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MOTIVATION AND ABILITY AS FACTORS IN MATHEMATICS EXPERIENCE AND ACHIEVEMENT

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This study examined relationships among interest, achievement motivation, mathematical ability, the quality of experience when doing mathematics, and mathematics achievement. One hundred eight freshmen and sophomores (41 males, 67 females) completed interest ratings, an achievement motivation questionnaire, and the Preliminary Scholastic Aptitude Test. These assessments were followed by 1 week of experience sampling. Mathematics grades were available from the year before the study started, from the same year, and from the following 3 years. In addition, a measure of the students' course level in mathematics was included. The results showed that quality of experience when doing mathematics was mainly related to interest. Grades and course level were most strongly predicted by level of ability. Interest was found to contribute significantly to the prediction of grades for the second year and to the prediction of course level. Quality of experience was significantly correlated with grades but not course level.

In light of the prominent role of mathematics among subject matters in school (e.g., Jones, 1988), it is not surprising that much educational and psychological research has been devoted to the identification of factors that enhance the learning and teaching of mathematics (e.g., Grouws, 1992). Extensive research (see reviews by Reynolds & Walberg, 1991; Steinkamp & Maehr, 1983) has led to the identification of three major groups of factors influencing achievement in mathematics, as well as in other subjects: student characteristics (e.g., use of learning strategies), home environment (e.g., occupation of parents), and school context (e.g., quality of instruction). The majority of studies confirm that cognitive student characteristics explain a large part of the observed variance in achievement. Motivational and emotional factors, such as attitude, anxiety, interest, or task motivation (McLeod, 1990), were often found to be less important (Aiken, 1970, 1976; Schneider & Bös, 1985; Steinkamp & Maehr, 1983; Willson, 1983).

Although the modest impact of motivation and emotion on mathematics achievement seems well supported, it would not be justifiable to neglect affective variables (McLeod, 1990; McLeod & Adams, 1989). There are several reasons for giving these variables a crucial role in explaining differences in mathematics achievement. The first reason has to do with the magnitude of explained variance. Although cognitive predictors were usually found to explain large amounts of

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variance (up to 50%) in achievement, detailed analyses showed that the variance explained by cognitive factors is reduced to 25% when motivational variables are held constant by statistical means (Schneider & Bös, 1985). Second, the impact of affective variables is often underestimated because they tend to have indirect rather than direct effects on achievement (Meece, Wigfield, & Eccles, 1990; Reynolds & Walberg, 1991; Schneider & Bös, 1985). For example, Reynolds and Walberg (1991) found that motivation influenced science achievement only indirectly through amount of out-of-school reading and engagement in schoolwork. Third, a number of findings suggest that problem solving, creativity, and deep comprehension of learning material require high levels of positive emotions and intrinsic motivation (Csikszentmihalyi, 1988b; McLeod, 1990; McLeod & Adams, 1989; Schiefele, 1992). Fourth, there is evidence for a decreasing trend in average mathematics performance (especially on tasks that require a deep understanding of mathematics), accompanied by a significant decline of students' interest in mathematics during the course of high school (e.g., Jones, 1988; Reynolds & Walberg, 1992). Many recommendations to overcome the deficit in mathematics achievement stress the importance of instituting changes to facilitate students' interest (see Jones, 1988, p. 329). This implies a need for investigating more intensively the emotional and motivational dynamics of achievement-related processes.

These considerations have important implications for research. First, cognitive predictors, such as mathematical ability, should be complemented by motivational predictors in order to reach a more complete understanding of mathematics achievement. In doing so, different motivational concepts should be compared to identify those most conducive to the learning of mathematics. Second, the quality of affective experience while being engaged in learning mathematics should be investigated as an outcome measure in its own right. As mentioned above, positive feelings contribute to students' creativity, problem-solving capacity, and deep comprehension. Furthermore, the quality of experience during learning is a crucial factor for future motivation to learn (Csikszentmihalyi & Nakamura, 1989; Csikszentmihalyi, Rathunde, & Whalen, 1993; Matsumoto & Sanders, 1988).

The present study was concerned with both the issues outlined above. In addition to mathematical ability, two different motivational variables were included as predictors in the present study: interest in mathematics and achievement motivation. Both variables are considered important factors in explaining differences in school achievement (e.g., Aiken, 1970, 1976; Eccles, 1983; Schiefele, Krapp, & Winteler, 1992). Interest represents a subject-matter-specific motivational factor, whereas achievement motivation can be regarded as a more general motivational orientation that captures a student's motivation to perform well without specifying a particular subject area (e.g., Brophy, 1983). We speak of interest when a student attributes high value to a particular subject area (Schiefele, 1991).

Although prior studies have investigated relations between cognitive and motivational predictors and affective outcome measures, such as self-esteem, satisfaction, attitude, anxiety, and other specific emotions (e.g., Matsumoto & Sanders, 1988; Meece et al., 1990; Reynolds & Walberg, 1992; Ryan, Connell, & Deci, 1985), there is a neglect of indicators that measure subjective experiences of students being engaged in mathematics in natural settings. In the present study, the quality of experience in mathematics classes was assessed during 1 week by means of the Experience Sampling Method (described later).

Quality of experience is a multidimensional construct that consists of emotional, motivational, and cognitive aspects of experience (Csikszentmihalyi, 1988a). The core dimensions of this construct include affect (happy, cheerful, etc.), potency (alert, active, etc.), cognitive efficiency (concentration, self-consciousness, etc.), and intrinsic motivation (wish to do the activity, involvement, etc.) (Csikszentmihalyi & Larson, 1987). Depending on the domain under study (e.g., sports, leisure, or school), additional dimensions addressing unique aspects of experience not shared by other domains may be assessed (e.g., the experience of risk when climbing a mountain). Because quality of experience is regarded here as an outcome measure in its own right, we examined whether quality of experience in mathematics class is related to interest, achievement motivation, and mathematical ability. In addition, the relation between quality of experience and achievement was explored.

The empirical evidence came from a large-scale longitudinal study conducted at the University of Chicago (Csikszentmihalyi et al., 1993). The study was begun in 1985 and was designed to trace the development of talented students over a period of 4 years. A wide array of measuring instruments, including personality tests, questionnaires, interviews, and experience sampling, were applied. For purposes of the present study only a part of the original measures was analyzed.

The issues we have discussed so far lead to the following research questions that are addressed in this article: (a) Is quality of experience when doing mathematics more dependent on ability or motivational characteristics? (b) Are subject-matter-specific measures of motivation more predictive of experience and achievement than general measures of motivation? (c) Do motivational characteristics and quality of experience when doing mathematics predict achievement in mathematics independently of ability?

On the basis of theoretical considerations and empirical evidence, the following hypotheses were derived: (a) Ability is a better predictor of the quality of experience in mathematics class and achievement than either interest or achievement motivation. In accordance with prior research (e.g., Meece et al., 1990; Reynolds & Walberg, 1992), we assumed that ability factors are the most powerful predictors of affective experience and cognitive performance in achievement settings. (b) Interest is a better predictor of quality of experience and achievement than achievement motivation. This hypothesis is based on the assumption that subject-matter-specific variables are more predictive of affective and cognitive outcomes than more global variables (e.g., Gottfried, 1985). (c) Both interest and achievement motivation predict quality of experience and achievement independently of ability. Prior research has shown that motivational variables can predict emotional and achievement outcomes independently of ability factors (e.g., Meece et al., 1990; Schneider & Bös, 1985).

The present study was not designed explicitly to investigate gender differences. However, because prior research (e.g., Hyde, Fennema, & Lamon, 1990; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; Jones, 1988) has repeatedly found significant differences between boys and girls with respect to mathematical ability, achievement, and motivation, analyses of gender differences were included.

METHOD

Overview

The following section provides information on the present sample, independent and dependent measures, the procedure, and specific features of the data analyses. Independent variables were interest in mathematics, achievement motivation, and mathematical ability. Dependent variables were quality of experience in mathematics class (components: potency, affect, concentration, intrinsic motivation, self-esteem, importance, perceived skill) and mathematics achievement (grades, course level).

Sample

The sample consisted of 108 freshmen and sophomores from two Chicago suburban high schools. The majority of participants came from white middle-class families. About 38% of the sample was male ($n = 41$; 17 freshmen, 24 sophomores) and 62% was female ($n = 67$; 24 freshmen, 43 sophomores). All students were nominated by teachers as being talented in one or more of five subject matters: mathematics, science, music, art, and athletics. Seventy-one percent of the sample was selected as talented in one area only, whereas 29% had multiple talents. Altogether, 37 students (34%) were nominated in mathematics, 30 (28%) in science, 43 (40%) in music, 14 (13%) in art, and 31 (29%) in athletics. In mathematics, 12 boys and 25 girls were nominated.

The sample of the present study is a subgroup of a larger number of students ($n = 228$) who completed the experience sampling procedure in different classrooms. The present sample is made up only of those students who provided measures for all of the following variables: experience in mathematics class, interest in mathematics, achievement motivation, mathematical ability, and mathematics grades (at least for one of the included five school years).

Independent Measures

Interest in Mathematics

As part of a larger questionnaire on background variables (e.g., life-events), the students were asked to indicate, using five-point rating scales, the extent to which mathematics is their favorite subject area ("Mathematics is my favorite subject: not at all, a little, somewhat, very, extremely"). These ratings were used as indicators of interest in mathematics. In a prior study (Schiefele & Csikszentmihalyi, 1994) it was shown that this measure of interest correlates positively with intrinsic learning goals and negatively with extrinsic learning goals, suggesting that this single-item measure of interest is valid. In addition, interest was found to be uncorrelated with grade point average (GPA), achievement motivation, and scholastic aptitude (PSAT).

Achievement Motivation

Different definitions of achievement motivation as an individual difference variable have been put forward in the past (cf. Heckhausen, 1991; McClelland, 1987). Most of these definitions define achievement motivation as a preference for high standards of performance or as the willingness to work hard and persistently to reach these standards. Two subscales from the Personality Research Form (PRF, Jackson, 1984), namely "Achievement" and "Endurance," were used to generate a measure of achievement motivation because they capture very well the meaning of prior definitions. The Achievement subscale measures the preference for high standards of performance and the willingness to invest intensive effort in one's work. The Endurance subscale taps the level of persistence a person shows when working on a task. Both scales have proved to be reliable and valid predictors of academic success (e.g., Clarke, 1973; Harper, 1975; Jackson, 1984).

Individual values of achievement motivation were computed by averaging the Achievement and Endurance subscales (each contains 16 items). The decision to combine the subscales into a single indicator of achievement motivation was based on their high intercorrelation ($r = .74$, $p < .01$; see also Jackson, 1984) and the fact that prior factor analyses have shown that they have high loadings on the same factor (Jackson, 1984). For the combined achievement motivation scale a coefficient alpha of .84 was obtained.

Mathematical Ability

Mathematical ability was measured by means of the mathematics subtest of the Preliminary Scholastic Aptitude Test (PSAT). The PSAT is a widely applied test of scholastic aptitude especially designed for high school sophomores and juniors. It is composed of two parts: mathematics (PSAT-M) and verbal (PSAT-V). The PSAT-M requires examinees to apply basic mathematical reasoning skills. Specific knowledge of mathematical subject matter past elementary algebra and geometry is not necessary (Becker, 1990). The PSAT is a reliable predictor of academic achievement. In the present study a correlation of .53 ($p < .01$) between PSAT and GPA was obtained. Most of the students took the PSAT during their sophomore year.

Although it seems legitimate to use PSAT-M scores as indicators of ability, a certain extent of overlap (that cannot be attributed to ability factors) between PSAT-M and measures of achievement is to be expected. Separating ability and achievement is difficult in a domain where people have received formal training (Carroll & Horn, 1981).

Dependent Measures

Quality of Experience

This section is divided into three parts: (a) description of the Experience

Sampling Method as used in the present study, (b) selection of relevant dimensions of the quality of experience, and (c) information on the reliability of the experience sampling measures.

Experience Sampling Method. Quality of experience was assessed with the Experience Sampling Method (ESM) (Csikszentmihalyi & Larson, 1987). The ESM allows the repeated measurement of everyday activities, thoughts, and experience in the natural environment. It consists of providing respondents with an electronic pager and a block of self-report forms with open-ended and scaled items. Usually, respondents wear the pager for a week and are paged about 55 times at random intervals from 7 a.m. until 10 p.m. Whenever the respondent is signaled, he or she fills out a page of the booklet, indicating activity, location, and companionship, as well as describing the quality of the experience at the time on a variety of dimensions. Detailed information on the validity of the ESM is summarized by Csikszentmihalyi and Larson (1987). For example, prior studies have shown that ESM reports of psychological states covary in expected ways with physiological measures and that the ESM differentiates between groups expected to be different (e.g., patient or non-patient groups).

In the present study, students carried electronic pagers for 1 week (7 days) and answered questions on the Experience Sampling Form (ESF) whenever they were signaled. Seven to nine signals per day were received by every student. The ESF in the present version consists of seven open-ended questions and 29 items (a copy of the ESF used here can be found in Csikszentmihalyi & Larson, 1987). Open-ended questions (e.g., "What were you thinking about?") were not analyzed in the present study. The items were either written in a seven-point semantic differential format (13 items) or in a ten-point unipolar format (16 items). They measure a few basic dimensions of experience as well as a number of single aspects of experience.

Students whose protocols contained fewer than 15 ESFs for the whole week were not included. This was true for 20 out of 228 students. Only those forms completed within 30 minutes after the signal were accepted. Generally, 70% of the ESFs were filled out immediately after the signal and 88% were completed within 5 minutes of the signal. Less than 1% of all ESFs had to be discarded. The average reported latency between receiving the beeper signal and beginning to fill out the ESF was 2.5 minutes.

For the whole week during which the ESM was conducted, the average number of completed ESFs per student was 35.64 (SD = 10.06, range: 15–63).[1] *During regular class time* (including mathematics), an average of 11.26 (SD = 4.79, range: 3–29) completed ESFs was obtained. *In mathematics class*, a total of 231 signals were available, with an average of 2.14 signals per student (SD = 1.14, range: 1–5). The signals obtained in mathematics class form the data basis of the present study.

[1]This value is considerably lower than the number of signals received by each student (about 55). This is due to the fact that there are many situations in which filling out an ESF is very hard for objective or subjective reasons. These situations include, for example, driving a car, writing an exam, or being involved in an interesting discussion with a close friend.

Dimensions of experience. For purposes of the present study, we analyzed only those items or dimensions that captured relevant aspects of the quality of experience in learning situations. As a consequence, we decided not to consider items measuring, for example, social aspects of experience (e.g., lonely-sociable, cooperative-competitive) or physical aspects (e.g., feelings of pain or discomfort). In accordance with prior studies (see Csikszentmihaly & Larson, 1987; Csikszentmihaly & LeFevre, 1989; Csikszentmihaly et al., 1993), the following dimensions were included: potency, affect, concentration, intrinsic motivation, self-esteem, importance, and perceived skill. The correspondence between these dimensions and individual items is based on prior studies that used factor analyses to classify the various ESF rating scales (see Csikszentmihaly & Larson, 1987). As can be seen in Table 1, some dimensions are measured by single items, others by two or more items. Zero-order correlations revealed that items were highly correlated *within* dimensions (with *r*s ranging from .50 to .83, median correlation = .62). Relations *between* dimensions proved to be less strong (with *r*s ranging from .06 to .55, median correlation = .28). For those dimensions measured by two or more items, mean values were computed for each student.

In contrast to prior analyses, no scale for "cognitive efficiency" was included because the corresponding items ("How well were you concentrating?" "Was it hard to concentrate?" clear-confused) were not significantly correlated. Instead, we decided to include only the item asking for amount of concentration. This item seemed to be most appropriate to capture the meaning of cognitive efficiency.

Table 1
Classification of Experience Sampling Variables

Dimensions of Experience	Items
Potency	Describe your mood as you were beeped: active-passive, strong-weak, alert-drowsy, excited-bored
Affect	Describe your mood as you were beeped: happy-sad, cheerful-irritable
Concentration	How well were you concentrating?
Intrinsic Motivation	Do you wish you had been doing something else?
Self-Esteem	Were you living up to your own expectations? Were you satisfied with how you were doing? Were you succeeding at what you were doing?
Importance	How important was this activity in relation to your overall goals? Was this activity important to you?
Skill	How were your skills in the activity?

Note. Bipolar items were rated on 7-point semantic differential scales. Unipolar items were rated on 10-point scales.

Reliability of experience sampling measures. To estimate the reliability of the ESM, Csikszentmihalyi and Larson (1987) compared the means of various dimensions of experience obtained in the first half of the week with those obtained in the second half. They found only small and nonsignificant differences between mean values. Furthermore, correlations between means in the first and the second half of the week were all significant. The median correlation coefficient ranged from .60 for adolescents to .74 for adults. Even over a 2-year period the stability of responses ranged from $r = .45$ to $r = .75$.

Because of the relatively small number of "beeps" on which individual scores of subjective experience were based in the present study, it seemed necessary to provide evidence for the reliability of these scores. Since the majority of subjects (n = 71) provided two or more ESFs, it was possible to compare values taken at different times of the week. For those students who filled out exactly two ESFs, the values obtained at Time 1 were compared with those obtained at Time 2. For those students who had available three or more ESFs, composite scores were calculated to arrive at two different measures for each dimension of experience. For example, in the case of students with five ESFs, the values of the first and second ESF and the values of the third, fourth, and fifth ESF were aggregated. The resulting means were compared to one another.

First of all, the reliability analysis revealed no significant ($p < .10$) differences between means at Time 1 and Time 2 for any ESM variables. Second, correlations between ratings at Time 1 and Time 2 were all significant and ranged from .44 to .64, with a mean correlation of .52. The size of the mean correlation is almost as high as that reported by Csikszentmihalyi and Larson (1987) for adolescents (.60).

Mathematics Achievement

Semester grades were used as an indicator of mathematics achievement. Grades were available for the school years 1984/85, 1985/86, 1986/87, 1987/88, and 1988/89. However, not all students provided grades for all 5 years. This is partly due to the fact that the sample consisted of students from two different grade levels and that mathematics courses in higher grades are not compulsory. The sample sizes were: 1984/85: $n = 67$; 1985/86: $n = 108$; 1986/87: $n = 106$; 1987/88: $n = 90$; and 1988/89: $n = 35$.

It is important to note that for 1985/86 we included only grades from the second semester. Because interest ratings took place during the first and second semester of the academic year 1985/86, it is only for grades from the second semester that we are able to claim a predictive relation between interest and achievement. For about half of the subjects ($n = 50$) interest was measured during the first semester and for the remaining subjects ($n = 58$) during the second semester.

An important feature of the present study is its use of course level as a measure of performance (cf. Eccles, 1983; Maple & Stage, 1991; Meece et al., 1990). To determine individual course levels, the highest level of courses taken by the end of high school was assessed for each student. There was a wide array of different course levels. In 1987/88, for example, students took courses that ranged from plane geometry to Advanced Placement calculus. On the basis of careful content analyses of the schools' mathematics curricula a rank order of the final mathematics courses taken by the students was derived. Rank values ranged from 1 to 17 (see Appendix).

Procedure

Each student was scheduled to meet with a member of the research staff three to four times in an office at the school. During the first meeting, the use of the pager and items in the ESF were explained. In addition, the achievement motivation test was administered along with a questionnaire including the interest rating described above.

The ESFs were bound in small pads (5.5 in. × 8.5 in.), each consisting of 15 forms. One week after the first meeting, the paging procedure started. The first day of paging was always a weekday. There were seven to nine random signals per day, between 7 a.m. and 10 p.m. on Sunday through Thursday, 9 a.m. and 12 p.m. on Friday and Saturday. On weekdays twice as many signals were sent before 3 p.m., in order to get a more representative sample of the classes the students took. Immediately after every signal the students had to fill out one ESF.

After completing the ESFs for 1 week, the students returned for a second meeting. During this meeting they were debriefed and asked to describe their experience during the week and the problems they had with the pager. The ESM data were collected over a nine-month period (October, 1985 to June, 1986).

Data Analysis

All analyses were carried out at the subject level (i.e., using the individual student as the unit of analysis). Therefore, aggregated scores for all ESF variables were computed for each student. As a consequence, it seemed unnecessary to use *z*-scores as is usually recommended for beep-level analyses (Larson & Delespaul, 1990). Data were analyzed mainly by means of Pearson product-moment correlation coefficients and multiple regression analyses. Pearson product-moment correlations were used to demonstrate the strength of the association between predictors and criteria. Multiple regression analyses served to assess the unique contribution of each predictor to the prediction of dependent variables.

Because of the large number of significance tests conducted, a procedure developed by Holm (1979) was applied to control for Type I error rate. According to Holm, in order to generate adjusted levels of alpha, p values should be ranked according to their size. Then the smallest p is tested against alphas of $.05/k$ or $.01/k$ (k being the total number of tests of significance), the second smallest p is compared to alphas of $.05/(k\text{-}1)$ or $.01/(k\text{-}1)$, and so on. As soon as a particular p value does not reach the adjusted level of significance, the procedure is aborted. Holm's method is less conservative than the sometimes applied Bonferroni inequality (Klauer, 1990).

In the present study, a total of 13 multiple regression analyses were conducted. From these 13 analyses, we obtained 11 significant multiple correlation coefficients (after applying Holm's procedure to adjust alpha). In these cases, significance tests of individual predictors were performed. These resulted in a total of 38 individual tests of zero-order correlations and corresponding partial regression coefficients. Therefore, in applying Holm's procedure, the smallest p value was tested against alphas of .05/38 and .01/38, the second smallest p value against alphas of .05/37 and .01/37, and so on. It should be noted that the total number of individual tests does not include analyses that were performed only for descriptive or exploratory reasons (e.g., intercorrelations among predictor variables). However, the adjusted levels of significance resulting from Holm's procedure were applied to these analyses as well.

RESULTS

In this section, we first report descriptive statistics for the key variables of the study. Next, the power of interest, achievement motivation, ability, and gender to predict quality of experience is analyzed. Finally, the same predictors, as well as quality of experience, are then tested for their contributions to predict grade points and course level.

Descriptive Statistics

Table 2 reports descriptive statistics for all variables involved in the present study. The average PSAT-V and PSAT-M scores of the present sample were well above the 70th percentile for college-bound juniors. In accordance with this result, relatively high mean values for GPA and mathematics grades were obtained. The mean score for achievement motivation is almost exactly equivalent with a standardized score of 50, indicating that the present sample was not different from the underlying population. No significant differences between females and males were found.

Table 2
Descriptive Statistics for all Variables

Variable	Range	*M*	*SD*
PSAT-Verbal	20–80	48.21	9.99
PSAT-Math	20–80	53.53	11.46
GPA[a]	0–4	3.15	.69
Achievement Motivation	0–16	10.13	3.16
Interest in Mathematics	1–5	2.57	1.36
Quality of Experience			
Potency	1–7	4.29	.97
Affect	1–7	4.46	1.10
Concentration	1–10	6.19	2.03
Motivation	1–10	3.41	2.46
Self-Esteem	1–10	6.50	1.87
Importance	1–10	6.34	2.20
Skill	1–10	6.68	2.06
Mathematics Grades[a]			
1984/85	0–4	2.99	.89
1985/86	0–4	2.94	.83
1986/87	0–4	2.95	.94
1987/88	0–4	2.82	.95
1988/89	0–4	2.96	.77
Course Level	1–17	10.70	3.73

Note. $n = 108$.
[a]0 = failure, 4 = grade A.

Students talented in mathematics had significantly higher values for mathematics ability, better grades for the first 4 years, and a higher course level than those talented in other areas (see Table 3). The two groups were not different with respect to interest, achievement motivation, verbal ability, and quality of experience.

Table 3
Significant Differences between Students Talented in Mathematics and Students Talented in Other Areas[a]

Variable	Talent Area					
	Mathematics			Other		
	n	*M*	*SD*	*n*	*M*	*SD*
PSAT-Math	37	59.89	8.16	71	50.21	11.58
Math Grades						
1984/85	21	3.74	.38	46	2.65	.85
1985/86	37	3.42	.60	71	2.85	.87
1986/87	37	3.43	.71	71	2.70	.95
1987/88	35	3.26	.71	55	2.55	.98
Course Level	37	13.41	2.39	71	9.30	3.53

[a]Differences between means were significant at $p < .001$ (t-test, two-tailed).

Positive but nonsignificant intercorrelations among interest, achievement motivation, and mathematical ability were obtained. Specifically, the correlation between ability and interest was .19, between ability and achievement motivation .25, and between interest and achievement motivation .07. From the size of the obtained correlations one can conclude that the various predictors actually tap different underlying factors. The low correlations obtained between indicators of motivation and ability are in line with prior research findings (Steinkamp & Maehr, 1983).

Predicting the Quality of Experience

In order to evaluate the relationships between interest, achievement motivation, ability, gender, and the quality of experience in class, we performed multiple regression analyses (see Table 4). Predictors were entered simultaneously into the regression equation. Interactional terms were not included.[2]

The results clearly indicate that interest was the strongest predictor of quality of experience in mathematics class. Specifically, interest showed significant relations to potency, intrinsic motivation, self-esteem, importance, and the perception of skill. Surprisingly, level of mathematical ability was not related to experience at all, not even to the perception of skill. Although achievement motivation exhibited positive relations to all dimensions of experience, none became significant.[3]

[2]Exploratory analyses did not reveal significant two-way interaction effects.

[3]Further analyses showed that the strength of relations between the predictors and quality of experience were nearly the same for those students who had just one beep and those who had two and more beeps.

Additional regression analyses revealed that replacing PSAT-M scores by grades for 1985/86 (both semesters) did not affect the relations between interest and quality of experience.[4] Thus, it can be concluded that the interest-experience relation was independent of the students' levels of ability and achievement.

Table 4
Regression of Experience on Interest, Achievement Motivation, Ability, and Gender

Experience in Class	Weights[a]	Interest	AchMot	Ability	Gender[b]	*R*
Potency	*r*	.33***	.18	-.07	-.03	.42***
	ß	.37***	.22	-.19	.07	
Affect	*r*	.21	.19	-.02	-.01	.30
	ß	.23	.21	-.11	.07	
Concentration	*r*	.06	.18	-.08	.11	.28
	ß	.11	.23	-.14	.15	
Motivation	*r*	.39***	.26*	.24	-.33***	.51***
	ß	.31**	.18	.10	-.21	
Self-Esteem	*r*	.37***	.12	.04	-.11	.38**
	ß	.37***	.10	-.06	-.02	
Importance	*r*	.25	.21	.06	.11	.38**
	ß	.29*	.23	-.02	.21	
Skill	*r*	.32***	.15	.16	-.14	.35**
	ß	.29*	.10	.07	-.04	

Note. $n = 108$.
*$p < .10$, **$p < .05$, ***$p < .01$ (adjusted significance levels).
[a]r = zero-order correlation, ß = standardized regression coefficient.
[b]Male was coded as 1 and female as 2.

Predicting Grades

In the first part of the following section, we consider interest, achievement motivation, ability, and gender as predictors of grade points in mathematics. Second, we analyze the relation between quality of experience and achievement.

Interest, Achievement Motivation, Ability, and Gender as Predictors of Grades

The strength of relations between the predictors and grades from three successive school years (1985/86, 1986/87, 1987/88) were tested by means of multiple regression analyses (see Table 5). As mentioned, 1985/86 grades included only grades from the second semester in order to reduce the probability of achievement effects on interest. 1988/89 grades were not included because only 48 students provided grades for that school year.

In accordance with expectations, ability was the best predictor of grades. Interest proved to be a moderate and significant predictor of 1985/86 grades.

[4]1985/86 grades were not significantly correlated with any dimension of experience.

The causal relationship between interest and achievement cannot be determined with the present data. However, the available evidence suggests that interest is not simply an outcome of successful performance. The correlation between 1984/85 grades and interest measured during the first semester of the year 1985/86 was positive but not significant ($r = .24$, $n = 45$)[5]. This result suggests that past achievement is not a strong predictor of subsequent interest.

Table 5
Regression of Achievement and Course Level on Interest, Achievement Motivation, Ability, and Gender

	Weights[a]	Interest	AchMot	Ability	Gender[b]	*R*
Grades						
1985/86	*r*	.32**	.23	.56**	.04	.64**
($n = 108$)	ß	.27**	.16	.48**	.21	
1986/87	*r*	.23	.15	.63**	-.15	.64**
($n = 106$)	ß	.10	.01	.58**	-.03	
1987/88	*r*	.16	.09	.44**	.08	.50**
($n = 90$)	ß	.15	-.02	.49**	.18	
Course level	*r*	.34**	.28*	.72**	-.08	.76**
($n = 108$)	ß	.23*	.11	.66**	.11	

Note. $*p < .05$, $**p < .01$ (adjusted significance levels).
[a]r = zero-order correlation, ß = standardized regression coefficient.
[b]Male was coded as 1 and female as 2.

Quality of Experience as a Predictor of Grades

For purposes of the present analysis all dimensions of experience were combined into a single composite score. A composite score was used here in order to reduce the overall number of statistical tests. This score was computed in two steps: (a) Individual values for all dimensions of experience (potency, affect, etc.) were z-standardized; (b) z-standardized values were then summed for every student. The resulting composite value indicates the overall quality of experience in mathematics class. Because we used individual dimensions of experience as "items" of a more general scale, it seemed appropriate to determine the reliability of this general scale. A reliability coefficient (alpha) of .72 was obtained.

A correlational analysis revealed a positive and significant relation between quality of experience (composite score) and 1985/86 grades ($r = .29$, $p < .05$). When each dimension of experience was looked at individually, correlations ranging from .02 (concentration) to .26 (perceived skill) were found (all nonsignificant).

In order to examine whether the correlation between quality of experience and grades was independent from other predictors, a regression model was tested that

[5]As was noted before, grades from the school year 1984/85 were available only from those students ($n = 67$) who were in 10th grade when the study started. Out of this group, 45 students completed interest ratings during the first semester of the subsequent year.

included quality of experience, ability, achievement motivation, and gender as predictors. Interest was not included in the regression equation to avoid multicollinearity (interest and quality of experience were substantially correlated, $r = .45$, $p < .01$). The results of the regression analysis showed that quality of experience failed to contribute significantly and independently of other predictors to the prediction of achievement ($\beta = .24$, *ns*).

Predicting Course Level

Interest, Achievement Motivation, Ability, and Gender as Predictors of Course Level

A regression analysis including interest, achievement motivation, ability, and gender as predictors was performed. In accordance with expectations, the results (see Table 5) confirmed that ability was the strongest predictor of course level. In addition, interest, but not achievement motivation, contributed significantly and independently of ability to the prediction of course level.

Quality of Experience as a Predictor of Course Level

A correlational analysis revealed that quality of experience was not significantly related to course level. The correlation between the composite measure of experience and the level of courses amounted to .17 (*ns*). Also, no significant correlations between individual dimensions of experience and course level were obtained.

DISCUSSION

The results of the present study suggest that quality of experience and achievement in mathematics depend on different factors. Quality of experience in mathematics class was mainly related to interest in mathematics and, to a lesser extent, to achievement motivation. Inconsistent with our hypothesis, ability was not at all correlated with experience. Even feelings of self-esteem, concentration, or skill seemed to be unaffected by ability.

Achievement, however, was most strongly related to level of mathematical ability. Interest could also account for a significant, though small, portion of achievement variance. This was, however, only true for grades from the second semester of 1985/86. The size of the correlation obtained between interest and grades (.32) is in accordance with results of a recently conducted meta-analysis on the relation between measures of subject matter interest and achievement (Schiefele et al., 1992), where an average correlation coefficient of .31 was found.

In our view, quality of experience in class is an outcome variable in its own right. Even if research does not reveal significant relations between quality of experience and academic performance, positive affect should be among those criteria used for evaluating instructional techniques and variables of the school environment.

However, given the empirically confirmed impact of intrinsic motivation on meaningful or conceptual learning (e.g., Ryan et al., 1985), it is likely that affective states are crucial for achieving success in school. By definition, intrinsic motivation is a form of motivation that is directed at activities that are inherently enjoyable, interesting, or challenging (Csikszentmihalyi & Nakamura, 1989; Deci & Ryan, 1985). Therefore, it seems reasonable to assume that intrinsic motivation can only be maintained as long as learning activities lead to a certain level of positive emotional experience. Indeed, the present results show that interest (which can be regarded as a proximal antecedent of intrinsic motivation; see Schiefele, 1991) and experience are significantly related. In contrast, ability was not at all predictive of experience. This is an important finding because it underlines the independent and significant role affective variables possibly play for learning mathematics in school.

The positive relation between interest and achievement is corroborated by the analysis of course level. Our results suggest that interest in mathematics, measured at the beginning of high school, is a significant and independent predictor of how far a student has progressed by the end of school. Although interest was not able to predict grades (which may be seen as *quantitative* indicators of mathematical knowledge or skills) acquired in a particular course in subsequent years (1986/87, 1987/88; see Table 5), it contributed significantly and independently of mathematical ability to the prediction of the *qualitative* level of mathematical proficiency students attempted to master. Similar results were reported by Maple and Stage (1991) and Meece and her colleagues (1990), who used causal modeling techniques. Maple and Stage found that attitude toward mathematics significantly influenced choice of mathematics major but not grades. Meece and her colleagues obtained for task value (a measure similar to interest) a stronger effect on course enrollment intentions than grades.

In addition, the results of our study support the hypothesis that subject-matter-specific motivational measures are more predictive of experience- and achievement-related variables pertaining to a particular subject area than general motivational orientations. Specifically, interest in mathematics, but not achievement motivation, proved to be a significant predictor of experience in class, grades, and course level. These results point to the need to investigate more thoroughly the content-specificity of motivational characteristics (e.g., Gottfried, 1985) and their relation to general motives of behavior.

Our findings are in line with the assertion that interest and achievement mutually influence one another. On the one hand, a positive, though nonsignificant, correlation (.24) was found between level of achievement in 1984/85 and interest that was measured during the following school year (1985/86). On the other hand, a positive and significant correlation (.32) emerged between interest and grades from the second semester of 1985/86. Recently, a number of studies and reviews have addressed the problem of causal relations between affect and achievement (e.g., Reynolds & Walberg, 1991; Steinkamp & Maehr, 1983; Willson, 1983). Although there is some disagreement about which variable possesses more weight, the majority of authors conclude that affect and achievement influence one another. In a meta-analysis of relevant research, Willson (1983) found that the relation between affect and science achievement changes with age or grade level. During early stages of schooling, affect is determined by achievement, whereas later achievement becomes more and more dependent on affect. A similar result was obtained by Helmke (1990) with respect to the relation of self-concept of ability to achievement in mathematics. On the basis of these studies, one would expect that for 9th- or 10th-grade students interest is a better predictor of achievement than achievement is of interest. It is precisely this result that we have obtained in our study. However, despite the evidence emerging from different sources, one should bear in mind that the real nature of the interest-achievement relation has to be explored by causal analyses of longitudinal data.

SUGGESTIONS FOR FUTURE RESEARCH

A number of suggestions for future research ensue from the present study. First, the interest measure used in the study (as well as in other studies, e.g., Feather, 1988) was based on a single item. Although we have provided some evidence for its validity, it seems desirable for future studies to include a more differentiated and reliable measure that tries to capture a student's interest in a certain subject area more directly (Schiefele, 1991). Second, since grades are problematic indicators of achievement (especially with respect to their reliability), a replication of the present results is recommended by using carefully constructed tests of mathematical knowledge. Third, generalization of the present results is limited because the sample used in our study was composed of high-ability students. Therefore, a replication of the present study is warranted with a sample that is more representative of the average student. Fourth, we were not able to disentangle the causal relations between interest and achievement. According to suggestions by Helmke (1990), an adequate causal analysis would require conducting a longitudinal study that includes at least three waves. Fifth, Meece and her colleagues (1990) have shown that ability perceptions have a strong impact on value perceptions (such as interest). Therefore, future research should include not only test-based indicators of ability, but also measures of *perceived* competence or ability. Sixth, a further important task for future studies would be the exploration of variables that mediate the positive relation between interest and achievement. For instance, as research by Pintrich and De Groot (1990) suggests, use of learning strategies plays a crucial role in mediating the effect of motivational variables on grades. Seventh, the application of the ESM could be improved in two ways. First, the ESM should be used during a longer period of time than in the present study. Second, the ESM should not only be applied to in-school but also to out-of-school learning situations. Thus, a more complete picture of the quality of experience during learning mathematics would emerge.

Weiss (1990) recently found that mathematics teachers of all grades most heavily emphasize as instructional objectives "to have students learn mathematical facts and principles and to have them develop a systematic approach to problem solving" (Weiss, 1990, p. 151). However, having the students become interested in mathematics and having them become aware of the importance of mathematics in daily life were among the least emphasized objectives of senior high school teachers. The most preferred instructional activities of senior high school teachers are lecture, discussion, and seatwork assigned from the textbook. The least preferred activities are use of hands-on or manipulative material, use of computers, working in small groups, and completing supplemental worksheets. These facts confirm that the usual way of teaching mathematics in high school is not apt to increase students' interest in the subject. The present study suggests that increasing students' interest in mathematics may result in higher quality of experience while doing mathematics and in higher levels of achievement and knowledge. Therefore, educators should be encouraged to focus more strongly on facilitating interest. As pointed out by Weiss (1990), this cannot be accomplished by increasing the teachers' qualification as mathematicians; rather, the teachers' "inappropriate vision of the mission of mathematics education seems to be a much more serious and pervasive problem" (p. 154). If a higher level of interest is desired, then instruction should involve more active and student-centered activities, such as mathematics laboratory activities or mathematics projects. In addition, learning about the application of mathematics concepts in the real world could facilitate increased interest in the subject (see also Meece et al., 1990, p. 69), which in turn should lead to higher levels of involvement and achievement in mathematics.

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APPENDIX

Ranking of Course Levels

Foundations of Algebra 4	1
Plane Geometry 1	2
Plane Geometry 2	3
Intermediate Algebra 1	4
Intermediate Algebra 2	5
Intermediate Algebra 3	6
Intermediate Algebra 4	7
Advanced Algebra 2	7
Trigonometry	8
Advanced Algebra/Trigonometry 1	8
Advanced Algebra/Trigonometry 2	9
College Algebra	10
College Algebra/Trigonometry 2	10
Analytic Geometry	11
Probability Statistics	11
Advanced Placement Calculus AB 1	12
Advanced Placement Calculus AB 2	13
Advanced Placement Calculus BC 1	14
Advanced Placement Calculus BC 2	15
Advanced Mathematics Topics 1	16
Advanced Mathematics Topics 2	17

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