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ABSTRACT

Causal modeling procedures were used to test causal inferences about hypothesized relationships among the major influences on science learning outcomes for a secondary-two (equivalent to grade 8) sample of Singaporean students. A sample of approximately 900 was selected from schools that represented the population of secondary-two students. Instruments were developed to measure attitudes toward science, perceptions of the science teacher, the classroom environment, the home environment, student motivation, and peer influence. Students also took an ability test and a science achievement test. Other variables explored included student use of time and the amount and quality of homework in science. The research design involved the LISREL approach to causal modeling. Attitudes toward science influenced achievement, and the converse was not true. Motivation, classroom environment, and attitudes toward science were the more significant and alterable variables for science achievement. One implication of the results is that science teachers cannot afford to overlook student attitudes. Seven tables present analysis results, and two figures illustrate the discussion. (SLD)

Factors Influencing Science Learning Outcomes for 14-year-old Singaporean Students[1]

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Various factors have been reported to influence science learning outcomes, some of which are school, home and individual variables. Some variables have been found to have significant influence on science learning outcomes (e.g., Tamir, 1985; Fraser, Walberg, Welch & Hattie, 1987; Twoli & Power, 1989; Simpson & Oliver, 1990).

Objectives of the Study

This study used causal modelling procedures to test causal inferences about hypothesized relationships among the major influences on science learning outcomes for a secondary-two (equivalent to grade 8) sample of Singaporean students. The hypotheses which were tested are:

1. Prior achievement, motivation, peer influence, classroom environment, home environment, parents' education, perception of the science teacher, amount of television watched, and homework for science, influenced attitudes to science.

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[1] Paper presented at the New England Educational Research Organisation Annual Meeting at Portsmouth, New Hampshire, on 6-8 May 1992.

[2] On study leave from the National Institute of Education, Singapore.

2. Prior achievement, ability, classroom environment, parents' education, perception of the science teacher, amount of television watched, homework for science, influenced achievement in science.

An alternative model in which achievement influenced attitudes, and a nonrecursive model in which it was hypothesized that attitudes affected achievement and that achievement affected attitudes were also tested. Hence, the interactive relationship between attitudes to science and achievement in science, and whether attitudes to science were both n outcome and antecedent of achievement, were examined.

Conceptual Framework

For more than two decades, there has been a large effort on the part of educational researchers to identify the theoretical constructs or productivity factors that may have an influence on the achievement and attitude scores of students.

Resembling early agricultural experimentation, many earlier educational studies focus on the relation between a single cause and its effect. However, education involves numerous means and ends, each with an implicit or explicit cost or value. Increasing the efficiency requires the specification and measurement of the main causes, means, or "factors" of production.

Research studies have shown that there are various factors influencing science learning outcomes. Willson (1983) reported a mean overall moderate correlation of 0.16, with values ranging between -0.18 to +0.48, in his meta-analysis of 43 studies of the relationship between science achievement and science attitude of students from kindergarten through college. Eisenhardt (cited in Schibeci, 1984) in his study involving 70,000 students concluded that achievement influenced attitudes more often than the reverse. Schibeci and Riley (1986) in their secondary analysis of NAEP data found that the reverse was true. Class environment, perception of the science teacher, peer influence, home environment, parents' education, motivation, ability, prior achievement, amount of television watched, and homework have all been reported to correlate to some degree with attitudes to science and science achievement (e.g., Simpson & Oliver, 1990; Cooper, 1989; Fraser *et al.*, 1987; Brophy & Good, 1986; Walberg, 1983; Iverson & Walberg, 1982; Fraser & Fisher, 1982, Walberg *et al.*, 1981).

However, the correlations reported in the studies vary quite substantially from negative through zero to moderate and to highly significant. Further research is required, and this study contributes to the research for a sample of 14-year-old Singaporean students.

Data Source

The study was conducted at the secondary-two level (equivalent to grade 8) in Singapore. A sample of about 900 was selected. Using the Student Data Bank of the Ministry of Education, the sampling involved selection of schools which reflected the characteristics of the population of secondary-two students in Singapore.

To ensure more valid and discriminating measures appropriate to the socio-cultural characteristics of the educational system, the instruments were developed by the authors to collect data for the variables. In the construction of the affective items, cognitive and value statements were avoided. The statements were moderately worded. Affective items calling for a personal or emotional reaction were written to establish conceptual validity. A five-point Likert scale (Strongly Agree, Agree, Undecided, Disagree, Strongly Disagree; or Never, Seldom, Sometimes, Often, or Always) was used for recording the students' reaction towards each item.

The attitudes to science instrument measured interest in science, enjoyment of science, career preference for science, and self-perception of ability to learn science. The questionnaire asked students to indicate their honest feelings about statements such as:

I enjoy science lessons.

I would enjoy being a scientist.

The perception-of-the-science-teacher instrument measured the students' perception of the teacher's enthusiasm and competence and whether they viewed their teachers as encouraging, caring and supportive in the course of teaching. Examples of statements from this instrument are:

Our science teacher shows concern for us.

Our science teacher makes science experiments exciting.

The classroom environment measured the satisfaction, cohesiveness, goal direction, involvement and related social-psychological climate of the classroom group as perceived by students. Examples of items from this instrument are:

We daydream in the science class.

We fool around in the science class.

The home environment instrument measured the social and psychological stimulation accorded to the student's academic development by parents or guardian in the home. The following are two items from this instrument:

Do your parents/guardian spend time with you?

Do you talk to your parents/guardian about school?

The motivation instrument measured the propensity for wanting to do well in science, studies and life, and for studying science on one's own accord. Examples of items from this instrument are:

I want to learn more about science.

I intend to continue studying science for more years.

The peer-influence instrument measured the influence of one's peers to study and to be interested in science. Examples of items from this instrument are:

My friends are not interested in studying.

My friends are interested in getting a good career.

The multiple choice items in the ability test measured verbal reasoning, numerical ability, abstract reasoning, and space relations.

Items in the science achievement test were based on instructional objectives common in all schools. A table of specifications was drawn up for the test to ensure content validity in the criterion referenced test.

Other items measured variables like average number of hours of television watched per day, the average number of hours spent on homework for science per day, the frequency of homework assigned, whether science homework was corrected and graded, prior achievement, as well as parents' education level.

After careful development and proof-reading, these instruments were administered to the sample of students. Optical scan sheets were used to expedite data collection, and to eliminate human errors in data entry. Only two researchers were in charge of the administration to the whole sample so as to standardize administration procedures as much as possible.

Method

The research design involved the LISREL approach to causal modelling procedures. It was hypothesized that for both the gender groups, peer influence, motivation, and home environment influenced attitudes to science (η_1) which, in turn, influenced achievement in science (η_2). Ability was hypothesized to influence achievement directly. In addition, classroom environment, parents' education level, perception of the science teacher, amount of television watched, and homework were hypothesized as influencing both attitudes to science and achievement in science. These hypotheses were used to develop the causal model. The causal chain $\eta_1 \longrightarrow \eta_2$ was postulated to be part of the model.

In the presentation of the path analysis diagram, the conventions used in the LISREL 7 manual (Jóreskog & Sórbom, 1989) were used. Observed variables were enclosed in rectangles; unobserved (latent) variables were enclosed in circles. In this model, the observed *x* variables (ability, prior achievement, motivation, peer influence, perception of the science teacher, classroom environment, home environment, parents' education level, amount of television watched, and homework) were taken to be the exogenous variables whose variabilities were assumed to be determined by causes outside the causal model. It was assumed that they were measured without error. The correlation between the exogenous variables would remain unanalyzed in the system. One variable would not be conceived as the cause of the other. Paths, in the form of unidirectional arrows, were drawn from the variables taken as causes (independent) to the variables taken as effects (dependent). The non-existence of an arrow between two variables meant that they were assumed not to be directly related.

Attitudes to science and achievement in science were the endogenous variables whose variations were hypothesized to be explained by the exogenous and/or endogenous variables in the system.

The covariance structure model or the full LISREL model was used. The measurement model was combined with the structural equation model. The full model allowed for measurement errors in the latent variables and errors in equations (residuals), and provided for the estimation of relationships. The unknown parameters were estimated so that the covariances and variances of the variables in the model matched the data.

The structural equation model is:

$$\eta = B\eta + \Gamma\xi + \zeta,$$

where B is the coefficient matrix of the endogenous (independent) variables (η); Γ is the coefficient matrix of the exogenous (dependent) variables (ξ); and ζ is a random vector of residuals.

The measurement model for y and x is:

$$y = \Lambda_y\eta + \epsilon,$$

$$x = \Lambda_x\xi + \delta,$$

where the parameter matrices Λ_y and Λ_x are the regression matrices of y (observed dependent variables) on η, and x (observed independent variables) on ξ respectively.

The ϵ's and δ's are the errors in variables or measurements, while the ζ's are the errors in equations or structural disturbance terms.

Since constraints are imposed on θ_ϵ or θ_δ, the normal theory standard errors in LISREL are valid only when the covariance matrix is analyzed (Jóreskog and Sórbom, 1989). To obtain correct standard errors and chi-squares, the covariances were analyzed.

The assumptions made in the covariance structure model are: the residuals are uncorrelated with the exogenous variables; the errors of measurement are not correlated with the residuals and the latent variables; latent variables and residuals are measured as deviations from their means; and the coefficient matrix B is nonsingular.

The unknown parameters were estimated using the maximum likelihood method of LISREL 7 (Jóreskog & Sórbom, 1989). Since there were no replicate measures for η_1 and η_2 (attitudes to science and science achievement), these variables were considered fallible measures. The alpha or factor score reliabilities were used rather than the assumption of an arbitrary value of 1.00. The error variance is equal to the product of the variance in the y variable and (1 - reliability). The error variances were used as fixed values in θ_ϵ and the structural parameters in B and Γ were estimated directly with LISREL.

Results

Since raw scores do not accurately reflect the true trait of a person, a more appropriate scoring procedure using item response theory was used. ASCAL, a program from MicroCAT (Assessment Systems Corporation, 1989) was used to estimate the item response theory parameters for the three-parameter model for the science achievement test and the ability test. Items which did not converge well and those with high χ^2 values were not selected for computing the maximum likelihood thetas. The alpha reliabilities were 0.693 for the science achievement test (36 items), and 0.734 for the ability test (42 items).

The other instruments were subjected to maximum likelihood factor analysis using STATA (Computing Resource Center, 1992), a statistical analysis package for personal computers. The number of factors was determined using the large sample χ^2 significance test associated with the maximum likelihood solution, which is considered to be the most satisfactory solution from a statistical standpoint, provided that the assumptions of the method are adequately met (Kim & Mueller, 1978). The number of factors retained was usually more than the number of factors expected. The minor factors were ignored on substantive grounds, and where appropriate, the major factors were subjected to varimax or promax rotation to assess their factor structure.

Since it was not appropriate to simply sum all the variables to construct the factor scale when the factor loadings were not uniform, regression scoring was used for the instruments. The reliability coefficients of the factor scores were 0.964 for attitudes to science (19 items), 0.925 for perception of the science teacher (12 items), 0.868 for classroom environment (9 items), 0.882 for home environment (10 items), 0.753 for motivation (4 items), and 0.560 for peer-influence (4 items).

After all the instruments had been subjected to analysis, the whole sample was divided into 2 groups according to gender. The covariance matrices among the observed *y* and *x* variables for the two groups were computed. The covariance matrices for the two groups are shown in Tables 1 and 2. The descriptive statistics for the variables in the two groups are summarized in Tables 3 and 4. The observed variables were attitudes to science (Att), science achievement (Ach), peer influence (Peer), motivation (Mot), classroom environment (Class), perception of the science teacher (Tr), home environment (Home), father's education (Fed), mother's education (Med), ability (Abi), prior achievement (PA), frequency of homework assigned (Freq), time spent on homework (HSc), correction of homework (Cor), and the amount of television watched (TV).

Insert Tables 1, 2, 3, and 4 about here.

It was found that the boys had higher means than the girls for attitudes to science, science achievement, motivation, home environment, father's education, mother's education, ability, prior achievement, correction of homework, and the amount of television watched. The girls had higher means than the boys for peer influence, classroom environment, perception of the science teacher, frequency with which assignments was given, and the time spent on science homework.

Multi-sample LISREL analysis was used to test whether there was any significant difference between the covariance matrices of the observed variables y and x for the girls and boys. It was found that the χ^2_{146} = 1674.85 with a p-value of 0.000. Thus, the hypothesis that the covariance matrices of the observed variables were the same, or the invariance of the model could be rejected. Therefore, there were differences among the girls and the boys, and they had to be analyzed separately.

The error variance for the science achievement test was used as a fixed value in θ_ϵ. Since the reliability of the factor scores of the attitudes to science instrument was very high

(0.964), the error variance was computed and used when necessary. The structural parameters in B and Γ were estimated directly with LISREL.

For the girls, the model has $\chi^2_4 = 3.19$ with a probability level of 0.527. The goodness of fit index was 0.999, and the adjusted goodness of fit index was 0.969, while the root mean square residual was 0.005. The Q-plot was steeper than the diagonal line. These values indicated that the model fits the data quite well.

For the boys, the model has $\chi^2_3 = 2.10$ with a probability level of 0.551. The goodness of fit index was high (0.999), and the adjusted goodness of fit index was 0.975. The root mean square residual was low (0.004). Again, the Q-plot was steeper than the diagonal line. These values indicated that the model fits the data quite well.

The maximum likelihood estimates for the standardized solution for the girls and boys are shown in Table 5. The maximum likelihood estimates for the unscaled solution for both the gender groups are shown in Table 6.

Insert Tables 5 and 6 about here.

The path diagrams of the causal model for educational productivity for science for secondary-two girls and boys are shown in Figures 1 and 2 respectively. The standardized solution is shown. In the standardized solution, all latent variables are standardized, i.e., they have a mean of zero and a standard deviation of one.

Insert Figures 1 and 2 about here.

The values of the parameter estimates are given near the arrows for the free paths. Significant paths in which $|t| > 1.96$ are shown. The correlations among the exogenous variables (x variables) are also not shown nor are the measurement errors in the attitudes to science instrument and achievement in science test. Errors in the structural equations between the exogenous and the endogenous equations are, however, shown.

The squared multiple correlations for y_1 (attitudes to science instrument) and y_2 (science achievement test) were 0.965 and 0.698 respectively for the girls. For the boys, they were 0.779 and 0.694 respectively. The total coefficient of determination for the y variables was 0.989 for the girls and 0.929 for the boys. The squared multiple correlations for the observed variables reflected the reliabilities of the instruments. The total coefficient of determination for the y variables was high. Since the values should be between 0 and 1, these large values indicated that the observed variables were reasonably good measurement instruments for the latent variables.

The squared multiple correlations for each structural equation for attitudes to science and science achievement were

0.724 and 0.699 respectively for the girls; for the boys, they were 0.870 and 0.663 respectively. The total coefficient of determination for the structural equations was 0.913 for the girls and 0.952 for the boys. This high value is an indication of a good proportion of variance in the endogenous variables accounted for by the variables in the structural equations, and that the model is good.

The parameters in both the gender groups were compared. The difference in the parameters, the standard error of the difference, and the *t*-ratio are shown in Table 7. Significant differences are marked with asterisks. Only two paths were significantly different - the path from attitudes to science to achievement, and the path from teacher to attitudes to science.

Insert Table 7 about here.

An alternative model in which achievement in science influenced attitudes to science (rather than attitudes affecting achievement) was tested. This model resulted in χ^2_4 = 15.89 with a probability level of 0.003 for the girls. The model for the boys yielded a χ^2_3 = 48.10, and a probability level of 0.000. The low probability levels imply that the model of educational productivity is not consistent with the data.

A nonrecursive model in which attitudes to science and achievement in science influenced each other reciprocally, was also tested. The results for the nonrecursive model for the girls yielded a χ^2_3 of 3.16 and a probability level of 0.368. For the boys, the χ^2_2 was 1.67 and the probability level was 0.434.

The path from attitudes to science to achievement in science was significant for both the groups: it was 0.236 for the girls and 0.473 for the boys. However, the path from achievement in science to attitudes to science was not significant for both the groups; it was -0.013 for the girls and 0.068 for the boys. (The values given were standardized.)

Discussion

The analysis showed that the data for the girls and boys did not contradict the model. This indicated the viability of the model. Attitudes to science affected achievement in science; the converse was not true. Neither was the relationship nonrecursive (two-way). Prior achievement, ability, motivation, classroom environment, and attitudes to science emerged as the more significant and consistent predictors of achievement in science for both the groups. Motivation and classroom environment were the significant predictors of attitudes to science for both the groups while another predictor for the male group was the perception of the science teacher. It must be noted, however, that the total effect of perception of the science teacher on achievement was negative for both the groups.

From the analysis of the results of this study, motivation, classroom environment, and attitudes to science were the more significant and alterable variables for science achievement.

Efforts should be directed to generating a greater interest in science and improving the classroom environment, thereby enhancing the students' attitudes to science in order to raise the level of achievement in science.

Science teachers can play an important role in the classroom by facilitating the formation and change of attitudes throughout students' lives. Hence, science teachers could increase their impact on students' achievement by doing more than teaching only facts and principles. The implication of the results is that science teachers cannot afford to overlook student attitudes.

The effect of motivation on attitudes to science, and science achievement mediated by attitudes to science was highly significant. This finding against the backdrop of the other variables is encouraging in that a student may come from a disadvantaged background but if he is motivated to do well in science, the chances are that he will succeed in his endeavor. Personal ambition is an essential ingredient for success. Motivation is an important factor that teachers should consider in order to improve students' attitudes to science and thereby achievement in science.

The study also showed that ability and prior achievement were relatively significant exogenous variables. This finding is in accord with studies in which aptitude is among the strongest and more consistent predictors of both science achievement and attitude (Boulanger, 1981; Fleming and Malone, 1983; Bloom, 1976; Fraser *et al.*, 1987). Therefore, teachers of lower ability students have to work harder to improve achievement in science.

The results indicated a surprising degree of social equity. Home environment and parents' level of education when used in the analysis did not play any statistically significant role in determining science achievement and attitudes to science.

Further research is also required to elucidate the negative effects of the frequency of correction of homework on attitudes to science, perception of the science teacher on achievement in science, and the time spent on science homework on achievement in science. Certain aspects of the efforts of teachers, and the effects of homework should contribute to gains in science learning outcomes.

Conclusions

The analysis showed that the data did not contradict the model hypothesized. The overall fit of the model was good and the relationships in the model were well determined as indicated by the squared multiple correlations and the total coefficients of determination.

This analysis reveals potential lessons to parents and science educators. Since motivation, classroom environment, and attitudes to science are more manipulable than ability and prior achievement, efforts should be directed to raising the motivation level of the students, improving the classroom environment, and enhancing the students' attitudes to science.

While establishing and strengthening certain attitudes to science has long been considered the domain of science educators, most of the attitudes to science held by teachers and students are acquired incidentally rather than as a result of planned efforts. It is time that science educators know more about attitudes and ho they can be inculcated and modified.

With ability and prior achievement having strong causal effects on science achievement, consideration and understanding should be given in the planning for and teaching of students of lower ability to not expect unreasonably good results. At the same time, teachers of lower ability students should recognize that individual motivation and effort, and the classroom environment can partially compensate for the effect of low ability and prior achievement. Finally, despite all the time and efforts devoted to the students, teachers should not always expect students to have good perceptions of them.

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Table 1

Covariance Matrix for Girls
(N = 411)

	Att	Ach	Peer	Mot	Class	Tr
Att	.932					
Ach	.151	.924				
Peer	.066	.040	.533			
Mot	.650	.181	.043	.744		
Class	.499	.030	.148	.310	.881	
Tr	.337	-.103	.130	.182	.530	.829
Home	.137	.053	.095	.147	.154	.116
Fed	.132	.198	.056	.139	-.009	-.039
Med	.036	.168	.021	.067	-.004	-.056
Abi	-.074	.472	.006	.052	-.196	-.188
PA	-1.361	12.053	.322	1.747	-4.439	-4.556
Freq	.267	.137	.050	.179	.329	.200
HSc	.281	-.055	-.047	.237	.220	.089
Cor	.129	.196	.086	.145	.072	.218
TV	-.165	-.200	-.033	-.180	-.147	-.057

	Home	Fed	Med	Ability	PA	Freq
Home	.981					
Fed	.245	1.269				
Med	242	.619	.997			
Abi	.041	.174	.163	.835		
PA	2.305	6.275	5.157	11.441	434.509	
Freq	.187	.154	.122	.005	2.739	.791
HSc	.064	.045	.070	-.087	-1.523	.214
Cor	.255	.185	.103	.144	5.982	.219
TV	-.106	-.172	-.210	-.111	-4.653	-.091

	HSc	Cor	TV
HSc	.765		
Cor	.047	1.507	
TV	.073	-.019	1.738

Table 2

Covariance Matrix for Boys
(N = 445)

	Att	Ach	Peer	Mot	Class	Tr
Att	.961					
Ach	.229	1.040				
Peer	.073	-.034	.577			
Mot	.610	.305	.080	.738		
Class	.490	.029	.170	.242	.870	
Tr	.454	-.116	.129	.216	.518	.985
Home	.107	.026	.100	.120	.115	.171
Fed	.154	.224	.044	.181	-.022	-.084
Med	.103	.168	.027	.141	.014	-.129
Abi	.026	.537	-.050	.126	-.096	-.102
PA	-2.639	8.478	-.409	.922	-5.590	-4.613
Freq	.165	.048	.117	.090	.206	.200
HSc	.275	.008	.059	.158	.250	.188
Cor	.016	.159	.028	.069	.040	.199
TV	-.140	-.093	.005	-.190	-.169	-.025

	Home	Fed	Med	Ability	PA	Freq
Home	.743					
Fed	.297	1.601				
Med	.222	.943	1.331			
Abi	.020	.184	.081	1.136		
PA	.816	3.337	3.274	8.491	303.327	
Freq	.112	.082	.005	-.028	-.556	.682
HSc	.143	.126	.137	-.141	-1.939	.177
Cor	.193	.151	.047	.245	3.969	.053
TV	-.070	-.285	-.227	.072	-.614	.030

	HSc	Cor	TV
HSc	.732		
Cor	.087	1.406	
TV	-.039	-.003	2.059

Table 3

Descriptive Statistics: Girls

Variable	Obs	Mean	Std. Dev.	Min	Max
Att	430	-0.143	0.963	-3.217	2.381
Ach	426	-0.095	0.954	-3.730	2.413
Peer	430	0.075	0.727	-2.198	1.632
Mot	430	-0.138	0.857	-2.917	1.764
Class	430	0.012	0.949	-2.802	2.547
Tr	430	0.014	0.920	-3.508	2.045
Home	430	-0.096	0.998	-2.708	2.323
Fed	420	2.462	1.123	1.000	5.000
Med	426	2.031	1.004	1.000	5.000
Abi	430	-0.117	0.929	-4.103	2.526
PA	428	227.519	20.831	180.00	266.00
Freq	429	3.091	0.896	1.000	5.000
HSc	430	1.556	0.880	0.000	7.000
Cor	430	3.605	1.239	1.000	5.000
TV	430	3.184	1.307	0.000	7.000

Table 4

Descriptive Statistics: Boys

Variable	Obs	Mean	Std. Dev.	Min	Max
Att	464	0.134	0.971	-3.020	2.413
Sc Ach	464	0.119	1.018	-3.279	3.042
Peer	464	-0.061	0.750	-2.679	1.593
Mot	464	0.124	0.853	-2.652	1.764
Class	464	-0.007	0.918	-2.967	2.106
Tr	464	0.004	0.984	-3.093	2.184
Home	464	0.097	0.866	-2.912	2.323
Fed	457	2.884	1.276	1.000	5.000
Med	460	2.437	1.156	1.000	5.000
Abi	463	0.136	1.067	-3.004	2.975
PA	459	232.231	17.491	180.00	276.00
Freq	463	3.015	0.826	1.000	5.000
Hsc	464	1.502	0.857	0.000	5.000
Cor	464	3.860	1.192	1.000	5.000
TV	462	3.227	1.432	0.000	7.000

Table 5

Maximum Likelihood Estimates (Standardized Solution) for the Girls and Boys (Significant Parameter Estimates in Asterisks)

Parameters	Girls	Boys
Attitude to Achievement	.231*	.483*
Peer Influence to Attitude	-.010	-.086*
Motivation to Attitude	.676*	.683*
Classroom Environment to Attitude	.212*	.267*
Teacher to Attitude	.069	.210*
Home Environment to Attitude	-.027	-.064
Father's Education to Attitude	.066	.079
Mother's Education to Attitude	-.031	-.006
Prior Achievement to Attitude	-.083*	-.051
Frequency of Homework to Attitude	.059	.016
Time on Homework to Attitude	.040	.103*
Correction of Homework to Attitude	-.002	-.069*
Television to Attitude	-.009	.040
Classroom Environment to Achievement	.239*	.096
Teacher to Achievement	-.172*	-.309*
Father's Education to Achievement	-.023	.009
Mother's Education to Achievement	.016	-.015
Ability to Achievement	.348*	.353*
Prior Achievement to Achievement	.520*	.436*
Frequency of Homework to Achievement	.017	.041
Time on Homework to Achievement	-.125*	-.033
Correction of Homework to Achievement	.029	.047
Television to Achievement	-.008	-.023

Table 6

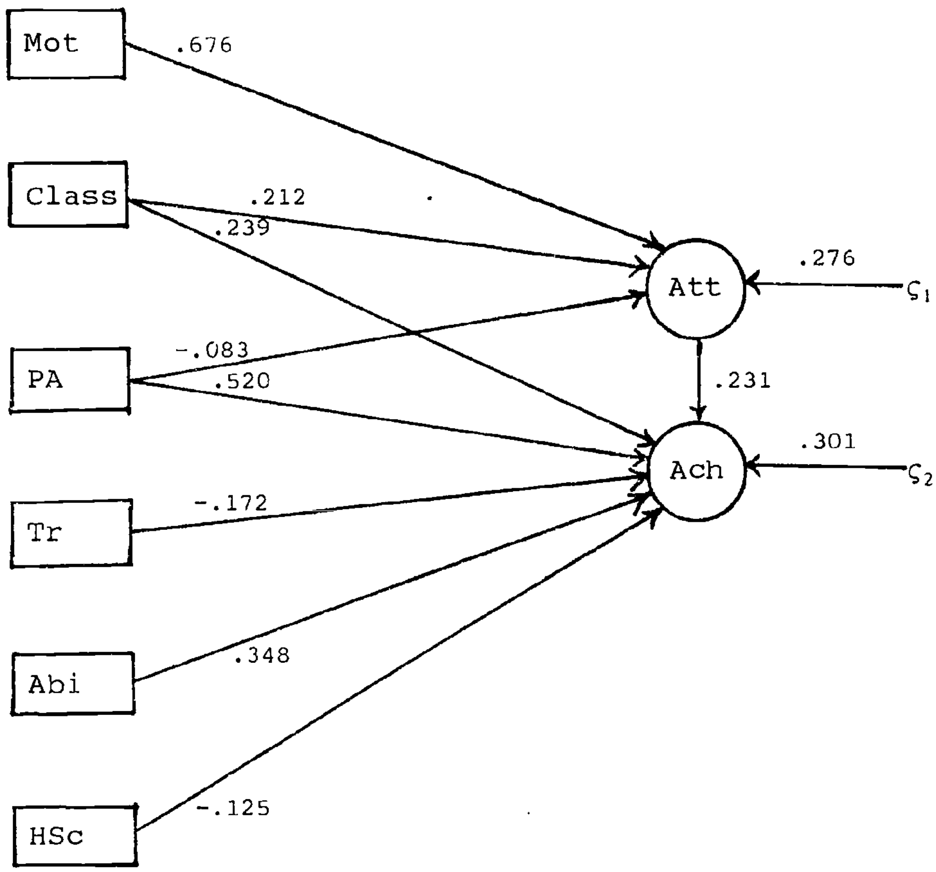
Maximum Likelihood Estimates (Unscaled Solution) for the Girls and Boys (Standard Errors in Parentheses)

Parameters	Girls	Boys
Attitude to Achievement	.196(.047)	.474(.069)
Peer Influence to Attitude	-.013(.038)	-.098(.035)
Motivation to Attitude	.743(.035)	.688(.034)
Classroom Environment to Attitude	.214(.041)	.248(.038)
Teacher to Attitude	.072(.038)	.183(.034)
Home Environment to Attitude	-.026(.029)	-.064(.033)
Father's Education to Attitude	.055(.029)	.054(.028)
Mother's Education to Attitude	-.029(.032)	-.005(.031)
Prior Achievement to Attitude	-.004(.001)	-.003(.002)
Frequency of Homework to Attitude	.063(.035)	.017(.035)
Time on Homework to Attitude	.043(.034)	.104(.034)
Correction/Homework to Attitude	-.002(.023)	-.050(.024)
Television to Attitude	-.006(.021)	.024(.019)
Classroom to Achievement	.205(.055)	.088(.058)
Teacher to Achievement	-.152(.050)	-.265(.051)
Father's Education to Achievement	-.017(.037)	.006(.040)
Mother's Education to Achievement	.013(.042)	-.011(.043)
Ability to Achievement	.306(.047)	.281(.040)
Prior Achievement to Achievement	.020(.002)	.021(.003)
Frequency/Homework to Achievement	.016(.045)	.042(.048)
Time on Homework to Achievement	-.115(.043)	-.033(.049)
Correction/Homework to Achievement	.019(.030)	.034(.034)
Television to Achievement	-.005(.027)	-.014(.027)
Measurement Error in Attitude	.033	.212
Measurement Error in Achievement	.279	.318

Table ~

Difference in Parameters between the Girls and Boys
(Standard Errors in Farentheses)
(Significant Differences Marked with Asterisks)

Parameters	Difference	t
Attitude to Achievement	.278(.083)	3.349*
Peer Influence to Attitude	.085(.052)	1.635
Motivation to Attitude	.055(.049)	1.122
Classroom Environment to Attitude	.034(.056)	.607
Teacher to Attitude	.111(.051)	2.176*
Home Environment to Attitude	.038(.044)	.864
Father's Education to Attitude	.001(.040)	.025
Mother's Education to Attitude	.024(.045)	.533
Prior Achievement to Attitude	.001(.002)	.500
Frequency of Homework to Attitude	.046(.049)	.939
Time on Homework to Attitude	.061(.048)	1.271
Correction/Homework to Attitude	.048(.033)	1.455
Television to Attitude	.018(.028)	.643
Classroom to Achievement	.117(.080)	1.463
Teacher to Achievement	.113(.071)	1.592
Father's Education to Achievement	.011(.054)	.204
Mother's Education to Achievement	.002(.060)	.033
Ability to Achievement	.025(.062)	.403
Prior Achievement to Achievement	.001(.004)	.250
Frequency/Homework to Achievement	.026(.066)	.394
Time on Homework to Achievement	.082(.065)	1.262
Correction/Homework to Achievement	.015(.045)	.333
Television to Achievement	.009(.038)	.237

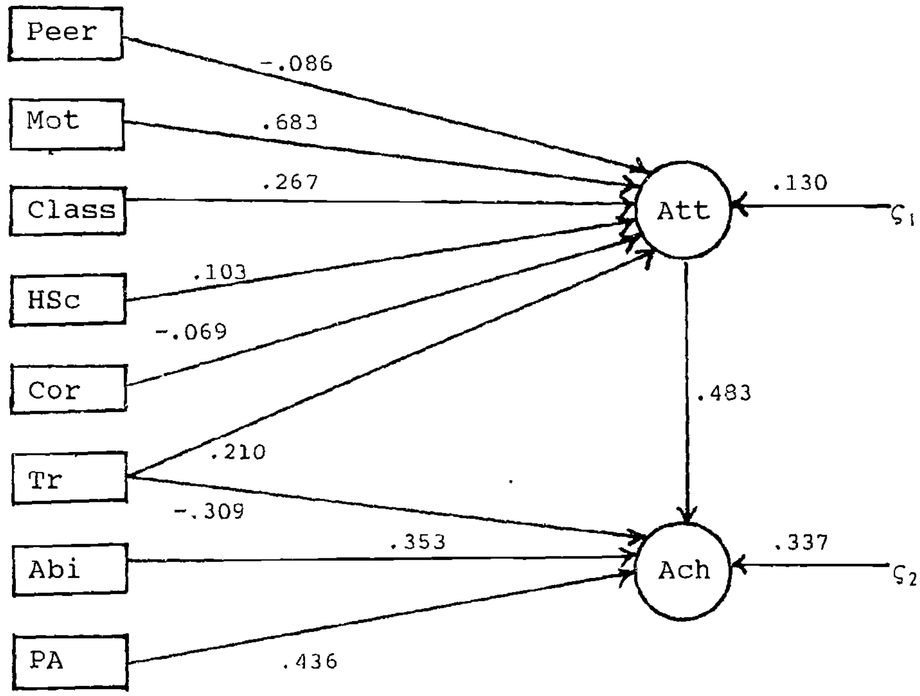


Legend:

Mot - Motivation Instrument
HSc - Time Spent on Science Homework
Class - Classroom Environment Instrument
PA - Prior Achievement Test
Tr - Perception of Science Teacher Instrument
Abi - Ability Test
Att - Attitudes to Science
Ach - Achievement in Science

Figure 1

Path Diagram of Causal Model for Educational Productivity for Science for Secondary-two Singaporean Girls



Legend:
Peer - Peer Influence Instrument
Mot - Motivation Instrument
Class - Classroom Environment Instrument
HSc - Time Spent on Science Homework
Cor - Correction of Science Homework
Tr - Perception of Science Teacher Instrument
Abi - Ability Test
PA - Prior Achievement Test
Att - Attitudes to Science
Ach - Achievement in Science

Figure 2

Path Diagram of Causal Model for Educational Productivity for Science for Secondary-two Singaporean Boys