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ABSTRACT

This paper reports the results of a longitudinal study of the relationship between affect and achievement in high school science. The conceptual model for science-related affect proposes that students' enjoyment in, and enthusiasm for science are determined by their perceptions of their past performance in science, their expected future performance in science, and the perceived usefulness to them of science at school. Data were collected from 342 grade 8 students in their first year of high school at two urban middle class schools in Australia. Students studied three topics in each of the three terms of the academic year. Multiple linear regression was used to examine the direction of the relationship between science-related affect and achievement and to apportion variance common between previous and subsequent achievement and the components of science-related affect. It was found that affect is related more strongly to previous than to subsequent achievement, and that students' perceptions of their past performance in science form the most important component variable of science-related affect associated with both previous and subsequent achievement. (YP)

Clarification of the Direction of the Affect-Achievement Relationship in Science

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Abstract

This paper examines the direction of the relationship between science-related affect and science achievement. Science-related affect is defined in broad terms, and has its theoretical base in Bloom's theory of school learning. The conceptual model for science-related affect proposes that students' enjoyment in, and enthusiasm for, science are determined by their perceptions of their past performance in science, their expected future performance in science, and the perceived usefulness to them of science at school. It is hypothesized that science-related affect has an interactive relationship with achievement in science.

Data were collected from 342 Grade 8 students in their first year of high school at two urban middle class schools. Students studied three topics in each of the three terms of the academic year. Two measures of science-related affect were made, the first during the middle topic of first term, and the second during the middle topic of the last term. Students' achievement was measured by the usual school tests given at the end of each science topic. Previous and subsequent achievement were measured, respectively, by the tests on the topics completed before and after affect was measured. The relationship between affect and achievement could thus be tested on two occasions in each of the two schools. Multiple linear regression was used to examine the direction of the relationship between science-related affect and achievement and to apportion variance common between previous and subsequent achievement and the components of science-related affect. It was found that affect is related more strongly to previous than to subsequent achievement, and that much of the common variance can be attributed to students' perceptions of their competence in science.

Clarification of the Direction of the Affect-Achievement Relationship in Science

Introduction

This paper reports the results of a longitudinal study of the relationship between affect and achievement in high school science. The study attempted to clarify a situation in which common sense suggests that attitudes and achievement in science should be positively and causally related, whilst empirical evidence continues to suggest that very little variance is shared between these variables, typically less than 5% (Fleming & Malone, 1983; Fraser, 1982; Steinkamp & Maehr, 1983; Willson, 1983). A number of qualitative and quantitative syntheses of research findings about attitude and achievement in science have summarized and clarified various aspects of the relationship but have been unable to establish its direction (Aiken & Aiken, 1969; Gardner, 1975a; Schibeci, 1984; Steinkamp & Maehr, 1983; Willson, 1983). For example, Willson's (1983) meta-analysis found a mean correlation of $\underline{r}$ = .16 between science attitude and later achievement, and the same value for the mean correlation between achievement and later attitude. In a more recent study, Cannon and Simpson (1985) report that science attitude accounted for 1% and 5% of variance (after controlling for ability) in two measures of later achievement of seventh grade life science students. They reported no correlations between achievement and later attitude. Schibeci and Riley (1986) used a path-analysis model on data from the 1976-1977 NAEP survey, and found their model had better fit to the data when attitude was considered to be an antecedent to achievement. These authors point out the problems in interpreting this finding in a causal way when it is derived from cross-sectional data.

On the basis of their quantitative synthesis, Steinkamp and Maehr (1983) make the reasonable suggestion that affect and achievement reinforce each other. They suggest that perhaps a nonlinear relationship may account for the low average correlation found between affect and achievement, or it could be a result of the multiplicity of affective variables related to science having a "cancelling out" effect. This latter comment points to an inadequacy well recognised in science attitude research: the variety of referents underlying scales purporting to measure attitudes to science. This problem was recognised by Gardner (1975a) and by Mallinson (1977) in his review of research in science education for 1975. His frustration in reviewing studies of attitudes led him to complain that "it is reasonably obvious ... that no one has yet 'gotten a handle' on the issue" (p. 166). Other reviews by Peterson and Carlson (1979), Haladyna and Shaughnessy (1982) and Munby (1980) present further evidence that the meaning of attitude has been problematic. Further, the quality of the measuring instruments has often suffered from inadequate development and failure to establish validity, reliability and unidimensionality (Gardner, 1975b; Munby, 1980, 1983). The state of attitude research is improving, however, with researchers such as Shrigley and his colleagues working to clarify both theoretical and measurement issues relating to the attitude concept (Shrigley, 1983; Shrigley & Koballa, 1984; Shrigley, Koballa & Simpson, 1988).

Despite recent improvements, much of the confusion and inconclusiveness of the research in the area of attitude and achievement in science can still be attributed to a lack of a theoretical base leading to inadequate conceptualization of attitudes to science and inappropriate measurement of both attitudes and achievement. Although the measurement of achievement has been of less concern, achievement has been measured by standardized tests of science knowledge, tests of process skills, and teacher or school-based grades. It is likely that research relating different achievement measures with different attitude referents will find different magnitudes of relationship between the variables. The present study attempted to clarify the direction of the relationship between affect and achievement in science by overcoming the problems identified in previous research. First, the study is longitudinal rather than cross-sectional, and it considers achievement as both an antecedent to, and a consequence of, affect about science. Second, the study is based on a theoretical framework which directs both the definition affect and its measurement, and the selection of the achievement measures.

Theoretical Framework

In this research, a composite definition of attitude is used consistent with the position taken by Shrigley (1983), who called for the definition of the science attitude concept to reflect the elements of cognition, prediction of behavior and readiness to respond, as well as the evaluative, emotional aspects of attitude. The term 'science-related affect' is preferred to the term 'attitude' in this paper, because the conceptualization of affect has its theoretical base in the affective part of Bloom's theory of school learning (Bloom, 1976). This definition conceptualizes science-related affect as a composite variable with four components which are causally related. The model assumes that students' enjoyment in, and enthusiasm for, science are determined by their perceptions of their past performances in science, their expected future performance in science and the perceived usefulness to them of science at school.

This composite definition not only encompasses the evaluative and emotional reactions of the students' like or dislike, interest or disinterest in school science (the attitude object), but also includes certain perceptions and beliefs the student has about science, and thus involves a cognitive component. However, these beliefs are evaluative rather than descriptive, and fall towards the affective rather than the cognitive end of the attitude-belief continuum described by Shrigley et al. (1988).

Shrigley (1983) pointed out that attitudes are affected by the social influence of others and Bloom (1976) illustrates the importance of the social dimension of the classroom in his explanation of what he perceives to be an interactive relationship between subject-related affect and achievement. Bloom believes that the perceptions students have about their past and expected future performances in that subject are based on judgments made (especially by the teacher and peers) about their performance relative to others in their class. Bloom has argued that such perceptions are most influenced by those achievement marks which are most significant and most public. In this sense, affect is clearly dependent upon actual achievement, which provides the cognitive base for the students' affective, evaluative perceptions about their performance and, in turn, for affect towards the next learning task. The students' favourable or unfavourable feelings about school science are reflected by their enthusiasm or willingness to be involved in science lessons; their predisposition to respond in certain ways. Hence, science-related affect is considered to be both an outcome and an antecedent of achievement. A more complete discussion of the theoretical model is presented by Rennie (1986).

Method

Because the model for science-related affect and its relationship with achievement is developed in the context of schooling, its empirical test requires a field study, carried out in the context of normal school routine, using intact classes with their usual science teachers. Moreover, as the theoretical base of the model depends on students' perceptions of their achievement in school science, the measures of achievement used in the study must relate to the students' achievement as measured by the school. Students are unlikely to accord much importance to achievement tests which are developed externally and are unrelated to their grading.

Sample

The sample of 342 students included all of the Grade 8 (13-year-old) students in their first year at two government, coeducational high schools in the metropolitan area of Perth, Western Australia. Both schools served areas of middle socio-economic status. In both schools, classes were unstreamed with respect to ability, and the curriculum materials were activity-based and students worked in small groups. However, the learning environment was different. In Red School, there was considerable teacher-centred whole-class instruction. In contrast, students in Blue School worked at their own pace through individualized materials with the teacher acting as a resource person rather than a leader.

Instruments and Data Collection

In the schools involved in this research, students studied three separate science topics in each of the three terms of the academic year. Data collection was planned around the middle topic in the first and third terms, that is, in March and October.

Science-related affect was measured by Likert-type scales developed for each of its four component variables. The development and validation of these scales are described in a study reported by Rennie (1986). Students' perceptions of their past performance are defined in terms of the judgmental reactions of their teacher, parents, peers and the students themselves about their work in science. This variable is measured by an eight-item scale named PAST and a typical item is "So far, my performance in science is below average for the class". Expected future performance in science is measured by a scale named FUTURE, and the nine items measure students' expectations about their future performance in the current and future science topics. An example item is "I expect to do well in the next science test". The perceived usefulness of school science is measured by a ten-item scale named USEFUL. A typical item is "The things we are doing in this science topic are useful to me", and other items measure the perceived importance of science in relation to students' goals and purposes, both present and in the future. Enjoyment and enthusiasm in science is measured in terms of students' enjoyment and interest in school science and enthusiasm for doing science at school. Typical items are "I look forward to science lessons" and "Science is one school subject I really like". The coefficient alpha reliabilities of the scales ranged between .81 and .90 and are reported in the diagonals of Table 1.

The affective variables were measured (in March and October, respectively) during the second and eighth of the nine topics covered in the first high school year. Previous achievement was therefore measured by the topic test results (as a percentage) on the first and seventh topics, and the previous achievement measures are identified as TEST 1 and TEST 7. Subsequent achievement measures are identified as TEST 2 and TEST 8, and are the percentage marks for the topic tests completed at the conclusion of the topics during which affect was measured. The topic test was chosen as the most suitable achievement measure because it is completed by all students in the school and forms the major part of the students' science assessment. No measures of reliability are available for the tests, but as the tests had been prepared, used and modified by teachers over at least two years, they were assumed to have content validity. In Blue School, no test was given for the eighth topic, so an assignment score had to be used.

Complete sets of data were obtained from 95 boys and 88 girls from Red School, and 77 boys and 82 girls from Blue School. The final figure of 342 students represents 88.6% of students from the original sample. About half the loss was due to absence or transfer from school during the year and the remainder due to incomplete data.

Analysis and Results

In this study, data are analyzed separately for each school, and for each occasion of measurement, allowing four separate tests of the model. To account for the possibility of systematic between-class differences which may be related to the teacher, to some factor of class history, or to the particular science topic studied at the time of measurement, the use of within-class analysis, where student scores are taken as deviations from the class mean, controls for bias associated with class membership.

The within-class correlation matrices between the affective and achievement measures are reported Table 1. Correlations among the affective variables are generally moderate to high, with the highest correlations between PAST and FUTURE. These two variables have higher correlations with the achievement measures than do ENJOY and USEFUL. The pairs of achievement measures have high correlations except for Blue School in October, which may be a result of using an assignment mark, rather than a test score, as the measure for TEST 8 in this school. Except for this result, the patterns of correlations are similar between schools, and between occasions except that the correlations for Blue School are consistently lower. For this school the correlations between achievement and ENJOY and USEFUL are not statistically significant.

Rennie (1986) discusses the different magnitudes of the correlations in terms of the social context of the classrooms in the two schools.

Insert Table 1 about here

To investigate the magnitude and direction of relationship between science-related affect and achievement, multiple linear regression analysis was used to estimate the variance shared between previous and subsequent achievement and the four components of science-related affect. The first multiple regression analysis compared the variance in common between science-related affect and previous achievement in each of the four data sets. The results of these analyses are reported in Table 2. Table 3 reports results of the corresponding analyses to find the variance common between the affective measures and subsequent achievement. A forward-stepping regression technique was used. At each step the variable entered was the one with the highest partial correlation with the achievement variable after controlling for the influence of those variables already in the regression equation.

Insert Table 2 about here

A number of results from Tables 2 and 3 require comment. Because the correlations between affect and achievement are generally higher for Red School than for Blue School, the values of $\underline{R}^2$ are also larger, in fact, more than twice as large. Table 2 shows that, within each school, the amount of variance previous achievement has in common with later affect is very similar on both occasions of measurement. In Red School, this percentage of variance is about 45% and in Blue School it is about 20%.

Comparison with Table 3 shows that for each school, the amount of variance science-related affect has in common with subsequent achievement is less than the corresponding value for previous achievement. For the March data, it is about half in both schools, with about 25% of variance common between affect and subsequent achievement in Red School, and 10% for Blue School. For the October data, the pattern is different. In Red School, the variance common between science-related affect and subsequent achievement is about 40%, still less than the 45% common with previous achievement in October but a substantial increase from the March data. In contrast, the October data for Blue School show no increase, the variance common between science-related affect and subsequent achievement is about 10% in both the March and October results.

Insert Table 3 about here

An important and obvious conclusion to be drawn from Tables 2 and 3 concerns the relative contributions of the four affective measures to the multiple correlation coefficient. The values of the squared semipartial correlations are unique for each order of entry into the regression equation, but the beta-weights are not dependent upon order of entry. In every set of results it is clear that PAST is the variable which makes the largest contribution to the variance in common with previous and later achievement. This is not surprising since in each case, PAST has the highest zero order correlation with the achievement variables, but it is surprising that the squared semipartial correlations reveal that in only two of the eight sets of results, do the other three variables contribute as much as an extra 3% of variance. These two results are for Blue School for previous achievement where USEFUL in March and FUTURE in October appear to act as suppressor variables--that is, they have variance in common with PAST and the other affective variables which is orthogonal to achievement.

Further stepwise regression analyses were undertaken to discover whether the four component variables of science-related affect add significantly to the prediction of subsequent achievement, over and above the contribution of previous achievement. The first variable entered into the regression equation was TEST 1 or TEST 7 (for March and October, respectively), followed by the four affective variables entered together as a block. The results shown in Table 4 reveal a rather similar pattern between schools in the March data. In each school, previous achievement accounts for around 35% of the variance in subsequent achievement, and the four affective measures add less than an additional 3%. In the October data for Red School, the influence of previous achievement increases, with 60% of its variance common with subsequent achievement, and again, affect adds less than a further 3% of common variance. However, the data for Blue School in October show quite a different pattern. Here, previous achievement accounts for only about 7% of the variance in subsequent achievement, with affect contributing a further 6% of variance common with subsequent achievement. The TEST 8 measure in this set of data is an assignment, and other analyses indicated that results involving TEST 8 are inconsistent with the results for other topics. It is possible that the cognitive aspects measured in the previous test (TEST 7) account for a smaller proportion of the variance in the results of an assignment, than in another test, simply because the completion of an assignment involves different cognitive skills than the completion of a test.

Insert Table 4 about here

The outstanding result in Table 4 is the barely significant contribution made by the affective variables to prediction of subsequent achievement, over and above the effect of previous achievement. The values of the multiple correlations between the components of science-related affect and previous and subsequent achievement range between .10 and .46 (see Tables 2 and 3). For science-related affect to have made such a small additional contribution to the variance in subsequent achievement, there must be a good deal of common factor variance. An understanding of the relationship between science-related affect and achievement is enhanced by using Venn diagrams to provide a visual illustration of overlapping variance. At the risk of oversimplifying the association between affect and achievement, science-related affect is represented in the diagrams by a single ellipse as if it were a single variable, rather than four component variables. Each of the three ellipses in Figure 1 and 2 represents unit variance, and the results of the regression analyses reported in Tables 2, 3 and 4 have been used to calculate the proportion of variance depicted in each section of overlap.

Insert Figures 1 and 2 about here

The Venn diagrams in Figure 1 and 2 display visually a number of points which have already received comment. First, the overlap is greater in Red School than Blue School, because of the generally higher correlations between the variables in Red School. Second, the amount of the common factor variance increases in Red School from March to October, whereas in Blue School the common factor variance decreases. The Venn diagrams help to make plain that the different patterns of overlap are essentially due to changes associated with subsequent achievement. In both Red and Blue Schools, the proportion of variance common between previous achievement and affect ($\underline{R}^2_{PA}$) remains constant between March and October, but the proportion of variance common between previous and subsequent achievement ($\underline{R}^2_{PS}$) changes. In Red School, there is an increase from about .36 to .60. Associated with this is an increase in the variance common between affect and subsequent achievement and the common factor variance. The variance contributed to subsequent achievement uniquely by previous achievement increases from .13 to .23, but the additional variance contributed by affect remains the same, about .03. In short, the total proportion of variance in affect which is common with the two measures of achievement is about .48, and is stable over occasions for Red School, but the magnitude of the relationship between the measures of achievement increases from March to October.

There is a different pattern of relationships for Blue School. In March, the variance common between previous and subsequent achievement ($\underline{R}^2_{PS}$) is .34, about the same as Red School in March. However, in Blue School, the smaller overlap between affect and the two achievement variables is associated with less common factor variance, and affect shares less additional variance with previous and subsequent achievement. In October, the overlap of affect with both previous and subsequent achievement is the same as in March, but a different pattern results from the much smaller overlap between the two achievement variables. Since the overlap of subsequent achievement with affect is the same as in March, it seems that the difference is due to less overlap on cognitive aspects of the tests, consistent with the fact that this measure of subsequent achievement was based on an assignment, not a test.

Summary and Discussion

This study proposed a conceptual model of science-related affect with four components in an attempt to clarify the structure of attitudes to science. Investigation of the nature of the relationship between science-related affect and science achievement revealed, first, that different components of science-related affect are differentially related to achievement. Students' perceptions of their past performance in science form the most important component variable of science-related affect associated with both previous and subsequent achievement. The highest zero order correlations between enjoyment and enthusiasm in science and achievement were in Red School, indicating about 7 to 8% of common variance, but this figure dropped to between 1 and 2% when variance common to past performance is extracted. Clearly, enjoyment and enthusiasm in science contribute little unique variance to the relationship between science-related affect and achievement. This explains why much research using measures of students' interest and liking for science has reported low correlations between attitudes and achievement. However, higher correlations might be expected between achievement and scores on attitude tests which are not unidimensional and include items referring to students' self-perceptions of competence as well as their interest.

Second, this study found science-related affect to be related more closely to previous achievement than to subsequent achievement. Although these variables were hypothesized to be interactive, it seems that there is a stronger influence by achievement on later affect than by affect on later achievement. The use of school-based achievement tests in this study is important in helping to interpret this relationship. Students know what marks they get for tests at school and they use this knowledge to form perceptions of their own competence, which, according to the model for science-related affect, affects their attitudes about science. Bloom (1976) suggests that marks which contribute to grades will assume most importance to students, and it seems likely that such marks would be more liable to influence students' attitudes. Other research studies in which standardized achievement tests are administered may not report scores to the students and, even if the scores are reported, they usually are not used to determine students' grades. This may be one reason for the low correlations often reported between attitudes and externally administered achievement tests. When school-based measures of achievement are used in research, correlations between enjoyment and achievement might be expected to be higher than correlations between enjoyment and external, standardized achievement scores. A recently published study by Germann (1988) had such a finding. Germann found that lab scores and semester grades had higher correlations with an attitude scale measuring enjoyment and interest in science than a variety of standardized tests.

The results of this study clarify, at least to some extent, the relationship between attitudes and achievement in science. By taking a broader and more comprehensive definition of affect than is often the case in attitude research, the direction of the relationship has been clarified, and at least a partial explanation can be proposed for the low correlation usually found between attitude and achievement in science. However, this research used a small sample of less than 350 middle-class students in a small geographic area. Before its findings can receive more general acceptance, the study needs to be replicated in other places, and with students of different ages, race and social background.

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Table 1

Coefficient Alpha Reliability Estimates[a] and Within-class Correlations[b] between Affect and Achievement Measures

	March						October					
Scale	1	2	3	4	5	6	1	2	3	4	5	6
1. ENJOY	.88	.44	.57	.60	.05*	.07*	.90	.44	.61	.64	.04*	.12*
2. PAST	.60	.81	.62	.26	.37	.28	.55	.89	.75	.24	.40	.30
3. FUTURE	.72	.78	.82	.37	.15	.21	.65	.80	.87	.48	.17	.23
4. USEFUL	.66	.38	.59	.85	-.11*	-.06*	.64	.41	.52	.87	-.06*	-.02*
5. TEST 1 or 7	.27	.66	.44	.17	NA	.58	.27	.65	.54	.30	NA	.27
6. TEST 2 or 8	.28	.50	.38	.13*	.60	NA	.29	.61	.50	.35	.78	NA

a Reliability estimates are underlined in the diagonal.

b Correlations for Blue School are above the diagonal, and correlations for Red School are below the diagonal.

* Correlations not significant, $p > .05$.

Table 2

Stepwise Multiple Regression Analysis: R^2s, Beta-Weights and Squared Semipartial Correlations of Affective Variables and Previous Achievement

School/Month	Scale Entered	β	SP^2	F to Remove	R^2
Red/March	PAST	.819**	.4324	137.89**	
	ENJOY	-.162	.0218	7.18**	
	FUTURE	-.094	.0021	.68	
	USEFUL	.023	.0003	.09	
	ALL				.4565
Red/October	PAST	.611**	.4179	129.96**	
	ENJOY	-.242**	.0104	3.27	
	USEFUL	.132	.0128	4.09*	
	FUTURE	.141	.0058	1.85	
	ALL				.4468
Blue/March	PAST	.455**	.1337	24.22**	
	USEFUL	-.219*	.0468	8.91**	
	FUTURE	-.066	.0020	.38	
	ENJOY	.019	.0002	.03	
	ALL				.1827
Blue/October	PAST	.607**	.1597	29.84**	
	FUTURE	-.230	.0402	7.85**	
	USEFUL	-.066	.0054	1.05	
	ENJOY	-.043	.0009	.17	
	ALL				.2062

* $p < .05$

** $p < .01$

Table 3

Stepwise Multiple Regression Analysis: R^2s, Beta-Weights and Squared Semipartial Correlations of Affective Variables and Subsequent Achievement

School/Month	Scale Entered	β	SP^2	F to Remove	R^2
Red/March	PAST	.500**	.2497	60.23**	
	USEFUL	-.088	.0037	.90	
	ENJOY	.028	.0005	.12	
	FUTURE	.021	.0001	.03	
	ALL				.2540
Red/October	PAST	.603**	.3730	107.67**	
	USEFUL	.207**	.0121	3.53	
	ENJOY	-.186*	.0158	4.74*	
	FUTURE	.030	.0003	.08	
	ALL				.4012
Blue/March	PAST	.253*	.0768	13.07**	
	USEFUL	-.156	.0184	3.16	
	FUTURE	.120	.0072	1.24	
	ENJOY	-.021	.0002	.04	
	ALL				.1026
Blue/October	PAST	.254*	.0911	15.74**	
	USEFUL	-.157	.0092	1.60	
	FUTURE	.079	.0034	.59	
	ENJOY	.059	.0016	.28	
	ALL				.1053

* $p < .05$

** $p < .01$

Table 4

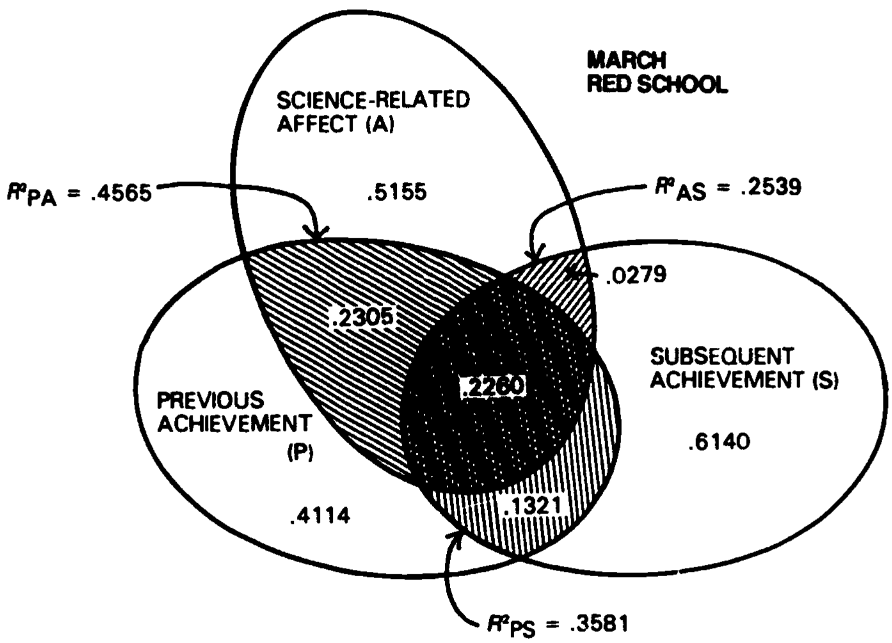
Stepwise Multiple Regression Analysis: R^2 and Beta-Weights for the Prediction of Subsequent Achievement from Previous Achievement and Science-Related Affect

School/Month	Scale Entered	β	F to Remove	R^2	Change in R^2
Red/March	TEST 1	.493**	100.96**	.3581	
	ENJOY	.108	1.27		
	PAST	.096	.68		
	FUTURE	.067	.34		
	USEFUL	-.099	1.46	.3860	.0279
Red/October	TEST 7	.644**	272.74**	.6011	
	ENJOY	-.030	.19		
	PAST	.209*	6.04*		
	FUTURE	-.061	.51		
	USEFUL	.122*	3.98*	.6309	.0298
Blue/March	TEST 1	.599**	80.92**	.3401	
	ENJOY	-.032	.12		
	PAST	-.001	.00		
	FUTURE	.156	2.92		
	USEFUL	-.033	.16	.3576	.0175
Blue/October	TEST 7	.180*	12.25**	.0724	
	ENJOY	.066	.36		
	PAST	.145	1.30		
	FUTURE	.121	.80		
	USEFUL	-.145	2.06	.1310	.0586

* $p < .05$

** $p < .01$

Figure 1. Diagrammatic representation of variance common between science-related affect and achievement for Red School.



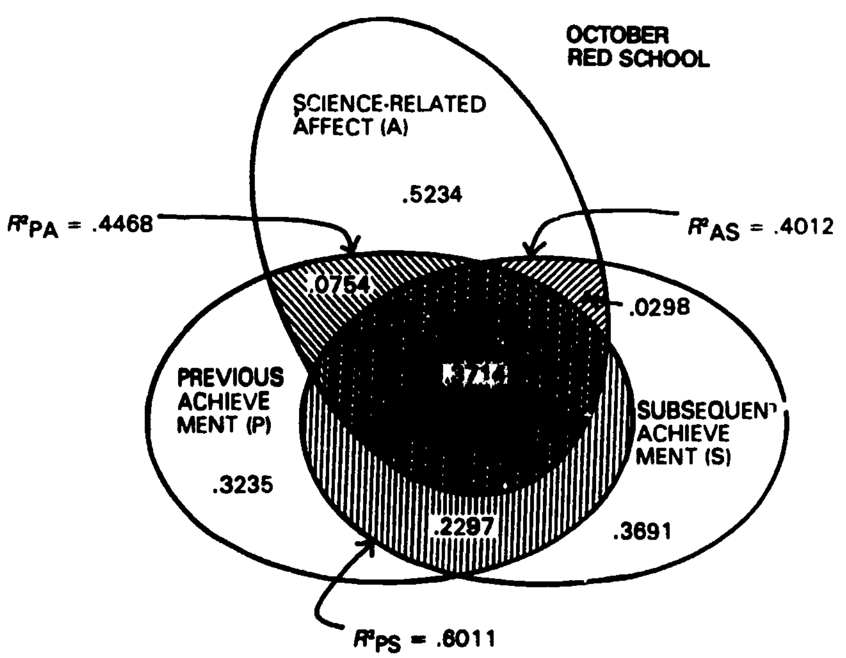


Figure 2. Diagrammatic representation of variance common between science-related affect and achievement for Blue School.