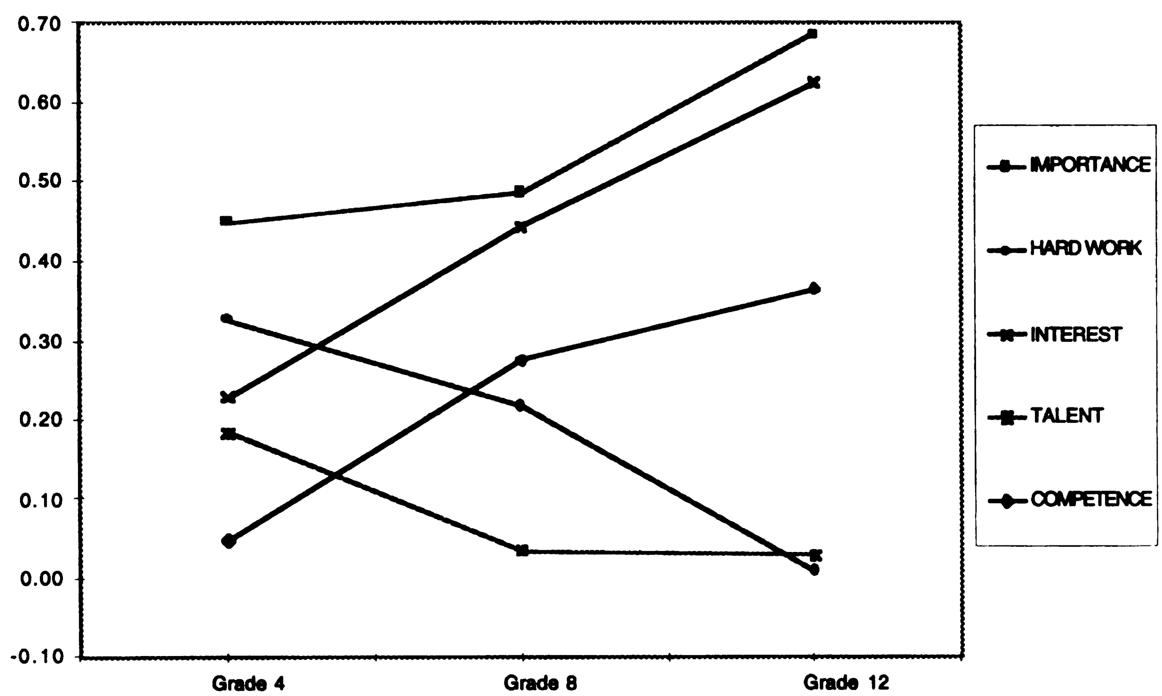
Students' mathematics perceived competence and success attributions (i.e., talent and effort) all significantly relate to each other at grade four. Grade four students' science attributions are similarly related except that the correlation between their Perceived Competence in science and attribution of success in science to natural Talent is not significant. In contrast, none of these relationships is significant with grade eight students. Only one of these relationship was significant among twelfth grade students –the correlation between students' perceived mathematics Perceived Competence and their attribution of mathematics success to Hard Work.

This pattern of relationships among students' Perceived Competence and success attributions is consistent with hypothesis 3: these relationships are positively and significantly related among grade four students but not among students in grades eight or twelve. This means that these concepts are not clearly differentiated in grade 4 students while they are differentiated among grade 8 and grade 12 students.

Hypothesis 4: Career Relevance and Other Aspects of Motivation

The relationship between students' subject-matter-specific career relevance and other aspects of motivation is the substance of hypothesis four. This hypothesis predicted that students' subject-matter-specific career relevance would demonstrate an increasing relationship with other motivational concepts from middle elementary to middle school to high school. These correlations are illustrated in Figure 5 and Figure 6 and presented in Table 5. The relationships between students' subject-specific career relevance and other motivational aspects appear quite similar for both mathematics and science. Not all of the correlations demonstrated the straightforward increase with other motivational variables across ages as predicted. Consistent with hypothesis four, students' mathematics Interest, Importance and Perceived Competence demonstrate an increasing relationship with their perception of the subject's Career Relevance across the three grade levels.

Figure 5 – Correlation Between Mathematics Career Relevance and Other Aspects of Mathematics Motivation by Grade



The picture for students' science motivation, illustrated in Figure 6, appears slightly different: these relationships are greater at grade 12 than grade 4 but at grade 8 are less than at grade 4. In contrast, and contrary to what was predicted in hypothesis four, the relationships between students' Career Relevance and their success attributions (i.e., Talent and Hard Work/effort) do not appear to increase but to decrease across the three grade levels.

Figure 6 – Correlation Between Science Career Relevance and Other Aspects of Science Motivation by Grade

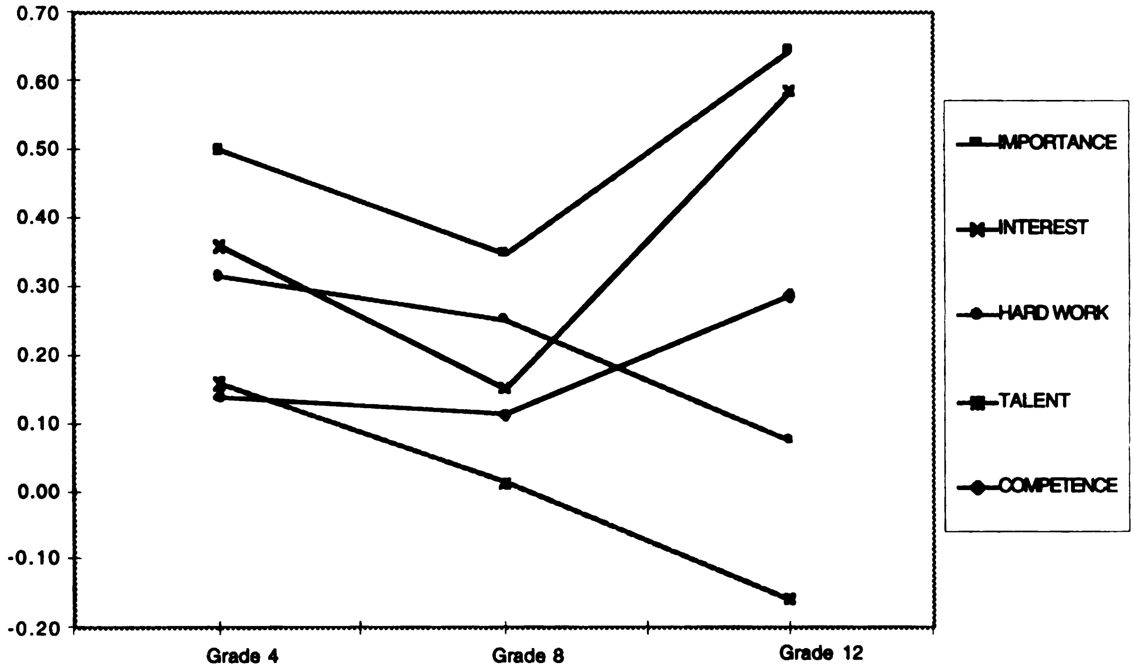


Table 5 summarizes the correlations across the three grade levels between students' career relevance and the other aspects of motivation for mathematics and science. Marascuilo (1966) described a general method for evaluating comparisons among statistics such as correlations and proportions as well as means or medians. The ratio between the square of the contrast

and the contrast variance, has an approximate χ^2 distribution

$$X^2 = \frac{\hat{\psi}^2}{\hat{\sigma}^2}$$

with J - 1 degrees of freedom where J is the number of independent statistics being compared. Table 4 contains the χ^2 values for the linear contrast across the three grade levels for each motivational aspect and the associated probability value of each χ^2 obtained. In each case, the contrast degrees of freedom is 2.

Table 5 – Correlations Between Career Relevance and Other Motivation Variables by Subject and Grade

	Grade 4	Grade 8	Grade 12	$\chi^2_2\ \psi_{linear}$	$\chi^2_2\ p$ value
Mathematics					
Interest	.23**	.44**	.63**	62.59	.000
Importance	.45**	.49**	.69**	21.85	.000
Competence	.05	.28**	.37**	46.50	.000
Talent	.18*	.04	.03	37.21	.000
Hard Work	.33**	.22**	.01	150.21	.000
Science					
Interest	.36**	.15**	.59**	18.45	.000
Importance	.50**	.35**	.65**	7.94	.019
Competence	.14*	.11	.29*	10.22	.006
Talent	.16*	.01	-.16	51.00	.000
Hard Work	.32**	.25**	.08	48.74	.000

two-tailed significance * $p < .01$ ** $p < .001$

The results reveal that the linear trends illustrated in Figure 5 with students' mathematics motivation are statistically significant ($\rho < .001$). These linear trends are also statistically significant for students' science motivation ($\rho < .05$). However, as Figure 6 would suggest, the quadratic trend for students' science Interest, Importance, and Perceived Competence across grades 4, 8 and 12, are also significant and yield larger χ^2 values than the linear contrasts (Interest, $\chi^2_2\ \psi_{quadratic} = 114.72$, $\rho < .001$; Importance, $\chi^2_2\ \psi_{quadratic} = 48.53$, $\rho < .001$; and Perceived Competence, $\chi^2_2\ \psi_{quadratic} = 14.98$, $\rho < .001$).

These linear trends indicate that students' perception of the relevance of mathematics and science to their future careers is increasingly related to their Interest in the subject, their perception of the subject's Importance, and their Perceived Competence in the subject. The opposite trend is observed with students' success attributions. These are positively related to students' perception of the relevance of mathematics and science to their future career among grade 4 students but not among students at grade 12.

Hypothesis 5: Relationship Between Mathematics and Science Motivation

Hypothesis 5 concerns the relationship between students' mathematics and science motivation. It predicted that this relationship would decrease across the three grades for each aspect of motivation assessed. Figure 7 depicts the declining relationship between the corresponding aspects of students mathematics and science motivation from grade 4 to grade 8 to grade 12.

Figure 7 – Correlation Between Aspects of Mathematics and Science Motivation by Grade

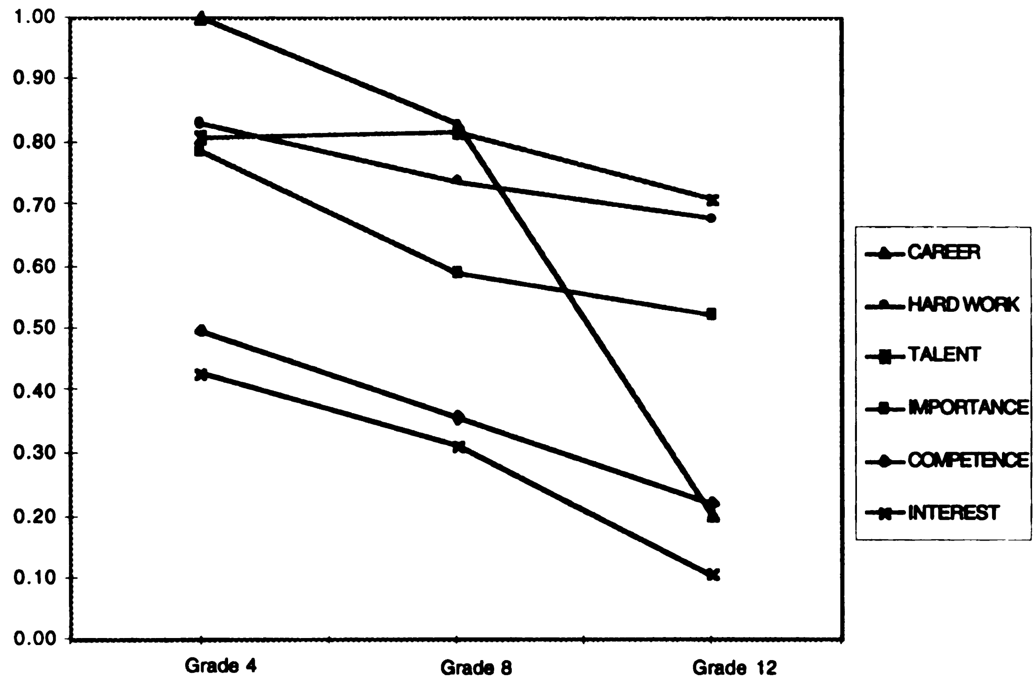


Table 6 contains the correlations between these corresponding motivational aspects at each grade level and the χ^2 value for the linear trend across the three grades. A significant decreasing linear trend is demonstrated for each motivational aspect except students' success attribution to Hard Work.

Table 6 – Correlations Between Corresponding Aspects of Mathematics and Science Motivation by Grade

	Grade 4	Grade 8	Grade 12	$X_2^2\ \psi_{linear}$	$X_2^2\ p$ value
Interest	.43**	.31**	.10	70.98	.000
Importance	.79**	.59**	.52**	26.51	.000
Career Relevance	1.00**	.83**	.20*	449.24	.000
Competence	.50**	.36**	.22*	34.66	.000
Talent	.81**	.82**	.71**	4.36	.113
Hard Work	.83**	.74**	.68**	10.52	.005

two-tailed significance * $p < .01$ ** $p < .001$

This decreasing relationship between corresponding aspects of students' mathematics and science motivation suggests that students' motivation is more differentiated at grade 8 than grade 4 and even more so at grade 12. Grade 12 students' motivation in mathematics and science is much less similar than is grade 4 students' motivation in these two subjects.

Relating Motivation to Achievement

Hypotheses 6, 7, and 8 are concerned with the relationship between students' motivation and their achievement. Table 7 presents the correlations between the aspects of students' motivation and their mathematics and science multiple choice and open-ended achievement scores. These relationships are illustrated in Figures 8, 9, 10, and 11. According to these figures, few of the relationships between the various motivational aspects and achievement appear to be linear across the three grades. Rather, most of the relationships appear curvilinear.

Table 7 – Correlations Between Motivation and Achievement Scores by Subject, Score Type and Grade

	Grade 4	Grade 8	Grade 12	$\chi^2\ \psi_{linear}$	χ^2 p value
Mathematics Multiple Choice Score					
Interest	.22**	.17*	.32*	3.37	.185
Importance	.21**	.15*	.22*	0.04	.982
Career Relevance	.15**	.10*	.26*	7.27	.026
Competence	.36**	.26**	.27*	2.79	.247
Talent	.01	.07	.14	14.85	.001
Hard Work	.17*	.02	-.14	44.78	.000
Mathematics Open Ended Score					
Interest	.18*	.19*	.32*	7.13	.028
Importance	.20*	.14*	.33**	6.14	.046
Career Relevance	.13	.12*	.30*	11.61	.003
Competence	.26**	.23**	.16	4.46	.108
Talent	-.04	.05	.11	20.77	.000
Hard Work	.22*	-.01	-.09	53.16	.000
Science Multiple Choice Score					
Interest	.20*	.14*	.07	11.67	.003
Importance	.22*	.22**	.01	43.47	.000
Career Relevance	.09	.00	.02	7.20	.027
Competence	.23*	.34**	.06	21.69	.000
Talent	.00	-.05	.19*	27.54	.000
Hard Work	.06	-.10	.07	0.06	.973
Science Open Ended Score					
Interest	.12	.13*	.12	0.00	.998
Importance	.15*	.21*	.26*	4.91	.086
Career Relevance	.04	.03	.15	8.47	.014
Competence	.09	.30**	.07	0.41	.814
Talent	-.11	-.06	.13	35.08	.000
Hard Work	.07	-.08	-.01	15.76	.000

two-tailed significance   * $p < .01$ ** $p < .001$

Hypothesis 6: Interest, Importance, Perceived Competence and Achievement

Hypothesis 6 stated that the relationship between students' Interest, Importance and Perceived Competence with their achievement would increase across the three grade levels. Contrary to hypothesis 6, these correlations do not appear to increase linearly across the three grades for any of the four different achievement scores. Although all the correlations between students' mathematics multiple choice and open-ended scores with Interest and Importance are significant, the only significant linear increases across the three grades are the correlations between students' Interest and Importance with their mathematics open-ended achievement score ($\chi^2_2\ \psi_{linear} = 7.13$, $\rho < .05$ and $\chi^2_2\ \psi_{linear} = 6.14$, $\rho < .05$ respectively). Quite the opposite of what was predicted in hypothesis 6, the correlations between students' Interest and Importance with their science multiple choice achievement scores demonstrate significant linear decreases ($\chi^2_2\ \psi_{linear} = 11.67$, $\rho < .01$ and $\chi^2_2\ \psi_{linear} = 43.47$, $\rho < .001$ respectively).

Although eight of the twelve correlations across the three grades between students' Perceived Competence and their achievement scores are statistically significant, no discernible pattern seems immediately obvious. Linear contrasts across the three grade levels yield non-significant χ^2 values for both types of mathematics scores ($\chi^2_2\ \psi_{linear} = 2.79$, $\rho = .247$ for multiple choice and $\chi^2_2\ \psi_{linear} = 4.46$, $\rho = .108$ for open-ended). Students' perceived

Figure 8 – Correlations Between Mathematics Motivation and Multiple Choice Score by Grade

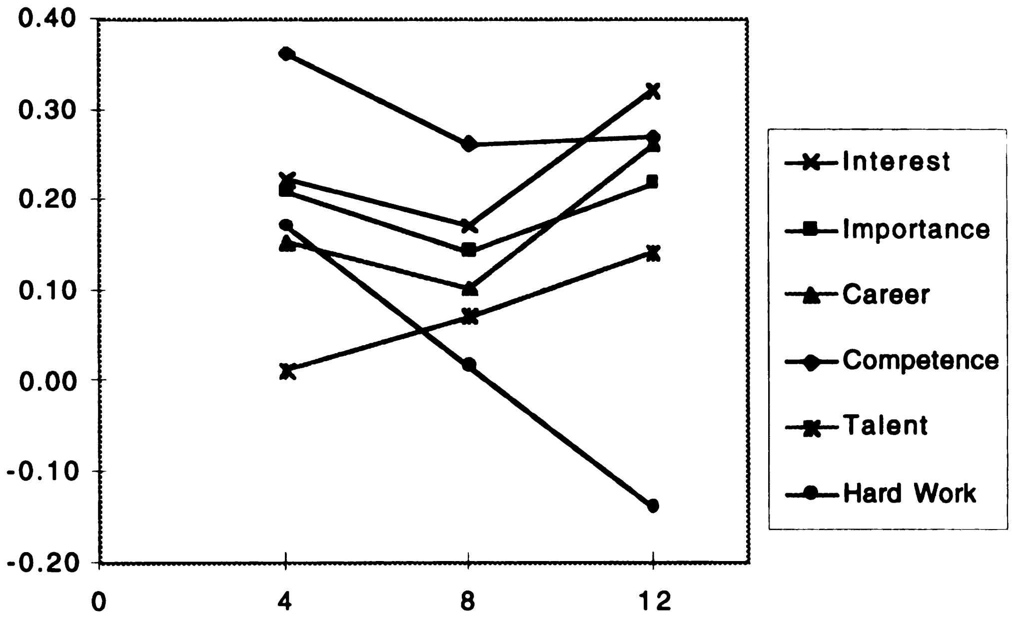


Figure 9 –Correlations Between Mathematics Motivation and Open-Ended Score by Grade

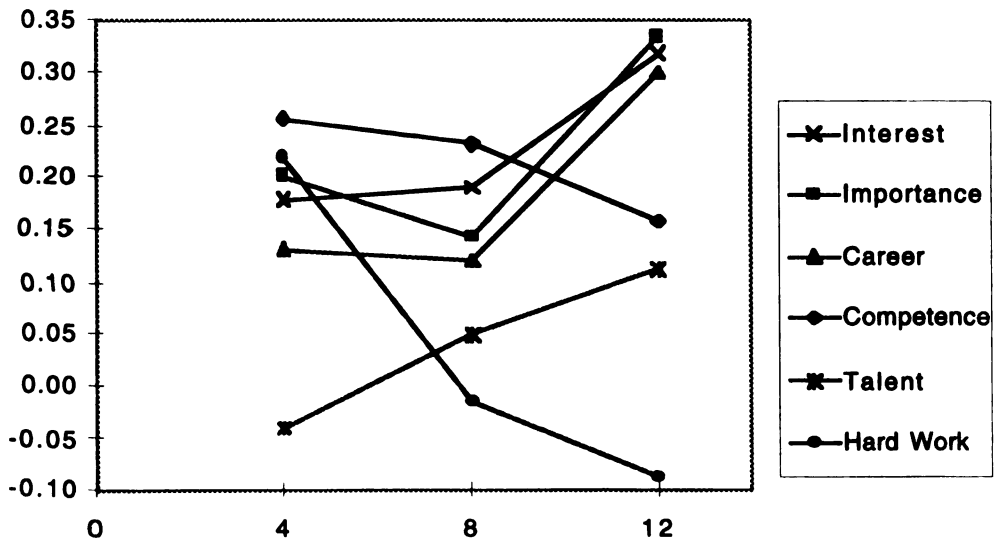


Figure 10 – Correlations Between Science Motivation and Multiple Choice Score by Grade

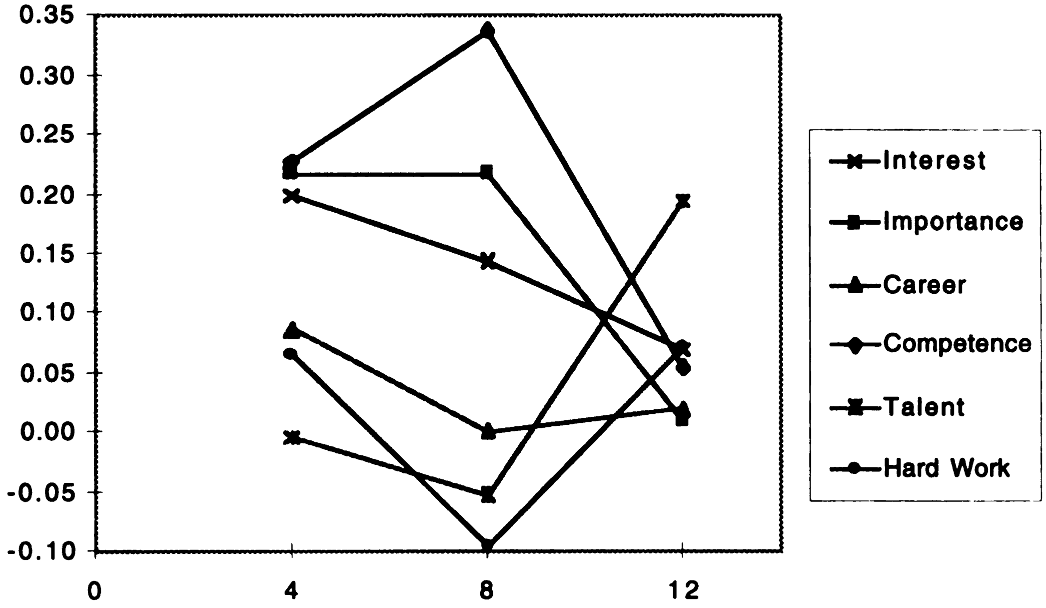
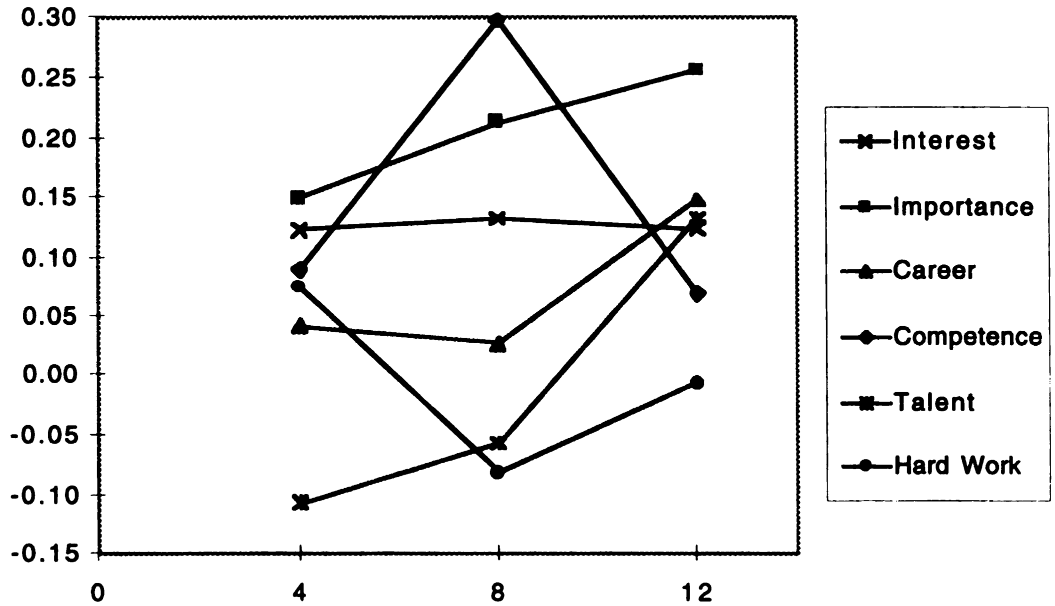


Figure 11 –Correlations Between Science Motivation and Open-Ended Score by Grade



Perceived Competence demonstrates a curvilinear relationship with their science achievement scores across the three grades with the highest correlations occurring with grade 8 students ($\chi^2_2 \psi_{quadratic} = 35.40$, $\rho < .000$ for multiple choice and $\chi^2_2\ \psi_{quadratic} = 50.61$, $\rho < .000$ for open-ended). In addition, out of the 24 correlations across the three grade levels between students' success attributions and their achievement scores, the only statistically significant correlations occur with grade 4 students' mathematics scores: $r = .17$ ($\rho < .05$) for hard work and mathematics multiple choice and $r = .22$ ($\rho < .05$) for hard work and mathematics open-ended score.

Hypothesis 7: Career Relevance and Achievement

Hypothesis 7 stated that subject-matter career relevance would demonstrate a stronger relationship with achievement among grade 12 students compared to the younger students. As can be seen from the correlations in Table 7, this hypothesis received mixed support. Across the three grade levels, the only statistically significant correlations between students' Career Relevance and their achievement were in mathematics. For both the multiple choice mathematics score and the open-ended mathematics score, the correlation with career relevance demonstrated a linear increase from grade 4 to grade 12 ($\chi^2_2\ \psi_{linear} = 7.27$, $\rho < .05$ and $\chi^2_2\ \psi_{linear} = 11.61$, $\rho < .01$). In science, there did not appear to be any relationship at all between either students' multiple choice score or their open-ended score and their perception of the relevance of science to their future career. The only exception was the significant positive correlation between students' science multiple choice science score and Career Relevance among grade 8 students.

Hypothesis 8: Mathematics and Science Motivation Related to Achievement

Hypothesis 8 stated that the relationship between motivation and achievement would be different for the two domains of mathematics and science. Structural equation modeling was used to compare the relationship between students' motivation and their achievement in mathematics and science. At the same time, this modeling approach was used to evaluate the usefulness of a general two-factor, expectancy-value model of motivation in predicting students' achievement. To accomplish this, a multi-sample analysis procedure was used in which a single model is fitted to data from several different groups simultaneously (Jöreskog & Sörbom, 1989). Pooled-within-school variance covariance matrices were obtained for the motivation and achievement measures at each of the three grade levels for both mathematics and science. This resulted in six matrices: grade 4 mathematics; grade 4 science; grade 8 mathematics; grade 8 science; grade 12 mathematics; and grade 12 science.

In the two-factor, expectancy-value model, Interest, Importance, and Career Relevance were value components while Perceived Competence and the two success attributions, Talent and Hard Work, were expectancy components. The two latent variables, Expectancy and Value, were allowed to be correlated. These two latent variables in turn predicted a third latent variable, Achievement, which was indicated by the two achievement measures, a multiple-choice score and an open-ended response score. This model was simultaneously fit across the six groups. This yielded a χ^2 of 348.17 with 102 degrees of freedom, $p = .000$. Although the χ^2 may theoretically be viewed as a statistic testing the significance of a model, it is more appropriately viewed as a "badness-of-fit" measure in that small values that are not statistically significant signify that the model fits the data well while large values that are statistically significant signify that the model does not fit the data (Jöreskog & Sörbom, 1989). This χ^2 test statistic is, however, overly sensitive to large sample sizes leading to a rejection of a model on the basis of relatively minor misspecifications (Gerbing & Anderson, 1993). This has led to the test statistic-degrees of freedom ratio comparing the χ^2 test statistic with its associated degrees of freedom. Criterion for an acceptable fit using this ratio ranges from as low as two or three to as high as five (Bollen, 1989; Bollen & Long, 1993). This ratio for the two-factor model was 3.4 which would indicate an acceptable fit.

Goodness-of-fit indices indicate the extent to which the matrices estimated according to the specified model agree with those observed with the sample data. For this reason, some have proposed that the best way to assess models is to compare competing models rather than rely upon any single or even a series of goodness-of-fit indices (Gerbing & Anderson, 1993). Previously, Eccles (1989), using structural equation modeling, had reported that a two-factor motivation model fit better than a single factor model. Consequently, the multiple group approach was used to evaluate a single factor motivation model for the purpose of comparing its fit to the data with that of the two-factor model. In this model, all motivation variables were components of a single latent variable, Motivation, which predicted a second latent variable, Achievement, which, again, was indicated by the two achievement measures. This model yielded a χ^2 of 416.98 with 144 degrees of freedom, $p = .000$. A comparison of the two models can be done by comparing the difference between the two χ^2 s (Jöreskog & Sörbom, 1989). This resulted in a χ^2 of 68.81 with 42 degrees of freedom, $p = .006$, confirming with these data Eccles' (1989) earlier finding that the two-factor model was a better fit than a single-factor model.

A third, no factor or MIMIC (Multiple Indicators and Multiple Causes) model was applied to the six groups. This model posits a single latent variable that is measured by two different sets of variables. Thus, each motivation variable directly predicts a latent variable, Achievement, which is, again, indicated by the two achievement measures. This model simultaneously estimates the relationships among the sets of motivation and achievement variables and basically represents a canonical analysis. This model yielded a χ^2 of 22.07 with 30 degrees of freedom, $p = .851$ which represents a good fit to the data. Comparing this model with the two-factor model yielded a χ^2 of 326.10 with 72 degrees of freedom, p = .000, confirming that this model was a better fit than the two-factor model. However, if all the measurement error terms in the two-factor model are freed for estimation, the resulting χ^2 is identical to the MIMIC model. In addition, two other goodness-of-fit indices are also identical but the coefficients of determination, an indication of the total amount of variance explained by all the equations in the model, are greater for each group according to the two-factor expectancy-value model than for the MIMIC model. Although the MIMIC model demonstrates favorable goodness-of-fit indices, the equating of motivation and achievement implied by the model lacks theoretical and conceptual support. Motivation has been theorized to affect or even determine achievement but this is not the same as positing that the two concepts are synonymous as implied by the MIMIC model. All of this considered together suggests that the two-factor expectancy-value structural model represents a satisfactory fit for the sample data and is a useful model for relating motivation and achievement. Table 8 summarizes three different goodness-of-fit measures for the two-factor and MIMIC models.

Table 8 – Goodness of Fit Measures for Two Models

	E – V Model			MIMIC Model		
	$\chi^2_6 = 22.07$ $p = .001$			$\chi^2_{30} = 22.07$ $p = .851$		
	Coefficient of Determination	Goodness of Fit Index	Root Mean Sq. Residual	Coefficient of Determination	Goodness of Fit Index	Root Mean Sq. Residual
4 Math	2.897	0.994	0.115	0.206	0.994	0.115
4 Science	3.165	0.995	0.114	0.110	0.995	0.113
8 Math	3.709	0.997	0.051	0.129	0.997	0.051
8 Science	3.567	1.000	0.031	0.194	1.000	0.031
12 Math	3.837	0.991	0.136	0.176	0.991	0.136
12 Science	12.537	0.990	0.142	0.243	0.990	0.142

Although the same general two-factor structural model relating motivation to achievement appears acceptable across the three grade levels and two subject-matter domains assessed, examining the path coefficients together with their standard errors provides an evaluation of the consistency with which these various aspects of motivation are related to achievement. However, despite the relatively good fit of the two-factor expectancy-value model, LISREL had difficulty estimating the error portion of the model preventing the generation of standard errors for path coefficients. Although the MIMIC model may not be the most appropriate for representing the structural relationship between motivation and achievement, comparing the path coefficients for mathematics and science across the groups can provide some information relevant to hypothesis 8.

Hypothesis eight stated that the relationship between motivation and achievement would be different for mathematics and science. Unfortunately, the size of the path coefficients and their associated standard errors did not permit meaningful comparisons to adequately address this hypothesis. Table 9 presents a summary of all motivation path coefficients for each grade and subject. Although differences in the path coefficients for each motivation variable at each grade level appear different between mathematics and science, few of these path coefficients are significant. At grade 4, Perceived Competence is the only significant path coefficient. This is significant, however, for mathematics but not for science. At grade 8, Perceived Competence again has a significant path coefficient and for these students it is significant for both mathematics and science. In addition, Importance also has a significant coefficient for science. At grade 12, none of the motivation variables had a significant path coefficient for either mathematics or science. While these findings do not establish a complete picture of the relationship pattern between aspects of motivation and achievement, they do suggest that this relationship pattern is not identical for mathematics and science nor identical for either subject across the three grade levels.

Table 9 – Path Coefficients (Std. Error) for MIMIC Model by Subject and Grade

	Interest	Importance	Career Relevance	Perceived Competence	Talent	Hard Work
Grade 4 Mathematics	-1.322 (1.134)	3.365 (1.726)	1.266 (1.000)	5.459 (1.093)	-0.777 (0.730)	0.261 (1.326)
Science	0.520 (1.011)	2.061 (1.291)	0.721 (0.841)	1.595 (0.943)	-0.593 (0.610)	-0.971 (0.917)
Grade 8 Mathematics	0.682 (0.704)	1.493 (1.082)	-0.637 (0.642)	3.303 (0.767)	-0.118 (0.475)	-0.814 (0.693)
Science	-0.747 (0.753)	3.420 (1.070)	-0.099 (0.622)	3.492 (0.821)	-0.444 (0.511)	-1.698 (0.753)
Grade 12 Mathematics	-1.051 (1.294)	-0.380 (1.692)	1.023 (1.162)	2.557 (1.472)	1.683 (0.899)	0.199 (1.127)
Science	-1.256 (1.133)	1.438 (1.190)	0.168 (0.489)	1.671 (1.222)	0.332 (0.468)	0.538 (0.575)

CHAPTER 4: DISCUSSION

The results of this study reveal a complex portrait of student motivation and its relationship to their achievement in mathematics and science at three different grade levels. The goal of the present chapter is to better understand this portrait by examining it in relation to previous research and the motivational theory on which the study is based. The first section explores the meaning and some of the implications of the mean differences and different patterns of interrelationships among the specific aspects of motivation involved in this study. The next section looks at the relationship between student motivation and achievement. The last section examines some of the limitations of the present study and concludes with some thoughts for further research.

Interpreting the Portrait of Student Motivation

One of the most important results of this study is the significant interaction of subject matter and grade level on the mean level of students' motivation. The significant linear grade level by subject-matter interaction upon the mean level of students' Interest and the significant quadratic grade level by subject interaction upon the mean level of students' Career Relevance highlights the importance of both these factors in determining students' motivation. The significant main effects of subject-matter and grade level on the mean level of virtually all the other motivational aspects measured confirm the important role these factors play in students' academic motivation.

The interaction of these two factors signifies that there is a difference in the relative evaluation of mathematics and science from one grade level to another. What's important in grade 4 may be less so in grade 8. The subject that is most fascinating at grade 4 may, at grade 8, seem much less so compared to another subject. The subject that appears to have great career relevance in grade 8 may, at grade 12, appear less relevant to one's future career plans than another subject. All of this suggests that the meaning of certain aspects of motivation does not remain constant. The meaning of these aspects of motivation, and hence the implications of these for students' behavior, is dependent upon the students' development (i.e., grade level) and the specific subject-matter being considered. In short, student motivation is both specific to a subject and distinctive at different developmental levels. Motivation is not unidimensional or general but must be examined in a subject-specific manner. This understanding of student motivation calls into question the assumption made by some that students' interests and academic preferences are "cast in stone" rather early in students' academic career.

Interest

In this student sample, fourth graders expressed more interest in mathematics than science. Eighth graders' interest in the two subjects was almost the same while twelfth graders expressed more interest in science than mathematics. What explanations could be offered for this shift in the relative evaluations of these two different subjects? One possible explanation may have to do with the relative exposure students have had to these two subjects. Students may simply be more interested in whichever subject is most salient in their current experience. Mathematics is typically a fundamental and highly visible part of the elementary curriculum and, hence, elementary students' experience. Science is typically not taught as frequently as mathematics in elementary schools and may not be as familiar to grade 4 students. Eighth grade students typically spend an equal amount of time in mathematics and science classrooms while all the grade 12 students surveyed were enrolled in science classes but not all were enrolled in mathematics classes. However, such an explanation seems rather superficial and at odds with the flexible and adaptive nature of motivation as developed in the introduction.

An alternative explanation may be found in the person-environment fit theory of Eccles and her colleagues (Eccles & Midgley, 1989; Eccles, 1993). According to their research and theory, the decline in students' subject matter interest from elementary school to middle school stems from the mismatch between students' cognitive and social needs and the cognitive and social demands placed upon them at the middle school level. Developmentally, middle school students have greater cognitive abilities and increased social interests and skills than elementary students. However, as Eccles develops the argument, middle school classrooms are often less personal than the elementary classrooms students have experienced and, contrary to what one might expect, the academic work in middle school is often less cognitively demanding than that in elementary school. At a time when students are ready for more interpersonal interaction, more demanding academic activities, and more responsibility they actually encounter less of these in their middle school classrooms than they did in their elementary classrooms.

Presumably, this mismatch could continue and be compounded through high school.

Still, the person-environment fit theory only explains the decline in students' interest from elementary school to middle school and, perhaps, into high school. The explanation for the developmental differences in students' relative interest in mathematics and science and, particularly, the increased interest in science demonstrated by the grade 12 students in this study may also reside in the nature of these two academic disciplines as they are encountered in schools. To the extent that students are socialized by their teachers and come to share the disciplinary perspectives of their teachers, students may find one subject a better "fit" than another at different points in their development. According to Stodolsky (1995), mathematics teachers rated their subject as being more defined and static than did science teachers. In addition, there is typically more diversity in the learning activities and social interaction in science classes than in mathematics classes. Mathematics classes typically involve little social interaction or discussion and students usually work alone on exercises for a good portion of the class. In contrast, science classes often involve experiments or other cooperative learning activities that provide students an opportunity to talk and work together.

Thus, grade 4 students' greater interest in mathematics might be a reflection of the relatively more rigid and static nature of mathematics. The relatively more structured approach to mathematics together with the relatively less time devoted to science (Stodolsky & Grossman, 1995) might be a better match with the cognitive and social needs of children at this age. Grade 8 students might not yet fully appreciate the differences between the two subjects in their classrooms. While these students are rapidly developing new cognitive abilities, social awareness, and social needs, the composite portrait in which students rate their interests in the two subject similarly may not accurately represent any particular student at this age. The portrait formed on the basis of mean levels may disguise the differences between those more rapidly developing students with needs and ideas similar to older students and those who are yet more like younger students. Thus, this may be a period of transition that reflects both changes in students' intellectual and social functioning as well as changes in the curriculum. Grade 12 students' greater interest in science could be explained by the relatively better fit science classrooms have to their general social and cognitive needs – greater social interaction, less structural rigidity while still presenting generally challenging cognitive demands.

Career Relevance

The specificity of students' motivation and the impact of their developmental level on their motivation is particularly evident in their indication of a subjects' relevance to their future careers. Fourth graders rated mathematics and science equally relevant; eighth graders rated science more relevant than mathematics and twelfth graders rated mathematics more relevant than science. The meaning of these differences in students' ratings of career relevance is made more difficult to interpret given that students at each developmental level rated mathematics as more important than science. In addition, students' interest in the two subjects demonstrated yet a different developmental pattern.

As previously noted, fourth graders expressed more interest in mathematics than science, eighth graders expressed only slightly more interest in science than mathematics, and twelfth graders expressed a greater interest in science. Thus, twelfth graders present the curious profile of rating mathematics more *important* than science, more *relevant* to their future careers yet expressing greater *interest* in science. This is all the more curious given that in this student sample, all twelfth graders were currently taking at least one science but not all were taking a mathematics class.

Given these patterns of students' interest and ratings of a subject's important and career relevance for two different subject-matters across the three grades, one might suppose that these motivational aspects were not integrated into a coherent whole. Perhaps a student's interest in a subject is essentially independent of evaluations of the subject's importance or relevance to the student's personal future career. As reasonable as this may seem, this interpretation would suggest that these aspects of motivation are less integrated or coherent among twelfth graders than among fourth graders. This contradicts one of the foundational concepts of career theory – that individuals desire to implement their self-concepts in their career choice. According to the career development theories of Super (1990) and Holland (1973), to the extent possible, people choose careers that are consistent with their interests, values and abilities. The more differentiated and developed concept of self exhibited by twelfth graders (Harter, 1983), together with career development theory, would lead one to expect twelfth graders to exhibit the more coherent relationship among their interest in a subject, their evaluation of the subject's important and their perceptions of the subject's relevance to their future career. These curious patterns between motivational aspects for two subjects across the three grade levels deserve further study but, at the least, suggest that not only is the meaning of mathematics and science different, as concluded in the previous discussion about students' interest, but the meaning of the specific aspect of motivation, career relevance in this example, may also be different.

An explanation of the developmental pattern exhibited by students' evaluation of a subject's relevance to their future careers may be built upon the person-subject matter fit explanation developed in reference to students' interest. In addition to the differences in subject matter previously noted, students at different developmental levels have quite different perspectives on their future careers. For fourth graders, the idea of a future career is not typically a particularly pressing issue. Children at this point do not have firm occupational or career identities nor do they have particularly well informed understandings of various occupations (Montemayor & Eisen, 1977). Thus, any subject may conceivably be as relevant to their future career as any other.

The issue of careers becomes a more relevant issue for eighth graders. More students have given serious thought to "what I want to be when I grow up" and have begun to make some decisions accordingly (Kelly, 1989). If students perceive their science classes as being a better "fit" with their intellectual and cognitive needs, they may also decide that science is going to be more relevant to their future careers. In addition, science may be presented in classrooms in a manner that more saliently links science to careers. Classroom discussions of science topics together with the use of specific words may more readily link science to specific careers; e.g., meteorology – meteorologist; chemistry – chemist; physics –

physicist/engineer; biology – biologist/doctor/veterinary/nurse/emergency medical technician.

By twelfth grade, students may have had enough exposure to the world of work to better understand the requirements, duties, and skills associated with various careers. On the basis of their knowledge of the world of work, they may have come to the conclusion that, despite their greater interest in science, the mathematics they've encountered is more relevant to a broader range of viable career options than are the sciences they've studied.

Effort, Ability and Perceived Competence

Contrary to previous research and hypothesis two, students consistently attributed success both in mathematics and science more to effort than to ability. In addition, these attributions for success in mathematics and science demonstrated the most consistent correlations between the two subjects across the three grades. While the means for these attributions did demonstrate a decrease across the three grades what is perhaps more significant is the stability of their relative rank among the motivation means. Students' success attribution to ability was consistently the lowest of all the means across the three grades and both subject-matter areas whereas their effort attribution was consistently either the highest or second highest. It appears that there were, in this student sample, very few, if any, at any of the three grade levels who endorsed ability more than effort as a reason for success. These findings deserve further exploration. Directly examining the differences between each students' success attributions and factors that affect this difference may prove more enlightening than the consideration of the two separately as has been done here.

The consistent attribution of success in a subject-matter to effort rather than ability is all the more surprising given the theoretical explanation that has been proposed for younger students' success attribution to effort and older students' success attribution to ability. Stipek (1984) reasoned that success attributions were based on the same evidence as were children's perceptions of their competence. She reasoned that younger children based both their perceived competence and their success attributions on the amount of effort they expended with respect to a particular subject-matter. Older students, given their increased cognitive abilities for self-evaluation and social comparison, based both of these on their subject-matter-specific effort and performance relative to that of their peers. While the results of the present study did not confirm this differential attribution of success between younger and older students, it did find evidence supporting Stipek's theoretically reasoned link between younger students' success attributions and perceived competence.

The relationship between success attributions and students' perceived competence were positively and significantly correlated at grade 4 but not at the other two grades. These findings are also consistent with Nicholls' (1990) explanation of children's levels of differentiation of ability and effort. According to Nicholls, children fail to differentiate between effort and ability and their effects until they are around six years old; effort and ability are perceived to be similar leading to success. Between the ages of six and nine, children begin to identify effort as the primary cause. Around the ages of nine to twelve, children begin to differentiate effort and ability noting that variations in either may yield a change in outcome. Finally, children arrive at the concept of ability as capacity, that is, the notion that an increase in effort can increase a performance outcome but only up to a limit.

Inherent in the concept of ability as capacity is the notion that capacity is relative to others. My perceived competence may not suffer, for example, if I am unable to jump to the moon since no one has or can. However, my perceived competence may suffer if I am unable to do something that most everyone else is able to do such as hit a ball with a bat, whistle, or add up a column of numbers. This notion may also explain the appearance of a negative correlation between effort and perceived competence in mathematics among twelfth graders. As Nicholls (1990) explains, "the concept of . . . capacity means that even tasks we are able to master as well as others can – if we expect others to need less time or effort – offer us no prospect of a sense of accomplishment" (p. 26). This is true at least in part because the lesser time or effort required by others implies that they have greater ability. In this manner, the two concepts of effort and ability are always inextricably linked but would only be positively correlated with one another in young students who do not yet differentiate the two. Thus twelfth graders who strongly endorse effort as a cause for success in mathematics may also be aware that their own success requires more time than other successful students resulting in a lower sense of perceived competence. The absence of a similar correlation for twelfth graders in science may again be related to the previously noted differences in mathematics and science classrooms. The type of learning activities in science classrooms are more cooperative and social and may present students with less opportunity to arrive at individual evaluations of links between effort, time, and successful task completion whereas activities in mathematics classrooms may make these types of evaluations particularly salient. These explanations for a different pattern with science are speculative but they highlight the need for further research. Why is there a different pattern of relationship between success attributions and perceived competence in mathematics and science? Is there something about the way these two subjects are taught in school that could account for this difference?

Means, Subject-Matter Specificity and Development

The specificity and developmental differences inherent in students' motivation is also demonstrated by the differences in the correlations between students' mathematics and science motivation across the three grade levels. The decrease in the correlations between students' mathematics and science motivation suggests that an individual student's motivation is increasingly specific and differentiated. In particular, the dramatic difference in the correlation between students' perceptions of the career relevance of mathematics and science, which was perfectly correlated among grade 4 students but one of the lowest correlations observed between corresponding aspects of grade 12 students' mathematics and science motivation, lends support to the notion that the meaning of these subjects changes over time for students. The correlations between corresponding aspects of students' motivation in mathematics and science decreased from grade 4 to grade 8 and again from grade 8 to grade 12. The basis for these differences among students at these three grade levels may lie in the different degrees to which these students differentiate one subject from another. Younger students' motivation for mathematics appears practically identical to their motivation for science. The relationship between mathematics and science motivation is less similar among eighth grade students and is clearly differentiated among twelfth graders.

Consistent with hypothesis one, the mean levels of students' Interest, Importance, and Perceived Competence decreased from grade 4 to grade 8 to grade 12. This provides clear evidence in support of the developmental trend noted by Eccles (1993), Harter, Whitesell, and Kowalski (1992) and others. However, the practical implications of these decreases are not entirely clear. While these declines are statistically significant this does not, and cannot, settle the issue of the practical importance of the observed decline in students' mean motivation levels. Does the observed decline in students' mean level of motivation signify a decreased interest in and willingness to learn from school? Or are these decreases simply a result of a more accurate reporting by students – the result of older students increased self-knowledge and the ability to communicate this knowledge. One wonders, how interested in mathematics or science should a student be? The fact is that, according to theories of the developing self and self concept (Harter, 1983), decreases in the mean levels of various aspects of motivation is exactly what one would expect as students mature and develop ever more distinct personalities and preferences.

Whatever the impact of an increasing differentiation of interests and self may be, the issue of the practical significance of the observed decline in students' motivational means is even more problematic in the light of the much greater mean differences noted among schools. In the process of creating the pooled-within schools variance-covariance matrix for use in the structural equation modeling analyses, mean differences between schools as corresponding grade levels two to five times as great as the mean differences due to grade level or subject-matter were discovered. This suggests that differences in the characteristics or schools, classrooms, or perhaps even home environments (assuming homes represented by a single school share a certain degree of homogeneity) should also be considered in developing a complete portrait of students' achievement motivation. Previous research suggests that these factors do play a significant role in students' learning and motivation (Ames, 1992; Cogan & Oka, 1992; McGillicuddy-DeLisi, 1985).

While the statistically significant differences between mean motivation levels according to grade level and subject matter cannot settle the issue of the practical importance of these differences, neither can a discussion of mean differences alone contribute to an understanding of what an optimal level of motivation may be. Both of these issues require some analysis that links motivation to specific behaviors of interest. The next section explores some of the issues involved in linking motivation to achievement through the correlational and structural analyses employed in this study.

Conceptual and Structural Links Between Student Motivation and Achievement

The preceding discussion has highlighted the specificity of motivation with respect to mathematics and science. It has also been posited that characteristic differences in these subjects and the way they are treated in schools is a partial explanation for the observed differences. This specificity is now extended to how motivation relates to achievement in the two domains.

For mathematics, hypotheses six and seven were generally supported: the relationship between aspects of students' motivation and their achievement increased across the three grade levels. This picture was much less clear for science. Many of the same aspects of motivation did demonstrate an increased relationship to achievement from grade 4 to grade 8 but almost none of the relationships between motivation and achievement were significant at grade 12.

The pattern of relationships between aspects of motivation and achievement were not entirely parallel with respect to the two domains of mathematics and science. Students' rating of the relevance of mathematics to their future career was consistently and significantly related to the mathematics achievement at all three grades levels. None of these six correlations were significant for science. As suggested in the discussion of the motivational means, this differential pattern suggests that motivation is not only subject-matter specific but that how motivation for a specific subject relates to achievement within that subject is also specific.

The explanation for these differential patterns may, once again, lie in the distinct natures of mathematics and science. Although mathematics courses may bear the names of different branches of mathematics such as geometry, algebra, trigonometry, or calculus, there is greater perceived, if not real, coherence among these than among the various branches of science. At the college level, mathematics is a single major while science becomes ever more specialized – chemistry, chemical engineering, botany, zoology, microbiology, and geology for example. In fourth and eighth grade, students in the United States typically follow a general science course that provides some exposure to all the different branches of science. However, at the high school level, schools begin to offer and students begin to choose courses that concentrate on a particular area within science. The differences among these various branches of science are potentially as great as the differences between any two other subjects or courses. The achievement measure for twelfth graders was very similar to the general science measure employed at grades 4 and 8. This general science approach is more consonant with the school experiences of students at the lower two grades and may not have been consistent at all with the conception of science held by twelfth graders or the more focused science classes they were taking (e.g., biology, chemistry, physiology, physics). This general science approach may also begin to explain why motivation demonstrated so few relationships with students science achievement at grade 12.

Structural equation modeling revealed that motivation could be useful in understanding students' achievement. The specific approach employed a single model that simultaneously estimated the relationship between motivation and achievement at all three grades and in both subjects. The idea that a single model could represent the relationship between motivation and achievement for two different subjects at three different grade levels may, at first, seem to contradict the preceding discussion stressing the specificity of motivation. However, motivation specificity can refer to differences in an individual's motivation in two areas. A single model may represent the *structural* relationships but the relative *strength* or value of these relationships could differ. An entirely subject-specific model would necessarily require that the number of factors in the model and the structural relationships among them would be different as well.

The structural modeling analyses in this study did not attempt to address the issue of an entirely subject-specific model, i.e., one relating motivation to achievement for mathematics and another one relating these two for science. The analyses in this study simultaneously fit a single structural model to data representing the relationship between motivation and achievement for two different subjects at three different grade levels. The results of this analysis suggest that the same two factor, expectancy-value model, could represent this relationship both for mathematics and science across grade 4, 8, and 12. Although the strength of these relationships looked different in each of the six sub-samples, problems in the estimation procedure prevented a thorough analysis and confirmation of these differences.

One of the strengths of structural equation modeling is that a number of models regarding the relationships among a set of variables may be proposed and empirically evaluated against data gathered from a relevant sample population. The three different models evaluated represent different ways of thinking about motivation. The MIMIC, or no factor, model implies that motivation and achievement are the same; the achievement measures simply provide alternative measures of the motivation indices. While many have argued for a close connection between motivation and achievement with motivation playing a pivotal role in determining the level of one's achievement, the two constructs are not synonymous or equivalent. Motivation refers to the personal resources, constructs, and ideas a person brings to bear in a particular situation. Achievement refers to a specific type of behavior one has accomplished at a given time within a given setting or accumulated over a series of times. However, many factors beyond one's motivation may affect one's level of achievement. Indeed, as Weiner (1990) has noted, academic achievement is an "overdetermined" phenomena – it can be related to a wide variety of psychological and sociological factors.

The preference for a two-factor motivation model over a single factor suggests that students do consider two different types of issues involving their academic behavior: their expectancies or how they think about their performance and their values, the various reasons why they would engage in the behavior under consideration. However, positing the important role of motivation in determining academic achievement and modeling this relationship is not to suggest that motivation tells the whole story about achievement. Motivation may be a necessary but not sufficient condition for determining a specific level of academic achievement. In relation to students' academic achievement, motivation may function similarly to the electrical system of a vehicle – it is necessary for proper functioning but the entire performance of the vehicle is determined by the specifications of other systems as well such as the engine, transmission, body shape and style. In this sense, all aspects of motivation together may function in a manner similar to Nicholl's (1990) concept of ability as capacity – that is, motivation is important but its effect on actual performance in any given situation may be circumscribed by a variety of other factors. Indeed, motivational indices may well serve as indicators of a person's general readiness and capacity to perform. More specifically, a student may place a high value upon mathematics or science and have reasonably high expectations about doing well in these subject areas. The student's ability to learn either of these subjects and perform well on an achievement measure, however, can be affected by a number of other factors. These may include a variety of classroom issues affecting the quality of learning such as adequate lighting, temperature control, and air quality conducive to learning, the quality of learning activities and instruction, and the opportunity to learn the specific topics included on the achievement assessment.

The discussion throughout this study has often referred to motivation and achievement as an abbreviated way of referring to a particular set of concepts. It is not assumed that the measures employed in these analyses exhaust or fully capture either of these constructs. Other ways of assessing both of these constructs are possible and may be desirable for future investigations. Nonetheless, the portrait of motivation that emerges from the present analysis suggests that students' academic or achievement motivation is not a stable or unitary concept. This is an important insight for parents, classroom teachers, administrators, and test constructors among others to maintain. As the student quoted at the beginning of this paper noted, students do change. What motivates, excites, interests, and activates students' energies and personal resources for learning are not likely to be identical across all subjects nor across the entire stretch of schooling. The specific aspects of motivation that are strongly related to achievement in elementary schools, such as the perceived importance of a subject, may be joined by other motivational aspects, such as the perceived relevance for a subject to a future career, in relating strongly to achievement later in students' schooling.

Limitations and Future Considerations

Several aspects of the present study contain limitations that affect the interpretation of results. Some of these same issues suggest directions for future research. This study employed a cross-sectional design to explore developmental issues. Students' grade level was employed as a way of investigating age-related differences. While there is a substantial overlap between grade level and age level the two are not identical and, while the difference between any two students in two different grades would be constant, there would be considerable variation in the age differences of individuals in different grades. This would not be case if the same students had been involved in the study at three different time periods when they were in the three grades employed in this study. While there is nothing in the data to suggest a particular cohort effect upon the factors considered here, the conclusions suggesting developmental differences require confirmation with longitudinal data.

The present study examined the effect of grade level and subject-matter on students' motivation. A number of previous studies have also found motivational differences between boys and girls (e.g., Post-Kammer & Smith, 1985; Eccles & Jacobs, 1986; Hackett & Betz, 1989). The extent to which a portrait of boys' and girls' motivation would differ from the motivation portrait constructed in the present study is unknown. It may well be that no significant changes would be necessary. Early analyses of item level responses seemed to indicate few if any differences in the responses of boys and girls. However, simple comparisons of means may mask more dramatic differences in the way in which factors relate to one another. If this were the case, the modeling approach employed in this study treating all students the same would mask the differences between boys and girls. It may well be, for example, that the relevance of a subject is more related to other aspects of motivation for boys than for girls or that girls' interest in science is more related to their perception of the importance of science than is the corresponding relationship in mathematics. These relationships might also differ for boys and girls at different grade levels – the relationships may be more similar among younger students, for instance. Separately modeling the relationships between the aspects of motivation and achievement for boys and girls would contribute to a more complete portrait of motivation.

Although the sample in this study is representative of students in the United States, the twelfth grade sample is admittedly biased. Unlike the general population of twelfth graders, the students in this study were all currently taking at least one science class with some taking two or even three. The extent to which this has affected the means and relationships reported here is unknown. Particularly in those analyses involving science achievement, much of the difficulty in finding the same patterns observed in the lower grades could be due to a more restricted range. A more general sample of twelfth graders that included many who were not currently taking a science would probably yield more students having less science motivation and lower science achievement scores. Given the general nature of the science test, however, this is by no means a certainty.

In addition, the instrumentation for science may not be as sensitive to subject specific motivation as were the mathematics items despite their parallel construction. As noted, science is a more diverse domain than mathematics. Consequently, while items were asked once about mathematics, at grade 12 some science items were asked three or four times each in reference to a specific science. In order to parallel the general science format in grades 4 and 8, the responses of students taking more than one science were averaged to obtain an indicator of "general" science motivation.

Furthermore, the specific manner in which science motivation was assessed at grade 12, i.e., with respect to biology, earth science, chemistry, and physics, might not relate well to the general science nature of the grade 12 achievement measure. The grade 12 science assessment was created to measure a literacy level of scientific knowledge – a level not much more advanced or in-depth than what was expected of grade 8 students. Phrasing the motivation questions either broadly in terms of "science" for some items and more specifically in terms of the four broad branches of science for other items probably did not tap the type of science motivation that would related well to the performance of these advanced science students on a general science literacy assessment.

All of the motivation items have good face validity – teams of researchers worked to word and construct items to address the specific aspects of motivation and constructs of interest. Nonetheless, ambiguities in the meaning and interpretation of some items remain. More specifically, the way in which the success attribution items are worded it would be possible for students to respond either on the basis of their belief about what is *generally* necessary for *someone* to do well or on the basis of their belief about what is necessary for their own *personal* success. In addition, some constructs, such as success attributions and perceived competence, were measured with fewer than three items. Three items are often recommended for obtaining reliable measures (McArdle, 1996). The lower reliabilities of the two-item fourth grade Importance scales compared to the three-item scales for older students illustrates the effect that fewer items have on obtaining reliable measures. These measurement issues do not necessarily negate the specific and multidimensional portrait of motivation constructed in this study but they do highlight the need for further confirmatory research with more refined motivation measures.

Because a few of the motivation items were not presented to grade 4 students but only to students in grades 8 and 12, motivational analyses were conducted with scales of two or three items where possible rather than with individual items. The consequence of this is that the structural equation modeling amounted to a second order confirmatory factor analysis. The reliability of the scales would affect the quality of the modeling analyses. Some of the problems encountered in estimating the error portion of some of the models may well be related to this issue. Evaluation of the various structural models might be improved if the analyses were conducted with all the corresponding motivation items rather than using the motivation scales.

As previously mentioned, structural equation modeling is a powerful tool for examining and evaluating theoretical models. However as with other statistical procedures, these evaluations require that a number of assumptions about the data be made. Consequently, the results of analyses are always dependent on the quality of the data that inform them. Restriction of range and the degree to which data deviate from the assumed normal distribution are two important factors that affect the quality of structural modeling analyses (McArdle, 1996). The biased twelfth grade student sample probably restricted the range of both the motivation and achievement measures. In addition, the distributions for almost every item were skewed at all three grade levels. Out of four possible categorical responses, students consistently responded to either the two upper or the two lower categories, depending on the item, much more frequently than the two remaining categories. This skew in the raw data is retained in the later summaries and scales which probably contributed to the estimation problems encountered in the modeling analyses. The problem of skewed data is especially common with the type of categorical data employed here. Although not a complete solution to this problem, some have recommended the use of tetrachoric or polychoric correlations rather than covariances in structural modeling with categorical variables (Muthén, 1993). The modeling analyses employed in this study were conducted with the pooled-within schools variance covariance matrix and might be improved if conducted with polychoric correlations.

Summary

The current study has drawn upon concepts associated with a general expectancy-value model of motivation to examine issues of specificity and developmental differences in students' motivation. These issues have been explored by: 1) examining specific aspects of students' motivation, i.e., subject matter interest, importance, career relevance, perceived competence, and success attributions, and their interrelationships, and 2) evaluating the usefulness of these aspects of motivation in predicting students' performance on an achievement test. Students' motivation in two different subjects, mathematics and science, and at three different developmental levels, grades 4, 8, and 12, was assessed to examine these issues.

Analyses of means and correlations demonstrated both the specificity and developmental differences in students' motivation. Achievement motivation is not a stable or unitary construct. In general, motivation becomes more specific and differentiated across the three grade levels. Decreases in the mean levels of students' indication of their interest in a subject, the importance of a subject, and their subject-specific perceived competence were observed. In addition, these aspects of motivation together with students' perception of a subject's career relevance were correlated to two different measures of achievement. These relationships between motivation and achievement appeared greater for mathematics than for science.

APPENDIX A

Items used to assess Students' Mathematics Motivation

EXPECTANCY

Perceived Competence – α = .40

I usually do well in mathematics.

Mathematics is a hard subject. (Reversed scored.)

Success Attributions

To do well in mathematics you need lots of natural talent.

To do well in mathematics you need lots of hard work studying the subject.

VALUE

Interest – α = .83

How much do you like mathematics?

I enjoy studying mathematics.

Mathematics is boring. (Reversed scored.)

Importance – α = .71, α = .63 for grade 4.

I think it is important to do well in mathematics lessons.

I think the study of mathematics is important.

*Mathematics is important to everyone's life.

Career Relevance – α = .70

I would like a job that involved using mathematics.

*I need to do well in mathematics to get the job I want.

*Items not included in the grade four version of the Student Background Questionnaire.

APPENDIX B

Items used to assess Students' Science Motivation
Multiple science options for grade twelve students in brackets [].

EXPECTANCY

Perceived Competence – $\alpha = .32$

I usually do well in science. [biology/earth science/ physical science]

Science is a hard subject. [biology/earth science/chemistry/physics] (Reversed scored.)

Success Attributions

To do well in science you need lots of natural talent.

To do well in science you need lots of hard work studying the subject.

VALUE

Interest – $\alpha = .76$

How much do you like science? [biology/earth science/physical science]

I enjoy studying science. [biology/earth science/chemistry/physics]

Science is boring. [Biology/earth science/chemistry/physics] (Reversed scored.)

Importance – $\alpha = .72$, $\alpha = .62$ for grade 4.

I think it is important to do well in science lessons.

I think the study of science is important. [biology/earth science/chemistry/physics]

*Science is important to everyone's life. [biology/earth science/chemistry/physics]

Career Relevance – $\alpha = .82$

I would like a job that involved using science.
[biology/earth science/chemistry/physics]

*I need to do well in science to get the job I want.
[biology/earth science/chemistry/physics]

*Items not included in the grade four version of the Student Background Questionnaire.

APPENDIX C

Item Content Categories and Type by Book and Population

Population 1 Mathematics								
TOPIC	BOOK 3		BOOK 5		BOOK 6		BOOK 8	
	MC	OE	MC	OE	MC	OE	MC	OE
Whole Numbers	19 %	5 %	23 %	6 %	8 %	0 %	11 %	2 %
Fractions & Decimals	10 %	2 %	2 %	0 %	6 %	0 %	33 %	8 %
Integers, Real Numbers, & Number Concepts	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Estimation & Number Sense	5 %	2 %	6 %	2 %	18 %	3 %	2 %	0 %
Measurement	8 %	0 %	10 %	0 %	9 %	8 %	3 %	2 %
Geometry	21 %	5 %	6 %	0 %	9 %	0 %	11 %	0 %
Ratios & Proportions	6 %	0 %	16 %	6 %	3 %	0 %	5 %	2 %
Functions, Relations, & Patterns	6 %	0 %	0 %	0 %	18 %	3 %	5 %	0 %
Data Representation, Probability, & Statistics	6 %	6 %	18 %	5 %	12 %	2 %	16 %	0 %
TYPE TOTALS	81 %	19 %	81 %	19 %	85 %	15 %	87 %	13 %
BOOK TOTALS	100 %		100 %		100 %		100 %	

Population 2 Mathematics								
TOPIC	BOOK 3		BOOK 5		BOOK 6		BOOK 8	
	MC	OE	MC	OE	MC	OE	MC	OE
Whole Numbers	2 %	0 %	1 %	0 %	1 %	0 %	2 %	0 %
Fractions & Decimals	19 %	6 %	14 %	0 %	15 %	5 %	21 %	5 %
Integers, Real Numbers, & Number Concepts	2 %	0 %	1 %	1 %	0 %	0 %	2 %	0 %
Estimation & Number Sense	3 %	5 %	18 %	3 %	3 %	0 %	3 %	0 %
Measurement	6 %	0 %	5 %	0 %	3 %	0 %	16 %	8 %
Geometry	21 %	3 %	20 %	4 %	11 %	1 %	6 %	0 %
Ratios & Proportions	0 %	0 %	0 %	0 %	19 %	4 %	2 %	0 %
Functions, Relations, & Patterns	13 %	3 %	8 %	1 %	27 %	1 %	17 %	6 %
Data Representation, Probability, & Statistics	11 %	6 %	20 %	3 %	8 %	1 %	11 %	2 %
TYPE TOTALS	76 %	24 %	88 %	12 %	86 %	14 %	79 %	21 %
BOOK TOTALS	100 %		100 %		100 %		100 %	

Population 3 Mathematics						
	BOOK 1		BOOK 2		BOOK 3	
	MC	OE	MC	OE	MC	OE
Whole Numbers	0 %	4 %	0 %	2 %	0 %	0 %
Fractions & Decimals	12 %	2 %	10 %	2 %	14 %	0 %
Integers, Real Numbers, & Number Concepts	2 %	0 %	0 %	0 %	0 %	0 %
Estimation & Number Sense	2 %	6 %	8 %	0 %	8 %	2 %
Measurement	10 %	6 %	15 %	2 %	12 %	4 %
Geometry	0 %	4 %	0 %	2 %	0 %	0 %
Ratios & Proportions	12 %	2 %	4 %	2 %	6 %	2 %
Functions, Relations, & Patterns	8 %	2 %	6 %	2 %	2 %	4 %
Data Representation, Probability, & Statistics	4 %	2 %	6 %	4 %	0 %	6 %
TYPE TOTALS	37 %	18 %	38 %	13 %	37 %	20 %
BOOK TOTALS	55 %		50 %		57 %	

Population 3 Science						
	BOOK 1		BOOK 2		BOOK 3	
	MC	OE	MC	OE	MC	OE
Earth Sciences	0 %	2 %	4 %	4 %	2 %	4 %
Life Sciences	6 %	6 %	4 %	8 %	10 %	8 %
Chemistry	4 %	2 %	2 %	0 %	2 %	4 %
Physics	12 %	4 %	6 %	10 %	4 %	4 %
Environment, Technology, & Science	6 %	4 %	10 %	13 %	4 %	0 %
TYPE TOTALS	27 %	24 %	25 %	27 %	22 %	22 %
BOOK TOTALS	51 %		51 %		51 %	

Population 2 Science								
TOPIC	BOOK 1		BOOK 2		BOOK 4		BOOK 7	
	MC	OE	MC	OE	MC	OE	MC	OE
Earth Sciences	0 %	0 %	23 %	6 %	14 %	4 %	16 %	4 %
Life Sciences	31 %	13 %	21 %	4 %	25 %	7 %	13 %	2 %
Physical Sciences	33 %	12 %	29 %	15 %	38 %	9 %	34 %	13 %
Environment, Technology, & Science	10 %	2 %	0 %	2 %	0 %	4 %	14 %	5 %
TYPE TOTALS	73 %	27 %	73 %	27 %	77 %	23 %	77 %	23 %
BOOK TOTALS	100 %		100 %		100 %		100 %	

Population 1 Science								
TOPIC	BOOK 1		BOOK 2		BOOK 4		BOOK 7	
	MC	OE	MC	OE	MC	OE	MC	OE
Earth Sciences	0 %	0 %	14 %	14 %	21 %	3 %	21 %	7 %
Life Sciences	48 %	16 %	23 %	7 %	33 %	7 %	21 %	2 %
Physical Sciences	16 %	13 %	25 %	7 %	16 %	9 %	21 %	7 %
Environment, Technology, & Science	5 %	2 %	7 %	2 %	7 %	5 %	7 %	13 %
TYPE TOTALS	70 %	30 %	70 %	30 %	76 %	24 %	71 %	29 %
BOOK TOTALS	100 %		100 %		100 %		100 %	

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