Science Achievement: Effect of Self and Engagement Variables

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Abstract: Science achievement in high school is of critical importance because it not only prepares students for future employment but also as citizens of a global technological society. There is a strong interest internationally among educators, researchers and policy makers in understanding the determinants of science achievement. Historically, research on science achievement had focused on cognitive factors such as ability, IQ and other measures of innate aptitude. But recent research has found that achievement is also related to other domains such as affective and motivational characteristics of individuals. The present study explored the relationship of self and engagement variables to science achievement, controlling for family and demographic variables. The data were collected in Virginia from six high schools to estimate models of science achievement, using both self factors and school level science engagement (N=1589). The results showed significant effect of science self-efficacy and behavioral engagement on science grades. Furthermore, the findings of the study confirmed earlier research on the importance of science attitude and psychological engagement in creating behavioral and task engagement in science learning. The study supported earlier findings that inclusion of non-ability factors improves the explanation and understanding of differences in science achievement. The study has both theoretical and practical significance, providing valuable insights for the pedagogy of science.
Keywords: science engagement, self-efficacy, science attitude

Introduction

Science achievement in high school is of critical importance because it not only prepares students for future employment but also as citizens of a global technological society. There is a strong interest internationally among educators, researchers and policy makers in understanding the determinants of science achievement. Historically, research on science achievement had focused on cognitive factors such as ability, IQ and other measures of innate aptitude. But recent research has found that achievement is also related to other domains such as affective and motivational characteristics of individuals. Researchers have included a number of psychological processes that motivate individuals to engage in and persist in achievement related activities. Individuals' task-related efficacy, interest and value of the activity all affect their desire and commitment to persist and engage in and put effort in learning activities. Research on science achievement is showing similar results; self-concept and motivational variables are shown to be important predictors of science achievement (Eccles, 1997; Nolen, 2003).

The present study explored and extended the earlier research on the relationship of science self-efficacy and science attitude variables to science engagement and science achievement (Singh, Chang & Dika, 2006). The data were collected in Virginia from six high schools to estimate models of science achievement, using both self factors and school level science engagement (N=1560). The primary focus of the present study was to examine the effect of self variables on science engagement and science learning of high school students. More specifically, the study focused on science self efficacy and science attitude factors that are related to engagement and achievement in science. Furthermore, gender differences in these effects were explored. The study is guided by the following questions:

1. What are the effects of science attitude, science self-efficacy on psychological and behavioral engagement in science learning, controlling for family background variables? Do these effects vary by gender?
2. What are the effects of science self-efficacy, science attitude, psychological and behavioral engagement on science grades in school, controlling for family background variables? Do these effects vary by gender?

Science achievement in high school is an important area of research. Despite a growing body of research on science achievement there is a dearth of empirical research on affective and attitudinal factors that are predictive of engagement in science learning. The study is described herein in three main sections: theoretical framework, method, and results. The paper concludes with a section on summary and implications of the findings of this study.

Theoretical Framework

Self and Engagement variables in Science Learning

Consistent with the focus of the present study on the relationship of self, engagement and achievement, we drew on the work of several researchers to create the theoretical framework for the study. The work of Eccles, Wigfield, & Schiefele (1998) has shown a number of non-ability factors such as self-efficacy, interest and value of the task can influence engagement and achievement. The work of Snow and his colleagues (Snow, 1989, 1992; Snow, Corno & Jackson, 1996) has shown that there are multiple pathways to achievement and commitment and engagement to the task is an important precursor of achievement (Lau & Roeser, 2002). Snow et al (1996) considered what they called conative and affective characteristics of the individual as important for learning. The conative domain referred to motivation, achievement orientations and volitional factors while affective domain described emotions and attitudinal variables. Snow (1989, 1992, 1994) provided a general theory of cognitive and conative-affective processes that affect achievement.

We further explored educational literature for relationship of achievement to motivational and self-regulatory constructs. Perceived self-efficacy, goals, values and interest have a role in the prediction of achievement behaviors in specific subject areas (Eccles et al, 1998). Social-cognitive theories of motivation focused on domain specific science beliefs and feelings, and found positive relationship of science related self-efficacy to science achievement. A number of studies have found that student self-beliefs are significantly related to academic achievement. Students' self-efficacy beliefs and attributions for academic success and failure are significantly related to achievement outcomes (Weiner, 2000; Wentzel & Wigfield, 1998). Students' academic self-efficacy and achievement expectancies have been shown to be significant predictors of several types of academic achievement outcomes such as cumulative grade performance (House, 1997), grades in several academic areas (House & Prion, 1998), and continued enrollment in school (House, 1992). With respect to science achievement, several facets of academic self-efficacy and achievement expectancies are significant predictors of subsequent outcomes (House, 2000). Students' self-appraisals of their overall academic ability were significantly related to achievement in their science courses (House, 1993).

Academic engagement

We also examined and integrated the literature on academic engagement in the framework of the study. Following Newmann (1992), engagement is defined as psychological investment in and effort directed toward learning. Both psychological and behavioral dimensions of engagement have been used to operationalize the construct of academic

engagement (Johnson, Crosnoe, & Elder, 2001; Newmann, Wehlage, & Lamborn, 1992). Engagement serves both as an important predictor and outcome variable in studies on science learning. Student engagement provides the greatest link to increasing student achievement (Darling-Hammond, 1997). High levels of achievement implicitly demand engagement; consequently, engagement is a potentially useful construct for organizing strategies to support achievement in schools (Hudley, Daoud, Polanco, Wright-Castro, & Hershberg, 2003).

After reviewing several bodies of literature, we used a heuristic model of science achievement that includes self-efficacy, science attitude, psychological & behavioral engagement in science learning (Singh, Chang & Dika, 2006). Family background variables such as parents' education, parents' occupational status, and parents' educational aspirations for their children were included as controls. Thus, in the present study, the interrelationships of several science-related affective factors such as attitude, self-efficacy, psychological engagement, behavioral engagement and grades were examined, using regression analyses. Gender was included to examine gender-based differences.

Method

Sample

Data were collected using a survey questionnaire. Students in the sample were high school students in grades 9 through 12 (N=1589). The six participating high schools are located in four counties in the southwest region of Virginia. Most of the students in the sample were White (91.1%); 4.5% were African American, 2.4%, Asian, 1.2%, Hispanic and .7%, American Indian. Most of the students were in grades 9 (33.4%) and 10 (28.0%); 24.4% were in grade 11, and 14.2% in grade 12. Most students indicated they were in a college track (49.8%); 42.8% were in general education track; about 6% were in vocational, and less than 2% were in special education. There was an equal balance of males and females, at 47.8% and 52.2% respectively.

Measures

Students completed the School and Social Experiences Questionnaire (SSEQ), a 45-question survey designed by the researchers. Table 1 summarizes the item wording, scoring, and Cronbach's alpha coefficients for the items and composite variables used in this study. The independent variables include parents' education, parents' educational aspirations, gender, science attitude (α=.92, 7 items), science self-efficacy (α=.84, 9 items) and two academic engagement factors. All items were measured on a four-point Likert scale (strongly agree to strongly disagree). Psychological and behavioral engagement in science served both as independent and dependent measures in different models. Psychological engagement in science learning (α=.80, 5 items) and behavioral engagement in science learning (α=.73, 5 items) were both measured on the same four-point Likert scale. Science grades earned in science courses was a single item self-report measure (1=below D to 5=A). Parents' education was a composite of the mother's education and father's education measured on a nine- point scale (1=Less than high school, 9=PhD/MD) and parental aspirations for their children's education was a composite of two items asked of both parents (See Table 1 for details).

Data Analysis and Models

Data analysis was conducted using SPSS to examine the distribution of the variables and compute descriptive statistics, frequencies, and correlations among items. After item level analyses, composites were created and reliability estimates were examined (see Table 1). Correlations, means and standard deviations of the variables are presented in Table 2. Using

prior research and theory, three models were specified for psychological engagement, behavioral engagement and science grades (one for each dependent variable). Parents' education and parents' educational aspirations and gender were used as control variables; since occupational status of the parents was not significant in earlier analysis, it was not considered further. Gender was included to examine the gender based differences. Since gender did not have significant interaction with any of the independent factors, the interactions terms were dropped in the final models.

In the first model, psychological engagement in science class was regressed on the parents' education, parents' educational aspirations and gender, and then science attitude and science self-efficacy were added to the model. The model was revised by dropping non-significant parental variables. In the second model, engagement in task-related behaviors was regressed on parental variables and gender. Self variables and psychological engagement in science were added in second and third steps. The third model used science grades as the dependent measure and included both psychological and behavioral engagement, science attitude and science self-efficacy and the three family & demographic variables, entered in different steps. In all models it was hypothesized that positive science attitude and science self-efficacy would have positive effect on engagement in science learning, both psychological and behavioral, and on science grades.

Results and Discussion

The purpose of the paper was to investigate the effect of self variables and science engagement on science achievement among high school students. Three dependent variables were examined, two domains of academic engagement: psychological engagement in science learning, behavioral engagement in science, and science achievement as measured by grades. All three models explained significant variance in the outcome variables. Results of the multiple regression analyses are presented in Table 3, 4 & 5. Findings of the study confirm the importance of self and engagement variables in science learning.

Psychological engagement in science: Psychological engagement was defined by the enjoyment and interest in science and science related activities in science classes. In the model, 34% variance in psychological engagement in science class was explained by three variables: gender, science attitude and science self-efficacy. There was no significant effect of parents' education or parental aspirations on psychological engagement in science learning, which makes intuitive sense. Because the items measuring psychological engagement were related to the science classes being interesting and science activities being fun, there was no significant effect of parents. Both self-efficacy (β=.129) and science attitude (β=.485) had significant effects on the enjoyment and psychological engagement in science learning. Comparing the standardized β's, the effect of science attitude was relatively of a larger magnitude. Gender had a significant effect, indicating the higher psychological engagement of girls in science classes. Gender did not have significant interaction with either self-efficacy or science attitude so the interaction terms were deleted from the model. (See Table 3 for details)

Behavioral engagement in science: Behavioral engagement was defined by task engagement such as doing home work, paying attention in class, doing more work than required and active participation in class. In this model, about 35% variance in behavioral engagement was attributed to parental educational aspirations, parents' education, gender, science attitude, science self-efficacy, and psychological engagement jointly. It is interesting to note that parents have a significant positive effect on the task engagement of students.

Controlling for parent variables, both self-variables, science attitude (β=.072) and science self-efficacy (β=.238) had significant effects on behavioral engagement in science learning. Psychological engagement also had a significant positive effect (β=.306) on behaviors that are related to learning. Thus, students who enjoy classroom science activities and find science topics interesting are more likely to study harder and do more home work. Gender was a significant factor, indicating that female students were higher in behavioral engagement. Again, there was no interaction between gender and other variables, meaning the effects of the self and engagement variables were similar for both male and female students. Thus, the interaction terms were not included. (See Table 4 for details)

Science achievement: Science achievement was measured by self-reported grades earned in science courses. In this model, approximately 43% variance in the science grades was explained by a combination of family, self and engagement variables. The variables were entered in three steps: first, family and demographic variables; second, self variables; and last, engagement variables. Both parents' education and parents' educational aspirations had a significant effect on science grades. Both science self-efficacy and behavioral engagement had significant effects on science grades (β=.485; β=.148 respectively). When other variables were in the model, neither science attitude nor psychological engagement had a significant effect on grades. There was a significant effect of gender, showing that female students earn higher grades in science courses. There was no interaction between gender and other independent factors, meaning the effects were similar in the two groups. (See Table 5 for details)

Over all these results support the importance of self and engagement variables in learning. The significant findings about the role of self-efficacy and engagement in learning on science achievement corroborate the earlier findings. It is also evident that attitudinal and affective variables such as attitude towards science and enjoyment of science positively influence task and behavioral engagement such as doing homework and participation in the science classes. The affective/conative variables are the process variables that create a pathway to learning outcomes. Students who have positive feeling toward science and scientific knowledge are more likely to have enjoyment of science learning and engage in more learning tasks, resulting in higher performance. These results underscore the importance of affective variables in creating psychological and behavioral involvement in science learning.

Science self-efficacy had strong and consistent positive effects on both engagement and achievement in science. The construct of science self-efficacy indicated a domain specific belief in one's ability to learn science. Self-efficacy had a significant effect on science psychological engagement, behavioral engagement in learning tasks, and grades. It had a strong effect on grades, indicating that the students, who believe in their ability to learn and succeed in science, are more likely to have higher achievement. The positive effect of science self-efficacy on both process (e.g. enjoyment and interest) and outcome variables (e.g. task engagement) is indicative of its importance in science learning. The significant effect of science self-efficacy on both engagement and achievement confirm earlier findings and provide further empirical support for the important role of domain specific self-efficacy in science learning.

These findings also point to the importance of family and parental effects on science learning. Socioeconomic effects on learning are well known. Parents' education and their aspirations for their children were found to have significant effect on behavioral engagement and grades. More educated parents with higher aspirations for their children are more likely

to influence their children to engage in learning tasks. Gender was significant in all outcome variables and indicated that female students are both more psychologically and behaviorally engaged in science learning and thus, earn better grades.

Summary and Implications

The findings of the study point to the importance of self and engagement variables in promoting learning behaviors and achievement. These results bring further support to earlier work of researchers on the relationship of self efficacy and achievement. It is important to acknowledge, however, that the study is based on cross-sectional data and only tentative conclusions can be made about cause and effect based on previous research and theory. An important contribution of the study is the measurement of several science related constructs such as science self-efficacy, science attitude and science engagement. The constructs measured in the study had high reliabilities; thus, further supporting the validity of the findings. Looking at the dearth of research on engagement in science learning, there is need for more research to understand the factors that promote science learning of high school students.

The study supported earlier findings that inclusion of non-ability factors improves the explanation and understanding of differences in science achievement. The study has both theoretical and practical significance, providing valuable insights for the pedagogy of science. There are implications of the study for high school students' science learning. Often the focus of reform for science learning has been structural in nature, emphasizing the need for greater numbers and better prepared science teachers, and more resources such as labs. Although these changes are needed, reform efforts should also examine the curricular and pedagogical changes that would increase students' interest and motivation in learning and bring about greater engagement in science learning.

Table 1: *Items and Descriptive Statistics for Scales*

Item and Scale	*M*	*SD*	*Loading*	*α*
Science Grades				
current science grades— reverse coded	4.04	1.021	—	
Parents' Education				
father's education	4.56	2.628	—	
mother's education	4.63	2.557	—	
Parents' educational aspirations				
how far father expects student to go in school	4.08	.942	—	
how far mother expects student to go in school	4.11	.912	—	
Science Self- Efficacy				.84
compared to other academic subjects, how good are you at science	3.34	1.05	.640	
compared to other students in class, how good are you at science?	3.31	1.01	.720	
even if the work in science is hard, I can learn it	3.03	.676	.660	
If I have enough time, I can do even the hardest problems in science	2.75	.818	.672	
I am sure I could do advanced work in science	2.74	.864	.766	
I think I am doing OK in my science classes compared to other students taking the same classes	2.91	.731	.554	
no matter how hard I try, there is some science work I will never understand—recoded	2.55	.868	.588	
some of the work we do in science is too difficult for me—recoded	2.82	.810	.682	
science has been my worst subject—recoded	3.22	.843	.635	
Science Attitude				.92
science is fun	2.78	.864	.862	
I have good feelings towards science	2.77	.823	.910	
I enjoy science courses	2.74	.832	.915	
I really like science	2.61	.873	.905	
I would enjoy being a scientist	2.13	.891	.705	
I think scientists are neat people	2.60	.838	.716	
everyone should learn about science	2.78	.855	.711	
Science Psychological Engagement				.80
science classes at THIS SCHOOL: we do a lot of fun activities in science class	2.70	.811	.775	
science classes at THIS SCHOOL: we learn about important things in science class	2.90	.696	.829	
science classes at THIS SCHOOL: we cover interesting topics in science class	2.78	.777	.861	
science classes at THIS SCHOOL: I like our science textbook	2.09	.799	.626	
science classes at THIS SCHOOL: we discover how science applies to everyday life	2.86	1.071	.595	

Science Behavioral Engagement			.73
in your science class how often do you: pay attention in class	3.90	.918	.823
in your science class how often do you: copy teacher's notes	4.21	1.117	.703
in your science class how often do you: do more work than is required of you	2.57	1.095	.673
in your science class how often do you: participate actively in class	3.86	1.726	.476
in your science class how often do you: do the homework	3.91	1.121	.767

Table 2: *Descriptive Statistics and Correlations*

	Variable	*M*	*SD*	1	2	3	4	5	6	7
1.	current science grades	3.973	1.047	—						
2.	parents' education	4.614	2.363	.264**	—					
3.	parents' educational aspiration	4.089	.904	.274**	.320**	—				
4.	science self-efficacy	2.962	.563	.588**	.202**	.194**	—			
5.	science attitude	2.630	.695	.347**	.112**	.112**	.617**	—		
6.	science behavioral engagement	3.696	.825	.393**	.144**	.191**	.366**	.375**	—	
7.	science psychological engagement	2.663	.608	.298**	.051	.090**	.415**	.566**	.457**	—

Table 3: *Regression Coefficients (Dependent Variable: Science Psychological Engagement)*

	Science Psychological Engagement		
	B	SE	β
gender	-.138**	.026	-.114**
science self-efficacy	.139**	.029	.129**
science attitude	.425**	.023	.485**
Total R^2		.335	

Table 4: *Regression Coefficients (Dependent Variable: Science Behavioral Engagement)*

	Science Behavioral Engagement								
	Model 1			Model 2			Model 3		
	B	SE	β	B	SE	β	B	SE	β
Step 1									
parents' education	.030**	.009	.093**	.012	.008	.037	.016*	.008	.049*
parents' educational aspiration	.123**	.024	.148**	.059**	.021	.071**	.058**	.020	.070**
gender	-.328**	.040	-.220**	-.412**	.036	-.277**	-.368**	.035	-.247**
Step 2									
science self-efficacy				.380**	.041	.281**	.322**	.040	.238**
science attitude				.232**	.032	.214**	.078*	.034	.072*
Step 3									
science psychological engagement							.381**	.034	.306**
Total R^2		.102			.288			.352	
R^2 change		.102**			.186**			.064**	

Table 5: *Regression Coefficients (Dependent Variable: Science Grades)*

	Science Grades								
	Model 1			Model 2			Model 3		
	B	SE	β	B	SE	β	B	SE	β
Step 1									
parents' education	.094**	.012	.217**	.058**	.010	.135**	.056**	.010	.131**
parents' educational aspiration	.225**	.032	.195**	.115**	.027	.100**	.103**	.027	.089**
gender	-.226**	.054	-.111**	-.388**	.045	-.191**	-.306**	.046	-.150**
Step 2									
science self-efficacy				1.014**	.041	.547**	.900**	.045	.485**
Step 3									
science behavioral engagement							.202**	.033	.148**
Total R^2		.134			.409			.425	
R^2 change		.134**			.275**			.016**	

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