CHAPTER 8

RESULTS OF MULTILEVEL ANALYSES

8.1 INTRODUCTION

Multilevel models address the statistical problems involved in simultaneously assessing factors at the classroom or school level and student-level factors operating within an educational context, and have been used in a number of studies (Raudenbush & Bryk, 1997). The multilevel models generated also provide the opportunity to explain why achievement may vary across classrooms or schools and why the individual distribution in achievement also may vary within classrooms (Fuller & Clarke, 1994). Furthermore, the development of multilevel analysis allows comparative researchers to carefully consider the distribution of school and student factors across differing communities, allowing researchers to formally conditionalize (operationalize) empirical findings (Riddell, 1989). This has occurred because of advances in analytic methods that depend on computer speed and processing.

The purpose of this chapter is to explore the extent to which factors at the student, classroom, and school level influence science achievement, and is guided by the main research question, which is: ***To what extent do the factors derived from the analysis explain the differences in the achievement of Korean and South African students?***. The question is operationalized by four specific questions, as follows:

1. Which factors influencing achievement are generic when comparing Korea and South Africa?
2. Which factors influencing achievement are specific to Korea?

3. Which factors influencing achievement are specific to South Africa?
4. How do these generic and specific factors explain the difference in the performance of the two countries?

Multilevel analysis is considered appropriate to address these questions as presented in Chapter 1. The results of the preliminary analyses identified factors functioning in each country and factors that have significant correlations with student science achievement. In order to identify the amount of the variance explained, considering the nested structure of the education system, multilevel analysis was carried out applying MLwiN. The analysis aims to show the degree to which the variables of each level explain the variation of student science achievement and which particular factors stand out as statistically significant predictors in the two countries.

Prior to running MLwiN, the preparation of the data and the selection of the variables included in the analysis are described in Section 8.2. Thereafter, the null multi-level model is presented and described in Section 8.3. Consecutively, the first level and second level models including explanatory variables are presented. The proportion of variance is explained and interaction effects follow (Section 8.3.4). In particular, the results of the multilevel analysis are explored, comparing the Korean data with the South Africa data. Finally, the chapter is summarized in Section 8.4.

8.2 PREPARATION OF THE DATA

There are some principles to consider where a model is built based on variables clustered and tested. Bos (2002) argues that items should be clustered keeping valid homogeneity both ‘empirically’ and ‘conceptually’, as stated in Chapter 7. When Howie (2002) studied a multilevel model, she considered both coherence between the conceptual framework and coefficients tested, and the simplicity of a model, which means the model should be parsimonious. Preparation of the data for multilevel analyses took into account those principles presented in Section 8.2.1. The initial model was built on the selected variables in Section 8.2.2 and the full model was developed in Section 8.2.3.

8.2.1 IDENTIFYING VARIABLES TO BE EXPLORED WITH MULTILEVEL ANALYSES

As a result of the factor, reliability, and correlation analyses, the factors were selected for inclusion in the multilevel models. The more detailed selection process at various levels was explored in Section 7.5. Once factors were identified and confirmed from the factor and reliability analyses, correlation analyses were undertaken to identify only significant relationships between factors and achievement to be explored by further analysis. Factors with a correlation coefficient of above 0.2 were identified as possible factors to be included in the multilevel models. In exploratory studies such as the current one, the value of 0.2 cannot be ignored if the sample is large (Cohen et al., 2007). Correlations between the variables selected were also considered to assess mulitcollinearity in the data.

The study used the correlations between variables to assess multicollinearity. Whether or not a variable should be dropped from the investigation is determined by taking into account both the importance of the variables in light of the conceptual framework and the absolute value of γ between variables. Where the correlation coefficient between two or more variables is above 0.6, only one variable among them remained and the rest were excluded. Korean ‘class size’ at the classroom level and ‘enrolment of all grade’ at the school level have a strong correlation, γ=0.637. Furthermore, judging from the researcher’s experience in Korean secondary schools, a larger school has more students in a classroom than a smaller school. Therefore, ‘class size’, which has a weaker correlation with science achievement, was excluded and ‘enrolment of all grade’ remained. In contrast, multicollinearity does not exist in South African data, possibly due to the many factors having already been excluded during the preliminary selection process.

The conceptual framework was also used for the selection of variables. In terms of the conceptual framework, where two or more variables represent the same construct, only one variable remained and the rest were excluded. For example, in the Korean data, 'high expectation' at the class level and 'educational ethos' at the school were highly related to each other conceptually. As regards South African data, teacher- and resource-related factors show overlapped constructs, and thus were reduced as the relationships between the factors and science achievement were empirically weak and their meanings conceptually overlapping.

Considering all the above points, 15 variables in the Korean data were identified for the multilevel modelling: eight variables including one aggregated variable at the student level, three variables at the class level, and four variables at the school variables, as presented in Table 8.1:

Table 8.1 ***Correlation coefficients of factors in Korean data***

Level	Contents in TIMSS	Factors	Correlation	% variance explained
Student	Books in the home	Books at home	0.381(**)	15
	Parents' education	Father education[12]	0.260(**)	7
	Educational expectations	Student education	0.365(**)	13
	Liking science	Liking science	0.407(**)	17
	Learning activities in science	Lecture learning	0.253(**)	6
	Computers	Computer use	0.206(**)	4
	Out-of-school activities	Study after school	0.272(**)	7
	Extra lessons/ tutoring	Extra tutor in science[@]	0.177(**)	3
Classroom	Teaching load	Time scheduled	0.231(**)	5
	Teacher interaction	Inform-interaction[@]	0.193(**)	4
	School climate	High expectation	0.285(**)	8
School	Enrolment	All grades	0.471(**)	22
	Type of community	Community size	0.369(**)	14
	Students' background	Disadvantaged	-0.509(**)	26
	Professional development	Professional development	0.229(**)	5

*Note: ** Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*
[@] *γ = below 0.2, but included due to the importance*

As for South African, 27 variables remained for the multilevel modelling: nine variables including one aggregated variable at the student level, ten variables at

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[12] mother education level also showed a strong relationship with science achievement but not as much as father' coefficient (see Table 7.45). Accordingly, father education level was selected.

the class level, and eight variables at the school variables, as presented in Table 8.2:

Table 8.2 ***Correlation coefficients of factors in South African data***

Level	Contents in TIMSS	Factors	Correlation	% variance explained
Student	Age	Student age	0.318(**)	10
	Language	Language at home	0.447(**)	20
	Books in the home	Books at home	0.213(**)	5
	Home possessions	Home possession	0.475(**)	23
	Liking science	Self-confidence	0.384(**)	15
	Safety in school	Safe school	0.351(**)	12
	Out-of-school activities	Mass media	0.274(**)	8
	Extra lessons/ tutoring	Extra science	-0.377(**)	14
	Student born in country	Country of birth	0.355(**)	13
Classroom	Age	Teacher age	0.324(**)	11
	Teaching requirement	1st degree	0.366(**)	13
	Teaching load	Time scheduled	0.210(**)	4
	Teacher interaction	Visit-interaction	-0.246(**)	6
	Class size	Class size	-0.282(**)	8
	Time spend teaching subject	Science teaching time	-0.209(**)	4
	Textbook	Textbook use	-0.293(**)	9
	Content-related activities	STS work	-0.262(**)	7
	Factors limiting teaching	Physical resource	-0.489(**)	24
	Use of homework	Basic homework	-0.203(**)	4
School	Enrolment	All grade	0.301(**)	9
	Type of community	Type of community	0.367(**)	14
	Student background	Disadvantaged	-0.616(**)	38
	School climate	Professional teaching force	0.302(**)	9
	School climate	High expectation	0.209(**)	4
	Principals' time allocation	Administrative duty	0.324(**)	11
	Principals' time allocation	Supervise & evaluate	-0.230(**)	5
	Student behaviour	Low morales	-0.208(**)	4

*Note: ** Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

There is a large discrepancy in the number of factors, in particular at the class and school level. A possible explanation for this might be that more factors at the class and school level influence student achievement in South Africa than in Korea. The descriptive statistics of the variables retained are presented in Tables 8.3 and 8.4, for Korea and South Africa respectively:

Table 8.3 *The Korean variables included in MLwiN*

Factors in the research framework	Variable in preliminary analysis	Variable in MLwiN	Description of variables	N	Mean[13]	SD	Range
Time on task	Tutorsci	Extutor	Extra tutoring in science	4876	1.51	1.33	0-3(3)
	Studyafsch	Timafsch	Study after school	4876	2.40	1.32	0-8(8)
Attitude toward science	Likescience	Liksci	Liking science	4876	16.67	4.12	7-28(21)
Social context	Bookhom	Bokhom	Books at home	4876	3.21	1.28	1-5(4)
	Edudad	Edudad	Education level of father	4876	5.13	1.65	1-8(7)
	Edustu	Edustu	School level expected by student	4876	3.99	0.74	1-5(4)
	Comuse	Comuse$^{\#}$	Computer use	4876	4.73	2.44	0-12(12)
Teacher background	Tchtotchpm	Tchtchpm$^{\#}$	Teacher interaction by information or pedagogy	137	2.80	1.26	0-6(6)
Teaching practice	Lectureag	lecturag*$^{\#}$	Lecture-centred teaching	137	2.39	0.22	1.66-2.8(1.14)
Classroom climate	Hixpect	Hixpect	High expectation	137	15.28	2.80	8-24(16)
Time for learning	Ttimew	Timspw$^{\#}$	Time scheduled/week	137	2.25	0.37	1.5-3.5(2)
Professional teaching force	Profdevelop	Profdeve	Professional development	137	4.48	1.65	1-10(9)
School climate	Enrtot	Schsize	Enrolment of all grades	137	4.25	1.36	1-7(6)
	Citysize	Citysize$^{\#}$	Type of community	137	5.05	1.21	1-6(5)
	Studis	Disadva	Percentage of disadvantaged students	137	2.01	0.91	1-4(3)

Note: ** aggregated variable*
$^{\#}$ *non-significant variables according to the multilevel analysis*

The variables as shown in Tables 8.3 and 8.4 were grouped under the factors defined in the conceptual framework. More specifically, the variables selected were classified in terms of the conceptual framework of the research, of which key concepts are ‘quality’, ‘time’, and ‘opportunity’. Instructional quality at the classroom level is classified with ‘teacher background’, ‘science curriculum’, ‘teaching practice’, ‘classroom climate’, and ‘physical resource’. Quality at the school level is specified with ‘curriculum management’, ‘professional teaching force’, ‘school climate’, and ‘resource’.

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[13] The options of items were recoded within each range shown in the Table and ‘Mean’ value is the average of scores recoded. This holds for the ‘Mean’ of Table 8.4.

Table 8.4 *The South African variables included in MLwiN*

Factors in the research framework	Variable in preliminary analysis	Variable in MLwiN	Description of variables	N	Mean	SD	Range
Time on task	Tutorsci	Extutor	Extra tutoring in science	6784	1.47	1.09	0-3(3)
Attitude toward science	Selfconsci	Selfcon	Self-confidence in science	6784	7.41	2.42	3-12(9)
Social context	Agesy	Agestu	Student age	6784	3.26	1.20	1-5(4)
	Stucon	Boncnty	Country of birth	6784	0.65	0.48	0-1(1)
	Languas	Languag	Student language at home	6784	1.33	0.94	0-3(3)
	Bookhom	Bokhom$^{@}$	Books at home	6784	1.97	1.13	1-5(4)
	Hompos	Hompos	Home possession	6784	6.13	2.99	0-11(11)
	Watvi	Media	Watch TV or video after school	6784	1.67	1.41	0-4(4)
Science curriculum	Textuse	Textuse	Textbook use	198	0.92	0.27	0-1(1)
Teacher background	Agetcher	Agetch	Teacher age	198	3.05	0.82	1-5(4)
	Reqgrad	1stdeg	Complete the first degree	198	0.18	0.38	0-1(1)
	Tchtotchvo	Tchtchvo$^{\#}$	Interaction by visit or observation	198	1.20	1.45	0-6(6)
Teaching practice	Useofhw	Basichw$^{\#}$	Use of homework(basic homework)	198	3.72	0.60	1-4(3)
	STS	STS	STS-centred teaching	198	7.13	2.40	2-12(10)
Physical resources	Phyresource	Phyres	Physical resource for science lesson	198	9.94	4.16	0-15(15)
	Clasize	Clasize	Number of students in class	198	4.41	1.58	1-7(6)
Time for learning	Ttimew	Timspw$^{\#}$	Scheduled time/week	198	2.87	1.38	1-5(4)
	Ttimts	Ttimpw$^{\#}$	Science teaching time/week	198	4.40	1.86	1-8(7)
Professional teaching force	Pcaddu	Admindt	Principal administrative duty	198	3.33	1.55	1-7(6)
	Pcsuevt	Supevdt	Supervise or evaluate as principal duty	198	2.05	1.05	1-7(6)
	Proftchingf	Proftchf$^{\#}$	Professional teaching force	198	13.97	2.46	7-20(13)
School climate	Enrtot	Schsize$^{\#}$	Enrolment of all grades	198	3.04	1.35	1-7(6)
	Citysize	Citysize$^{\#}$	Type of community	198	3.12	1.58	1-6(5)
	Studis	Disadva	Percentage of disadvantaged students	198	3.76	0.68	1-4(3)
	Hixpect	Hixpect$^{\#}$	High expectation	198	5.67	1.64	2-10(8)
	lowmorals	Lomoral	Severity of low morale	198	4.37	2.16	0-8(8)
	Safeschag	Safschag*	Safety in school	198	2.39	0.54	1.27-3.87(2.6

*Note: * aggregated variable*
$^{\#}$ *non-significant variables according to the multilevel analysis*
$^{@}$ *deleted variable due to low deviance improvement*

TIMSS collected contextual information at four levels, viz., student, class, school and context (or country) level, and the current study examined three levels among them, excluding context level. Although there are three-level questionnaires examined, as TIMSS sampled one class per school, the data from class level and school level were not distinct from each other. If more than one class per school are sampled, one can explore the variance between classes within a school. Therefore, the study built a two-level model representing the student and class/school level, just as other studies had previously addressed using TIMSS data (Bos, 2002; Howie, 2002). Accordingly, the multilevel analyses used a two-level model that consists of student and class/school level.

8.2.2 THE INITIAL MULTILEVEL MODEL

The MLwiN software was used to specify a two-level model. Even though there are three-level questionnaires, since TIMSS 2003 was addressed to one classroom per school, there are no between-class variations within the school observed. Therefore, a two-level model was built, representing the student and class/school level. The model built here is to explain the variation in science scores between students (within schools) and between schools by the explanatory variables.

A two-level model for Korea was proposed in Figure 8.1 (below). The direct relationship between the variables at each level and science achievement was investigated, and it was presumed according to the results summarized previously that seven variables at the student level and eight variables at the classroom/school would have an effect on science achievements of Korean students. The model proposed here can be compared to the final model in Chapter 9.

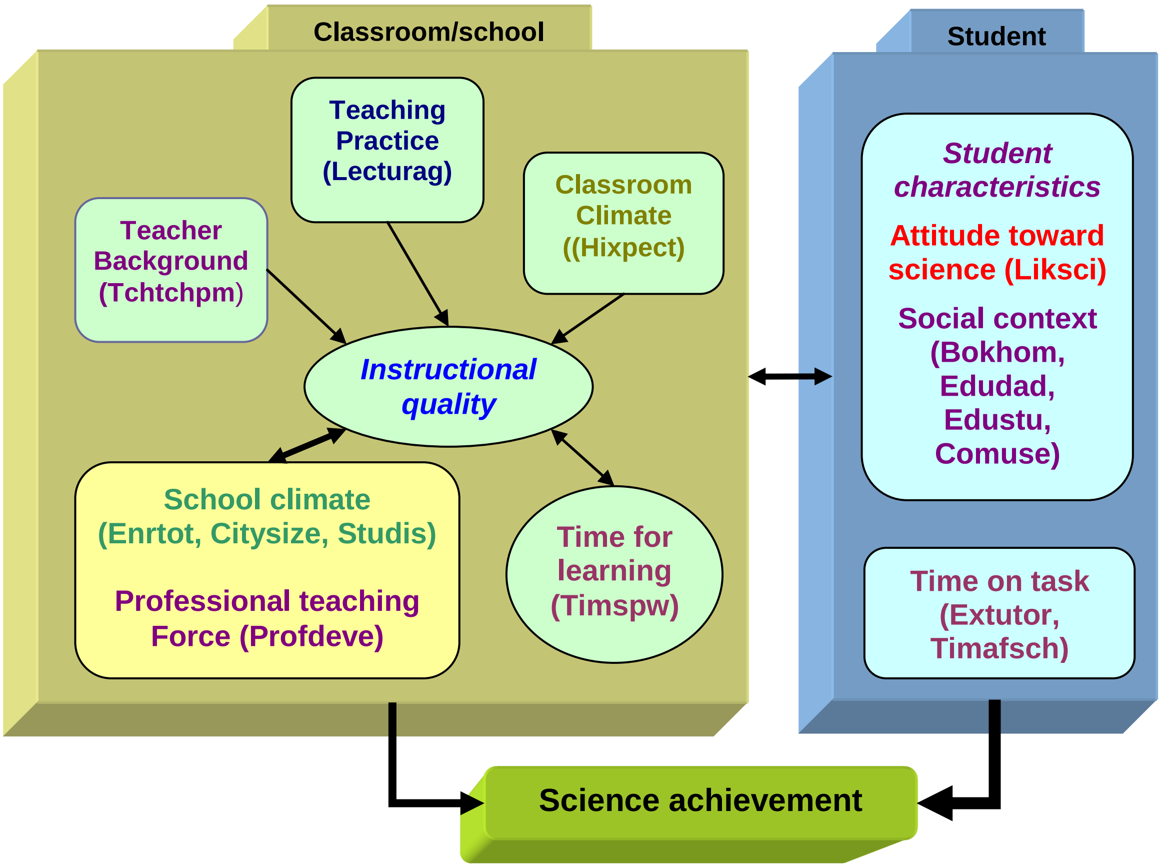

Figure 8.1 **Korean model proposed for multilevel analyses**

The South African two-level model proposed for multilevel analyses is presented in Figure 8.2 (below). The direct relationship between each independent variable and science achievement was examined. It is presupposed based on the results identified previously, that eight variables at the student level and 19 variables at the classroom/school would influence student achievement in science in South Africa. The model proposed for South Africa can be contrasted to the final model shown in Chapter 9.

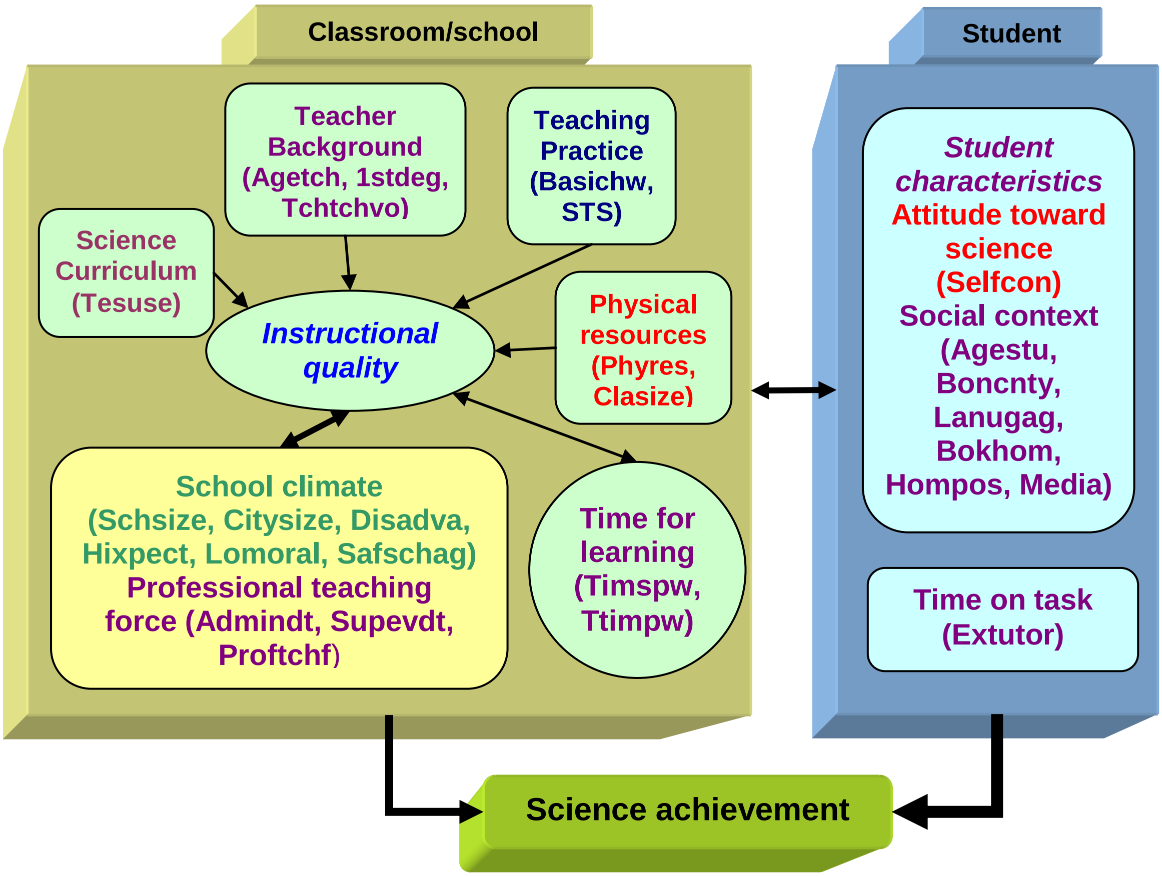

Figure 8.2 **South African model proposed for multilevel analyses**

8.2.3 APPROACH TO MODEL BUILDING

A data set was compiled in preparation for model building which had no missing data prior to testing the model presented above. All the student, teacher, and school level variables were merged into one dataset in the SPSS programme. The identifiers in the multilevel analysis are school and student. The data set was sorted according to these variables. Ultimately, 137 schools and 4,876 students in Korea were included in the analysis. Regarding South Africa, 198 schools and 6,784 students were included in the multilevel analysis (see Tables 8.3 and 8.4, above).

The multilevel analyses were developed from the null model to the final model. As added explanatory variables increase, the estimated number of parameters increases and thus it makes the model complicated. Therefore, starting with the simplest possible model is preferable (Hox, 2002), and it makes it possible to see if a multilevel modelling is appropriate and how many levels should be included. Explanatory variables at the student level and class/school level were added to the model built on a one-by-one basis. In particular, the model built here used fixed regression coefficients along with variance components, since fixed parameters are considered as likely to be estimated with much more precision than random parameters (Hox, 2002).

Once each variable was added, significance testing of the newly produced parameter was carried out by means of a Z-test, and the contribution to the model was examined by identifying any change in the deviance. The difference (chi-square variant) of the deviance from the model under investigation to the null model was computed to find out whether or not there was any improvement in each consecutive model (Hox, 2002).

There were a number of variables retained as significant in the two datasets after the multilevel analysis for the student level and class/school level. However, it is important to note that multilevel modelling can avoid making the built model complicated and the interpretation difficult (Hox, 2002). Rather, researchers can make a clearer and stratified interpretation of phenomenon by means of multilevel modelling. For that reason, interaction effects across levels were examined by more limited models, with only those parameters that have been proven worth examining by previous research, or being of special interest from the perspective of the conceptual framework (Hox, 2002).

8.3 THE RESULTS OF THE MULTILEVEL ANALYSES

There were many models run, however, for the purposes of presentation only the final models are included in this chapter, and all the models run are included in Appendix K and L. First, the null model was presented, along with the deviance (Section 8.3.1). Thereafter, the student model and the student-class/school model followed (Section 8.3.2 and 8.3.3). The proportion of variance explained at each model is described and finally the interaction effects are discussed (Section 8.3.4).

8.3.1 THE NULL MODEL

The null model or intercept-only model contains only the dependent variable (science achievement score) with no explanatory variables, which refer to student or class/school level variables (Hox, 2002). The null model is a base on which consecutive models can be built and evaluated. The null model makes it possible to estimate the total variance in the science score. Accordingly, it can help to estimate how the variation in students' achievement was divided into between-students variance and between-schools variance without any explanatory variables (Howie, 2002).

The null model specified in the first step of running the two-level model is:

$$\text{Achievement}_{ij}=\beta_0+u_{0j}+\text{e}_{ij}$$

where achievement$_{ij}$ is the specific score on the science of the i^{th} student of the j^{th} school, written as the sum of:

β_0 : the intercept (the grand mean of the science scores)
u_{0j} : the average score of the j^{th} school
e_{ij} : a residual part, the student error term.

As shown in Table 8.5 (below), the intercept of the null model for Korea is 558 (1.878), which is equivalent to the result of Table 6.1. The variance of the residual part for the student level is 4646 (95.445), and 350 (58.353) for the class/school level. The standard errors are all smaller than the estimated parameters. To evaluate whether or not these parameters are significant, the Wald test, referred to as the Z-test, was employed. Z values can be calculated with the formula 'Z=parameter/SE' and compared to a standard normal distribution. The result was that all parameters were statistically significant at $p<0.001$, which means that effects depending on levels do exist and variables from the two levels should be included.

The results of the null model for Korea reveal the overall variation in science achievement is derived predominantly from between-students variance (93%), while only about 7% of the variation comes from between-schools variance in the Korean data (see Table 8.8). This means that within the country the differences between schools in Korea were quite small. This result is consistent with the previous research undertaken in other developed countries (Kupari, 2006).

Table 8.5 ***The null models***

Effects	**Null model**			
	KOREA		SOUTH AFRICA	
	Coefficient	Standard error	Coefficient	Standard error
Fixed effects				
Intercept	558.307	1.878	245.040	7.223
Random effects				
σ^2_e	4646.078	95.445	7034.088	122.582
σ^2_{u0}	350.446	58.353	10109.060	1037.217
Deviance	55187.250		80118.130	

The intercept of the null model for South Africa is 245 (7.223), which is almost equivalent to the result of Table 6.1. The variance of the residual error term is 7034 (122.582) for the student level and 10109 (1037.217) for the class/school level respectively. The standard errors are smaller than estimated parameters as in Korea. The result of the Z-test indicated that all parameters were statistically significant at $p<0.001$, implying that effects derived from the two levels are worth examining.

The null model for South Africa can also be used to estimate the intra-class correlation, which is referred to as the proportion of the total residual variation that is attributed to differences between schools. As for the explained proportion of the total residual variation, 41% of the variation in science achievement is attributable to student level and 59% is the proportion of the total residual variation derived from between-schools variance (see Table 8.9, below). This is the opposite of what was observed in the Korean data and consistent with previous research (Howie, 2002; Scherman, 2007). Howie (2002) found that 55% of the variance explained was on the school level, and 45% of the variance was on the student level in South Africa using mathematics in TIMSS-R. Scherman (2007) documented 46% of the total variance as attributable to the school level, 5% to the teacher level, and 49% to the student level in the study to ascertain which factors influence the performance of South African learners on the Middle Years Information System assessment.

8.3.2 STUDENT MODEL

Once the null model was explored, the student-level model was built. In this model, students' background variables were added to the model as explanatory variables to estimate how much of the variance the student-level variables explain before considering the class/school-level variables. The student-level model was specified by the following equation:

$$\text{Achievement}_{ij} = \beta_{0j}+\beta_{10}X_{ij}+e_{ij}$$

Where $\beta_{0j} = \beta_0+u_{0j}$ and β_{10} is the intercept for X_{ij} which represents explanatory variables at the student level. The explanatory variables were included consecutively as the model was developed. As each individual variable was added, the contribution of the explanatory variable was assessed in order to ascertain whether the variable improved the model. The equations for the two countries are described in more details in Section 8.3.2.1 for Korea and Section 8.3.2.2 for South Africa.

8.3.2.1 Student-level model for Korea

The student-level model was progressed from the null model by including variables on a one-by-one basis. The student-level model was developed separately for each country. Using variable labels included instead of algebraic symbols, the equation for Korea reads:

$$\text{achKOR}_{ij}=\beta_{0j}+\beta_1\text{liksci}_{ij}+\beta_2\text{bokhom}_{ij}+\beta_3\text{edustu}_{ij}+\beta_4\text{timafsch}_{ij}+\beta_5\text{edudad}_{ij} \\ +\beta_6\text{extutor}_{ij}+e_{ij}$$

The variables above were inserted one-by-one into the model to estimate the effect of each variable according to the step-by-step procedure described in Chapter 5. Six out of seven variables selected for the multilevel analysis in Korea were statistically significant, as shown in Table 8.6 (below). ‘Computer use’ (comuse) was not significant at the student level in Korea. In particular, ‘attitudes towards science’ (liksci) proved to be clearly the strongest predictor for the between-students variance and increased the percentage of explained variance by 16% points. With a closer look at Table 8.3 and Table 8.6, a student who has a highly positive interest in science may score the most, with 101 (4.821*21=101.241) points more than a student who has an extremely negative attitude toward science. In addition, a student who takes extra tutoring and spends more time studying after school, will score up to 56 points more than a student who does nothing related to science after school (5.715*8 + 3.360*3=55.8). Likewise, a student who has more books in the home and a more educated father will score 71 points more than a student who does not (11.901*4+3.352*7=71.068). The more a student expects to move into higher-education, the better s/he may score, by up to 76 points (18.901*4=75.604). To sum up, variables that can be manipulated or developed by education practice, such as ‘attitudes towards science’ and ‘time on task’, resulted in a significant effect on science achievement, which means it is worth making an effort to improve them.

Table 8.6 ***Multilevel analyses of the Korean dada***

Model	**Null model**	**Student model**	**Class/school model**
Fixed effects			
Student level			
	Coefficient(SE)	Coefficient(SE)	Coefficient(SE)
Intercept	558.307(1.878)	329.016(5.459)	319.418(9.634)
Attitude toward science			
Liksci		4.821**(0.212)	4.759**(0.211)
Social context			
Bokhom		11.901**(0.701)	11.779**(0.698)
Edustu		18.901**(1.199)	18.993**(1.195)
Time on task			
Timafsch		5.715**(0.659)	5.683**(0.656)
Social context			
Edudad		3.352**(0.551)	2.878**(0.554)
Time on task			
Extutor		3.360**(0.639)	3.309**(0.636)
Class/school level			
School climate			
Disadva			-5.417**(1.181)
Schsize			1.656*(0.776)
hixpect			0.747*(0.371)
Professional teaching force			
Prodeve			1.305*(0.614)
Random effects			
σ^2_e	4646.078(95.445)	3225.629(66.264)	3223.994(66.223)
σ^2_{u0}	350.446(58.353)	91.298(22.076)	43.997(16.357)
Deviance	55187.250	53325.210$^{\#}$	53281.750$^{\#}$

Note: N=4876 learners in 137 schools
*** t-value > 2.58 a confidence interval of 99%*
** t-value > 1.96 a confidence interval of 95%*
$^{\#}$ Deviance from null model to present model is significant at 0.01

The variance in science achievement at student level, (Table 8.6, above) describes the changes occurring in that variance when different background variables are controlled. As can be seen in Table 8.6, the difference between the deviances of the student model and the null model are highly significant. This deviation is a measure of the likelihood of the appropriateness of the student model as compared to the null model. It is considered that the student model (53325) improved significantly when compared to the null model (55187).

8.3.2.2 Student-level model for South Africa

Based on the null model, a student-level model for South Africa was developed similar to the one for Korea. The equation for South Africa using variable labels included is:

$$\mathrm{achRSA}_{ij}=\beta_{0j}+\beta_1\mathrm{selfcon}_{ij}+\beta_2\mathrm{boncnty}_{ij}+\beta_3\mathrm{agestu}_{ij}+\beta_4\mathrm{tutorsci}_{ij}+\beta_5\mathrm{media}_{ij}$$
$$+\beta_6\mathrm{languag}_{ij}+\beta_7\mathrm{hompos}_{ij}+e_{ij}$$

With regard to South Africa, seven out of eight student-level explanatory variables identified in Table 8.4 were statistically significant as shown in Table 8.7 (below), and one variable, ‘books at home (bokhom)’, was excluded because this variable did not improve the deviance, indicating the goodness of fit of the model. Therefore, no difference of deviances between the models with and without ‘books at home’ means the variable does not improve the goodness of fit of the model. As in Korea, ‘attitudes towards science’ (selfcon) proved to be the strongest predictor when using the South African data for the between-students variance and increased the percentage of explained variance by 8% points (see Appendix L). A student who has more self-confidence in science may score 73 points higher than a student who has an extremely lower level of self-confidence in science (8.162*9=73.458), and given that the intercept of the null model was 245 points, self-confidence in science can be thought of as having a great effect on science achievement. It is also revealed that social context concerning ethnicity, such as ‘born-in country’ (boncnty) and language at home (languag), have an influence on science achievement. A student who was born outside the country, which might mean an immigrant, scored less by 43 points than natives (43.060*1=43.060), and students who speak the language used in the test at home more often may score up to 40 points more than those who do not (13.319*3=39.957). Variables such as ‘watch TV or video after school’ (media) and ‘home possession’ (hompos) also turned out significant. A student who watches TV or video after school scored up to 25 points more than others (6.360*4=25.44), and the more students have possession in their home the better they scored, up to 31 points (2.805*11=30.855). The oldest students scored 43 points less than the youngest students in classrooms (10.809*4=43.236). Students who took extra tutoring in science, besides regular classes, scored 32 points less than those who did not (10.638*3=31.914).

The results do not differ substantially when compared to those using the Korean data in terms of the factors such as ‘attitudes towards science’, ‘social context’, and ‘time on task’. However, a closer look at the specific variables under each factor revealed a slightly different picture. For example, ‘attitudes towards science’ in Korea cover ‘liking science’ and ‘self-confidence in science’ (see Section 7.2.1.1). In contrast, ‘attitudes towards science’ in South Africa only means ‘self-confidence in science’ (see Section 7.2.1.2), which has a narrower coverage than in Korea. In addition, ‘time on task’ influences science achievement in reverse in the two countries. It can be said from a policymaker’s point of view that the two countries have in common variables that can be manipulated or developed by interventions. For example, the results show that ‘attitudes towards science’ and ‘time on task’ have more influence on science achievement than other variables such as ‘social context’. Research has documented that teachers or schools can improve those factors by some intervention, and thus student achievement (Dechsri et al, 1997; Freedman, 1997; Odom et al., 2007). Nonetheless, the results are still subject to change, depending on the addition of other variables.

Table 8.7 ***Multilevel analyses of the South African data***

Model	Null model	Student model	Class/school-model
Fixed effects			
Student level			
	Coefficient(SE)	Coefficient(SE)	Coefficient(SE)
Intercept	245.040(7.223)	92.750(7.032)	135.674(29.915)
Attitude toward science			
Selfcon		8.162**(0.412)	8.102**(0.411)
Social context			
Boncnty		43.060**(2.204)	41.934**(2.183)
Agestu		10.809**(0.739)	10.868**(0.733)
Time on task			
Extutor		-10.638**(0.967)	-9.983**(0.963)
Social context			
Media		6.360**(0.701)	6.453**(0.699)
Languag		13.319**(1.351)	13.029**(1.323)
Hompos		2.805**(0.413)	2.809**(0.408)
Class/School level			
School climate			
Safschag			49.986**(5.295)
Disadva			-27.896**(4.566)
Physical resource			
Phyres			-3.050**(0.703)
Teacher background			
1stdeg			16.977**(7.322)
Professional teaching force			
Admindt			3.809*(1.813)
Teacher background			
Agetch			10.891**(3.171)
Science curriculum			
Textuse			-28.560**(10.153)
Resource			
Clasize			-2.878*(1.598)
Teaching practice			
STS			-2.197*(1.109)
Professional teaching force			
Supevdt			-6.592**(2.718)
School climate			
Lomoral			-2.165*(1.217)
Random effects			
σ^2_e	7034.088(122.582)	5609.017(97.749)	5608.399(97.738)
σ^2_{u0}	10109.060(1037.217)	4633.674(482.463)	1089.370(126.504)
Deviance	80118.130	78475.770$^{\#}$	78210.480$^{\#}$

Note: N=6784 learners in 198 schools, $^{\#}$ Deviance from null model to present model is significant at 0.01
** t-value > 1.96 a confidence interval of 95%, ** t-value > 2.58 a confidence interval of 99%*

In terms of social context, educational factors such as ‘books at home’, ‘parent education level’, and ‘students’ expectation of higher education’ were significant in Korea. In contrast, ethnical factors such as ‘born-in country’ and ‘students’ language at home’ were significant effectors in South Africa.

8.3.3 CLASS/SCHOOL-LEVEL MODEL

Once the student model was confirmed, the class/school level variables were added to the student model step-by-step, resulting in the class/school model. The model can be written as:

$$\text{Achievement}_{ij} = \beta_{0j}+\beta_{10}X_{ij}+ \beta_{01}Z_j+e_{ij}$$

where β_{01} is the intercept parameter for Z_j it represents explanatory variables at the class-school level. The equations of the class/school model for the two countries are presented in more details in Section 8.3.3.1 for Korea and Section 8.3.3.2 for South Africa.

8.3.3.1 Class/school-level model for Korea

Class/school-level models were built in accordance with the procedure outlined in Section 5.10.2. Using variable labels instead of algebraic symbols, the equation for Korea reads:

$$\text{achKOR}_{ij}=\beta_{0j}+\beta_1\text{liksci}_{ij}+\beta_2\text{bokhom}_{ij}+\beta_3\text{edustu}_{ij}+\beta_4\text{timafsch}_{ij}+\beta_5\text{edudad}_{ij}$$
$$+\beta_6\text{extutor}_{ij}+\beta_7\text{disadva}_j+\beta_8\text{schsize}_j+\beta_9\text{hixpect}_j+\beta_{10}\text{prodeve}_j +e_{ij}$$

The equations above represented only the variables that were statistically significant. Whereas most of variables added at the student level have a significant effect on science achievement, with only a single variable being not significant in the two countries respectively, there are many class/school-level variables which turned out as non-significant effects on science achievement when added to the second model. Non-significant variables include ‘teacher interaction by material or pedagogy’ (tchtchpm), ‘lecture-centred teaching’ (lecturag), ‘time scheduled per week’ (timspw), and ‘type of community’ (citysize). Accordingly, of eight class/school-level variables in the Korea data, only four variables were statistically significant.

Taking a closer look at a specific variable, ‘percentage of disadvantaged students’ (disadva) emerges as the strongest predictor at the class/school level. The more schools have students who come from disadvantaged homes, the worse the students fared, by up to 16 points (5.417*3=16.251). The larger schools performed better by 10 points (1.656*6=9.936), and a stronger educational ethos such as ‘high expectation’ (hixpect) resulted in a higher performance by up to 12 points (0.747*16=11.952). The more teachers are involved in professional development, the better their students fared, by up to 12 points (1.305*9=11.745).

8.3.3.2 Class/school-level model for South Africa

As in Korea, the equation for South Africa can be represented using variable labels instead of algebraic symbols, as:

$$
\begin{aligned}
&\text{achRSA}_{ij}=\beta_{0j}+\beta_{1}\text{selfcon}_{ij}+\beta_{2}\text{boncnty}_{ij}+\beta_{3}\text{agestu}_{ij}+\beta_{4}\text{exturtor}_{ij}+\beta_{5}\text{media}_{ij}\\
&+\beta_{6}\text{languag}_{ij}+\beta_{7}\text{hompos}_{ij}+\beta_{8}\text{safschag}_{j}+\beta_{9}\text{disadva}_{j}+\beta_{10}\text{phyres}_{j}+\beta_{11}\text{1stdeg}_{j}\\
&+\beta_{12}\text{admindt}_{j}+\beta_{13}\text{agetch}_{j}+\beta_{14}\text{textuse}_{j}+\beta_{15}\text{clasize}_{j}+\beta_{16}\text{STS}_{j}+\beta_{17}\text{supevdt}_{j}\\
&+\beta_{18}\text{lomoral}_{j}+e_{ij}
\end{aligned}
$$

Unlike the Korean results, the South African results have more variables that are significant after non-significant variables were removed. Among 19 class/school variables tested, 11 variables remained statistically significant. It also happened that when a variable was first added to the equation, it had a significant effect, but when the next variable was added the variable was no longer significant, as was the case with variables such as ‘type of community’ (citysize), enrolment of all grades’ (schsize), and ‘interaction by visit or observation’ (tchtchvo). There might be some effects that cancel each other out, or are related to each other (Howie, 2002).

An aggregated variable, ‘safety in school’ reported by students (safschag) was the strongest predictor at the class/school level. A student who thinks that s/he attends a school in which the less bullying happens may perform better by 130 points (49.986*2.6=129.9636). Given that the initial intercept was 245 points, this is a substantial result. Other variables concerning school climate, such as ‘percentage of disadvantaged students’ (disadva) and ‘severity of low morale’ (lomoral) were also significant.

With regard to resource variables, ‘physical resource for science’ (phyres) and ‘number of students in class’ (clasize) turned out to have significant effects. A science curriculum variable, ‘textbook use’ (textuse), was statistically significant. It is however surprising that textbook use in class negatively influences student achievement by up to 29 points (-28.560*1=-28.560). A possible explanation might be that using a textbook means reading the text only, without any explanation. Judging from the researcher’s experience in secondary schools it is not enough to read the text when teaching scientific knowledge and skills to students. It should be translated corresponding to students’ cognitive development stage. From the descriptive statistics, it was previously found that South African teachers tend to use textbooks as a supplementary resource. As mentioned in the preliminary analysis, there is a need for further research to ascertain how teachers are actually using science textbooks in their classes.

Among the teacher background variables, there were two variables that were statistically significant, namely ‘completion of the first degree’ (1stdeg) and ‘teacher age’ (agetch). Students whose teachers were older or more experienced, and had completed the first degree, performed better than the others, with up to 61 points (43.564*4+16.977*1=60.541).

Professional teaching force, which was defined as educational leadership (see Section 3.3.5.2), and in particular educational leadership by principals, was evidenced as an effective factor in research. There were two variables that explained student achievement with statistical significance, namely ‘administrative duty’ (admindt) and ‘supervising or evaluating teachers’ (supevdt). It is predicted that the more devoted the principal is to administrative duty and the less involved in supervising or evaluating teachers, the better the students performed in science, by up to 62 points (3.809*6+6.592*6=62.406).

South Africa has more variables that are significant at the class/school level than Korea. In particular, resource- and teacher background-related factors such as ‘physical resource for science lesson’ (phyres) or ‘completion of first degree’ (1stdeg) influenced student science achievement in South Africa. Of interest is that only a single variable, ‘percentage of disadvantaged students’ (disadva), is significant in both countries at the classroom/school model. For the most part, variables that accounted for student science achievement in each country are quite different as compared in Table 8.3 and Table 8.4. This might imply that factors influencing student achievement are common across the countries; however, the educational condition of each country only exposes which one is more urgent or significant at that present time.

8.3.4 PROPORTION OF VARIANCE EXPLAINED BY THE CONSECUTIVE MODELS

By examining the change occurring in the estimates of variance after adding each set of variables, the researcher analyzed the effects of different level variables on student science achievement. The proportion of the total residual variation that is due to differences between schools, referred to as ‘intra-class correlation’, can be calculated by the formula $R^2 = \sigma^2_e/(\sigma^2_e+\sigma^2_{u0})$. Thereafter, the total variance explained by the consecutive models can be calculated by the formula $R^2_e = (\sigma^2_{e0}-\sigma^2_{e1})/\sigma^2_{e0}$ and $R^2_u = (\sigma^2_{u0}-\sigma^2_{u1})/\sigma^2_{u0}$ (Hox, 2002). After calculating the total variance, Akaike Information Criterion (AIC) was also calculated. The AIC is a fit statistic based on the deviance, and can be calculated by adding the deviance and twice the number of parameters. The lower the value of the AIC, the better the model (Scherman, 2007). The results of the calculation are described in Section 8.3.4.1 for Korea and Section 8.3.4.2 for South Africa.

8.3.4.1 Proportion of variance explained for Korea

A closer look at the Korean results shown in Table 8.8 (below) reveals that most of the variance in the null model occurred at the student level (93%), while relatively small percentages of the variance (7%) were attributable to the classroom/school level. From a point of view that the degree of variability within a classroom/school or between classrooms/schools indicates the homogeneity of the classroom or school environments where students learn (O'Dwyer, 2005), the large amount of variance explained at the student level indicates that students attending one school are really heterogeneous across the country. Likewise, the small amount of variance explained at the school level means schools in Korea do not vary much across the country. This finding is in accordance with several earlier studies in other countries using mathematics achievement (Reezigt et al., 1999; O'Dwyer, 2005; Kupari, 2006).

Table 8.8 ***Explained proportion of variance by consecutive models for Korea***

	Null model	**Student model**	**Class/school model**
Student–level Variance	0.930(93%)	0.306(30.6%)	0.306(30.6%)
Class/school-level variance	0.07(7%)	0.739(73.9%)	0.874(87.4%)
AIC	55193.25	53343.21	53307.75

The student-model explains 31% of the total variance at the student level and 74% of the variance at the class/school level in the null model (Table 8.8, above). Consecutively adding the class/school variables to the student model to some extent increased (from 74% to 87%) the proportion explained for between-schools variance, but it made no difference in view of the between-students variance (within-schools).

In the student-class/school model, the class/school-level variance is estimated at 87%, whereas 31% is estimated on the student-level. Thus, it seems clear that there are additional factors that would need to be explored at each level to account for the unexplained variance. One of the possible factors might be 'student aptitude', which is evidenced as more likely to influence student achievement as reviewed in Chapter 3 (Fraser, 1989; Lindemann-Matthies & Kamer, 2006), and TIMSS did not collect any data on aptitudes towards science, such as prior achievement or opportunities used at the student level.

The largest contributor in terms of explaining the variance within school is 'attitudes towards science' (liksci) (16%) (see Appendix K). 'Books at home' (bokhom) (8%) and 'school expected by students' (edustu) (5%), all of which are also good predictors at the student level. The greatest contributor in terms of explaining the variance between schools is 'books at home' (bokhom) (29%). 'Percentage of disadvantaged students' (disadva) (10%) and 'father education level of father' (edudad) (9%) increased the percentage of explained variance. The rest of the variables brought only a slight increase to the proportion explained both for the within and between school variance. On the whole, the added variables increased the percentage of explained variance on the class/school-level model rather than on the student-level model.

8.3.4.2 Proportion of variance explained for South Africa

The South African results revealed quite a different picture from the Korean results. As opposed to the result that Korean student achievement in science is explained mainly by the student-level variables, the class/school level variables accounted to a greater extent for the South African science achievement. More than half of the total variance in science achievement, for the null model, is on the class/school level (59%) and the rest (41%) can be explained at the student-level implying that the South African teachers and schools are heterogeneous across the country to a greater extent than in other countries, including Korea.

Table 8.9 ***Explained proportion of variance by consecutive models for South Africa***

	Null model	Student model	Class/school model
Student level variance	0.410(41.0%)	0.203(20.3%)	0.203(20.3%)
Class/school level variance	0.590(59.0%)	0.542(54.2%)	0.892(89.2%)
AIC	80124.13	78495.77	78252.48

The student-level model explains 54% of the between-school variance, whilst only 20% of the within-school variance is explained. In the class/school model, a higher proportion of the variance is explained between schools (89%), while the variance explained within-schools is not different, as expected. As was the case in Korea, a higher proportion of variance explained between schools than within schools was explained in the final model, implying additional factors to be explored at each level to account for the unexplained variance.

The largest contributory predictor at the class/school level is ‘safety in school’ perceived by students (safschag) (24% on the class/school level) and to a lesser extent ‘attitudes towards science’ (selfcon) (14%) at the student-level model (see Appendix L). ‘Language at home’ (language) and ‘physical resource for science lesson’ (phyres) increased the percentage of explained variance by 10% and 9% respectively on the class/school-level model. The remaining variables brought only a slight increase in the proportion explained both for the within and between school variance, although there were many variables added at the class/school level. As was the case in Korea, and expected from Table 8.9 (above), as variables are added to it was more likely to increase the percentage of explained variance on the class/school-level model than on the student-level model.

Once all the explanatory variables were inserted to the model, most of the class/school level variance in science achievement may be explained in the model. Whereas 87% and 89% of the total variance explained between schools in the null model were estimated at the final model for Korea and South Africa respectively, it did not hold for the student-level variance as shown in Tables 8.8 and 8.9. Only 31% and 20% of the total variance explained in the null model were explained by the variables added in Korea and South African respectively. This may imply that other variables not included but significant do exist in particular at the student level. It was documented that students' aptitude, such as cognitive ability, explained a great deal of the variance at the student level (Van den Broek & Van Damme, 2001). As put forward, TIMSS did not address a question related to aptitude due to issues such as time and cost limit. In addition, prior achievement, which is also referred to as student aptitude, cannot be collected as TIMSS is not a value-added and longitudinal study but a cross-sectional study addressed. There is, however, need to develop an item or a question to account for the unexplained variance at the student level. On the other hand, the result that most of the variance between schools is explained by variables added here means the gaps between schools in terms of student science achievement can be attributed to these very variables.

8.3.5 INTERACTION EFFECTS

As a final step of the multilevel analysis, the cross-level interaction effects were investigated. A number of possible interactions between a variable from the student level and a variable from the class/school level were examined comprehensively. In particular, 'attitudes towards science' at the student level was the prior interest of the researcher since it was considered as an easy-to-manipulate variable at the class/school level by science teachers. There were some interaction effects, which were statistically significant in the Korean data but in terms of the variance explained, they did not improve substantially the fit of the model to the data at all. Regarding South Africa, there was some interaction effects between such variables as 'attitudes towards science', 'student age', 'extra tutoring', and 'home possession'. However, no interaction effect could better fit the previous model, as was the case in Korea. Consequently, no effects worthy of inclusion emerged in the investigation.

8.4 CONCLUSION

The selection of the variables was made prior to multilevel analysis. The selection was based on the results of the preliminary analyses outlined in advance. The research framework drawn in Chapter 4 also contributed to the choice of the more appropriate factors. With the selected variables, multilevel analysis was carried out separately for Korea and South Africa. Although the difference between Korea and South Africa was expected, the results of multilevel analysis clarified this aspect. Ultimately, the exploration in this chapter draws the answers to the second main question, '***To what extent do the factors derived from the analysis explain the differences in the achievement of Korean and South African students?***'. The question constitutes four specific questions regarding generic and specific factors, as well as the degree of variance explained in terms of science achievement in Korea and South Africa.

First, at the student-level model, it seemed that the two countries had factors in common in terms of 'attitudes towards science', 'social context', and 'time on task'. 'Attitudes towards science' emerged as the most significant factors in both countries. The time-on-task factors, such as extra tutoring, were also significant in both countries, although they worked in reverse. However, social context factors gave a slightly different picture. South Africa has more ethnic factors such as 'born-in country' and 'language at home', whereas Korea has more educational factors such as father education (edudad), 'school level expected by student' (edustu), and 'books at home' (bokhom).

Nonetheless, it is worth explaining that the two countries have variables in common that can be addressed by interventions such as 'attitudes towards science' and 'time on task', which tend to have more influence on science achievement than other variables such as 'social context' that cannot be manipulated.

Next, at the class/school-level model, the differences between the two countries were more distinguishable than at the student-level model. The result shows South Africa has 11 significant variables at the class/school level, as opposed to four significant variables in Korea. As a common point prior to the difference, the percentage of students who come from disadvantaged homes influenced student achievement in science in both countries.

Another difference of interest is that aspects of teacher background, such as 'teacher age' and 'completion of first degree' were important in South Africa. Furthermore, variables pertaining to resources such as 'physical resource' and 'class size' were significant as well. The largest contributor was 'safety in school' perceived by students. As for Korea, besides 'percentage of disadvantaged students', there are 'high expectation', 'professional development', and 'enrolment of all grades' which were significant and accounted for the variance between schools.

The greatest difference is the portion of variance explained. Whilst 93% of the variance explained occurred at the student-level model, only 7% of the variance is attributed to the class/school-level variables in Korea. Regarding South Africa, 41% of the variance explained is attributed to the student-level variables and 51% to the class/school-level variables, which is a much higher proportion compared to Korea, implying that South African schools are more likely to influence student achievement in science.

As expected from the beginning, different variables which influence science performance operate in Korean and South African schools, although some common variables function. It might be suggested that intervention or manipulation by decision-makers should take these differences into account in order to improve science achievement across countries. This is assuming that the educational condition of each country only exposes the variable which is more urgent or significant at that time.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 INTRODUCTION

Although TIMSS summarises mean achievement and provides a global view of how countries compare to each other, such differences do not take into account the varying education systems and the factors which possibly could have contributed to variations in performance. Countries such as Korea and South Africa, examined in this study, differ in many ways with respect to their social and educational, cultural, historical, and demographic contexts. These differences may affect the observed differences in science achievement amongst students in each of the contexts. Such achievements tend to be considered as a reflection of the quality of education and thus outcomes need to be examined in the learning context of individual countries (Association for the Development of Education in Africa, 2003).

In order to better understand the different learning environments in which students learn in these countries, the current research used multilevel modelling techniques to deconstruct the total variance in Grade 8 TIMSS 2003 science achievement in Korea and South Africa into within- and between-class/school level. As a preliminary stage of variable selection for inclusion in the model, this research included exploring descriptive statistics, factor, reliability, and correlation analysis to better identify the factors associated with higher achievement. The selection of variables included in the models was guided both by the conceptual framework and extensive preliminary analyses. Subsequently, the research identified predictors of achievement at the individual and class/school levels that explain some of the variance within and between class/schools in both countries.

In this final chapter, the summary of the research into answering the research questions is given (Section 9.2), followed by reflections and discussions on the conceptual framework developed, and the methodology used (Section 9.3). It also outlines how this research may contribute to the body of knowledge in the domain of education. Thereafter, recommendations for further research are presented for Korean and South African science education, TIMSS, and SER (Section 9.4). Finally, conclusions are drawn (Section 9.5).

9.2 SUMMARY AND THE RESEARCH QUESTIONS

The purpose of this research was to explore the difference between Korean and South African student achievement in science from the perspective of educational effectiveness. As a preliminary stage, the educational contexts of the two countries were explored in Chapter 1. Korean education has a long tradition, based mainly on Confucianism, and is highly competitive as parents and students have a strong zeal for higher education that is believed to create opportunities for socially-upward mobility. As a result, most of the students tend to take extra tutoring after school. In addition, education is highly centralised in terms of curriculum and management (Lee, 2002).

On the other hand, South African education featured segregation according to different racial groups for a long period of colonization with the result of a backlog in education delivery and unequal distribution of resources. Therefore, the black majority was deprived of qualified teachers, physical resources, and teaching aids (Fiske & Ladd, 2004). In recent years the democratic government has tried to redress such inequity and promote racial equity through various educational reforms.

The two countries are found at opposite ends of the achievement scale in TIMSS, which was conducted by the IEA, a large scale international comparative study of student achievement in mathematics and science. The substantial gap between Korea and South Africa in science achievement led to the main research questions as follows: *To what extent does TIMSS 2003 reflect factors related to effective science education? To what extent do the factors derived from the analysis explain the differences in the achievement of Korean and South African students?*

To provide answers to these questions, a framework for effective science performance was built by consulting school effectiveness research (SER) and reviewing extensive previous research concerning science performance, as described in Chapter 3 (Scheerens, 1990; Stringfield & Slavin, 1992; Creemers, 1994; Teddlie & Reynolds, 2000; Scheerens, 2001; Howie, 2002; Kyriakides, 2005). SER identified many factors to explain student outcomes in schools at various levels. At student level, 'time on task', 'opportunity to learn', and 'student social contexts' including SES, ethnicity, language, and gender were documented in the literature (Reynolds & Walberg, 1991; 1992; Howie, 2002; Papanastasiou, 2002; Papanastasiou & Zembylas, 2004; Von Secker, 2004; Murphy et al., 2006; Shen & Tam, 2008). 'Instructional quality' factors including 'science curriculum', 'teacher background', 'teaching practice', 'resource', and 'classroom climate', as well as time and opportunity to learn, were identified at the classroom level (Fraser, 1989; Wise, 1996; Scheerens & Bosker, 1997; Kahle et al., 2000; Mayer et al., 2000). Many factors related to staff, management, and resources were identified at the school level, specifically 'principal leadership', 'community size', and 'school climate' (Hanushek et al., 1998; Mayer et al., 2000; Supovitz & Turner, 2000; Valverde & Schmidt, 2000; Tate, 2001; Howie et al., 2008). The literature review was extended into science performance-related research to formulate a conceptual framework, particularly for science achievement. Factors derived from the literature review were incorporated into the conceptual framework portrayed in Chapter 4. The conceptual framework drew mainly on the multilevel and integrated school effectiveness model developed by Creemers (1994), factors offered by Scheerens' (1990) and interactions across factors proposed by Shavelson et al. (1989).

The research used the TIMSS 2003 survey data to compare Korea and South Africa in terms of science achievement at Grade 8. For TIMSS 2003, the sample for Korea consisted of 151 schools with 16 explicit strata by province and 83 implicit strata by urbanization and gender, resulting in 5,300 learners participating in the study (Martin, Mullis & Chrostowski, 2004). For South Africa, 265 schools were sampled with 9 explicit strata by province and 19 implicit strata by language, resulting in approximately 9,000 learners being tested across the provinces. Korea tested from 14 to 19 April 2003 (Park et al., 2003) and South Africa tested from 21 October to 1 November 2002 (Reddy, 2006). Instruments addressed in TIMSS 2003 consisted of questionnaires as well as science achievement test items, which were designed to assess science knowledge and skills based on school curricula. The questionnaires were designed to gather information about five broad areas, viz., curriculum, school, teachers and their preparation, classroom activities and characteristics, and students at various levels of the educational system (Mullis et al, 2003), with the study analysing in particular student, science teacher, and principal questionnaires.

Thereafter, appropriate statistical analyses were identified and used in order to address the research questions. It included factor, reliability, and correlation analysis as a preliminary analysis. Finally, this research used multilevel modelling analyses to identify predictors of achievement at the individual and school levels that explain some of the variance within and between classrooms /schools. Details of the methodology were outlined in Chapter 5. Exploratory analysis of the TIMSS data sets from Korea and South Africa were presented by examining the contextual information data in Chapter 6. Background information based on descriptive statistics was elucidated at various levels, namely those of student, classroom/teacher, and school/principal. The results of factor, reliability, and correlation analyses were discussed in Chapters 7 and 8. Finally, answers to the research questions are given in Chapter 9.

The factor analysis of the Korean data identified ten factors at the student level, 22 factors at the classroom level, and 11 factors at the school level. Factor analysis of the South African data also found ten factors at the student level, 22 factors at the classroom level, and 11 factors at the school level. Thereafter, reliability coefficients were calculated to construct internally consistent scales. The results revealed that most of the items examined had internal consistency, and factors that had below criterion, alpha=0.5, are listed as ‘home possession’, ‘attitudes toward subject’ by teachers (knowledge practice), ‘parent involvement’ in Korea, and ‘use of homework’ (extensive) in South Africa. Finally, correlations between the scales or factors and student achievement were examined comprehensively through the questionnaires, including the factors or scales identified above. Correlation analyses of the Korean data identified 13 significant scales or single-item factors at the student level, four factors at the classroom level, and ten factors at the school level. At the other end of the scale, correlation analyses on the South African data identified ten significant scales or single-item factors at the student level, 23 factors at the classroom level, and 17 factors at the school level at the 0.01 or 0.05 significance level. Taking the above analyses into account, answers to the research questions are presented as follows:

Question 1: To what extent does TIMSS 2003 reflect factors related to effective science education?

The first question was translated into three sub-questions, to be answered according to the results of the analyses above. Each sub-question is presented and answered separately in the light of the findings:

1. Which factors at the student level influence science achievement?

Based on the literature review, the conceptual framework and the preliminary analyses, there are ten factors in Korea and nine factors[14] in South Africa identified at the student level that had a significant correlation with student achievement as seen in Table 9.1 (below).

Table 9.1 ***Factors significant at the student level***

Levels	Effective factors		Korea	South Africa
Student	Time on task		Study after school Play after school(-) Extra tutoring	Extra tutoring(-)
	Opportunities used			
	Student characteristics	Aptitudes towards science		
		Attitudes towards science	Liking science Valuing science	Self-confidence in science
		Social context	Books at home Father education Mother education Student education Computer use	Student age(-) Language at home Books at home Home possession People at home(-) Born-in country Media(watch TV)

Note: (-) Negative relationships with science achievement

Time on task, viz., ‘play after school’, ‘study after school’, and ‘extra tutoring’ showed significant relationships with science achievement. ‘Extra tutoring’ was considered to increase time on task as well as content exposure in terms of opportunity to learn (Wang, 1998b). It is evident that the more time students spend on studying and the less on playing, the better they perform, as proposed in teaching and learning theory discussed above (Carroll, 1963; Bloom, 1974). However, ‘extra tutoring’, unlike Korean results, had a negative relationship in South Africa. This can be understood in terms of extra tutoring given to students who were lagging behind by school teachers in order to compensate for their deficiencies in knowledge in South Africa. It should be noted that there are no significant factors related to homework that is considered to increase time on task.

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[14] One factor in South Africa was aggregated and moved to the school level (safe school) as shown in Table 9.3.

Other significant factors are students' attitudes towards science, such as 'liking science', valuing science', and 'self-confidence'. Students who have more positive attitudes performed better within the country, as was the case with many previous studies (Kahle et al., 2000; Shen & Pedulla, 2000; Papanastasiou & Zembylas, 2004; Chang & Cheng, 2008; Howie et al., 2008; Shen & Tam, 2008). This will be discussed further in the second question as a factor generic to Korea and South Africa.

Educational resources referred to as 'books at home', 'father education', and 'mother education' are important and these findings are consistent with previous research (Goldhaber & Brewer, 2000; Von Secker, 2004; Marks, Cresswell & Ainley, 2006). The results also show a significant relationship between Korean students' expectation to progress to higher education and their achievement, which might reflect Korean educational zeal prevailing across the country.

Related to resources, 'computer use' in Korea and 'media' in South Africa showed positive relationships with science achievement. 'Computer use' was reported to have a negative relationship with mathematics achievement in Korea in TIMSS (Park & Park, 2006), but in science teaching practice, instructional technology strategies using computers proved effective (Chang, 2003) as discussed in Chapter 3. Therefore, the results for resources might be explained in terms of teaching practice as well. Regarding 'media', according to Fraser (1989), the more time students spend on leisure such as watching television the less well they performed, as opposed to South Africa which showed a positive relationship with science achievement. This will be discussed further in the second question.

Specifically in South Africa, ethnicity-related factors such as language or born-in country and SES-related factors such as 'student age', 'home possession', and 'people at home' are significant at the student level. Students from disadvantaged homes tend to have large families and to stay at home to take care of ailing parents or their younger siblings in addition to undertaking chores.

Those obstacles keep them from consistently attending school and progressing through grades (Fiske & Ladd, 2004). As a result, older students performed less well than younger students in South Africa. These issues will be discussed further in the second question.

2. Which factors at the classroom level influence science achievement?

The current study focused in particular on classroom as teaching and learning actually take place in the classroom. The conceptual framework also stressed classroom level, specifying instructional quality in various aspects such as science curriculum, teacher background, teaching practice, classroom climate, and physical resources. There are four factors identified at the classroom level in Korea (Table 9.2, below) and three additional factors are presented in teaching practice. There are as many as 23 factors identified in South Africa, where, unlike the Korean results, teacher qualification-related factors such as ‘formal education’, ‘completion of first degree’, and ‘licence type’ are important. In addition, resource-related factors are significant in South Africa. These two issues will be discussed further in the second question.

With respect to teacher background, colleague interaction (infor-interaction) showed a significant relationship with science achievement in Korea. The more often science teachers interact with each other by discussing or preparing materials the better their students score. This finding is consistent with literature indicating that professional development that is school-based, collaborative, and focused on students’ learning is effective (Ruby, 2006). On the other hand, in South Africa, the more teachers interact with colleagues by observing lessons or visiting classrooms the worse their students fare. A possible explanation for this may indicate that observation or visiting by a colleague is currently used to evaluate teachers in South Africa and is seen as threatening rather than as improving pedagogy.

Table 9.2 ***Factors significant at the classroom level***

Levels	**Effective factors**		**Korea**	**South Africa**
Classroom	Instructional quality	Science curriculum		Textbook use(-)
		Teacher background	Inform-interaction	Teacher age Teaching experience Formal education Completion of 1st degree Licence type Preparation to teach physics & chemistry Visit-interaction(-)
		Teaching practice	Practical learning(s) STS learning(s) Lecture learning(s)	STS work(-) Practical work(-)
		Classroom climate	High expectation Class size	High expectation(t)
		Physical resources		Class size(-) Physical resource(-) Computer resource(-) Student SES(-) Computer availability
	Time for learning		Time scheduled per week	Time scheduled per week Inquiry homework(-) Knowledge homework(-) Monitor & feedback hw(-)
	Opportunity to learn			OTL-biology(-)

Note: (-) negative relationships with science achievement
(s) factor drawn from student questionnaire

Researchers tend to use ‘class size’ from a resource point of view, as discussed in Chapter 3. ‘Class size’ has been shown to influence student achievement (Hedges, Laine & Greenwald, 1994; Greenwald, Hedges & Laine, 1996; Blatchford et al., 2007) and the impact was greater in particular for younger, disadvantaged, and minority students (Mosteller, 1995; Rice, 1999). This is the case in South Africa. Nonetheless, it operates in reverse in Korea, unlike in other countries. A larger class in Korea has a more positive impact on achievement, a possible reason being that Korean parents who place a high value on education tend to move to more prestigious school areas, leading to overcrowded classes. Therefore, it is assumed that ‘class size’ is related to ‘high expectation’ in Korea. ‘High expectation’ was presented in more detail in the second question.

Research reported high expectations from the school, community, and home in turn have a bearing on student achievement (Phillips, 1997). The current research confirmed this finding at the classroom and school levels in both countries.

A further result emerging as significant has to do with the number of allocated science periods. It is not surprising that the more periods science teachers teach per week, the better their students score. The maximum number of periods a teacher in Korea takes per week is limited to 24 by regulation, including home run[15] and club activity[16], and four periods of science lesson per week taught in every class in Grade 8. Therefore, taking fewer science periods means that more time is assigned for administrative tasks other than teaching. It was also documented that time for teachers to plan and prepare lessons with other instructional resources had a statistically significant impact, in particular on teachers' investigative practices (Supovitz & Turner, 2000). Jita (1998) argues that science teachers might not be able to devote sufficient time to prepare adequately for effective teaching when they are distracted by other subjects.

As regards teaching practice, ‘practical learning’, ‘STS learning’, and ‘lecture learning’ were found statistically significant in Korea. In particular, ‘lecture learning’ was more significant than other practices. It might be because teacher-centred practice like ‘lecture learning’ is well-organized and thus students at the stage of schooling tested may acquire knowledge and skill efficiently (Kupari, 2006). Another explanation can be that students under more hierarchical cultures may learn better where being taught in a more directly explicit approach, as Fradd and Lee (1999) put forward. In contrast, in South Africa, STS-based teaching and practical teaching showed negative relationships. This may be an indiction that these practices are handled at a superficial level,

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[15] Home run: each class is allocated to a teacher and the teacher is supposed to take a period per week for the class.

[16] Club activity: many club activities are presented to students and each teacher is in charge of one club. A period per week for club activity is allocated in Korea.

possibly resulting from insufficient preparation of South African teachers to implement the learner-centred practices of the curriculum (Rogan, 2004; Rogan & Aldous, 2005).

In terms of time dimension, the results showed a complex picture that cannot be interpreted directly. Specifically, homework-related factors showed a negative relationship with student achievement in South Africa. Given that teachers use homework differently, depending on the grade, and thereby the relationship between homework and achievement varies across subjects and grades (Van Voorhis, 2003), it might indicate that teachers in South Africa use homework for lower performers to make up their study.

As presented above, Korea has fewer factors to influence student achievement at the classroom level as opposed to many factors in South Africa. Furthermore some of them, viz., teaching practice or time for learning in South Africa, need to be researched further as they show reverse results against findings reported in the literature.

3. Which factors at the school level influence science achievement?

From the preliminary analyses, ten factors were identified at school level in Korea compared to 17 in South Africa as shown in Table 9.3 (below). School size, referred to as ‘all grades’, ‘eight grades’, and ‘computers at school’[17], is important in Korea. This can be explained in the same as in ‘class size’ (see sub-question 2 above), where more students indicate popular schools, reflecting higher expectations of parents and students.

Community size is important in Korea and South Africa. It was reported globally that school location has a bearing on student achievement, indicating urban areas performing better than rural areas in both developed and developing countries (Phillips, 1997; Webster & Fisher, 2000; Bagata et al., 2004; Reddy,

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[17] One computer is allocated to each teacher and each class in Korean schools, therefore number of computers at school may be seen as a proxy of school size.

2006). The community around a school can influence students in many ways. For example, students attending a school with more advantaged students may have high expectations from the school, community, as well as home (Phillips, 1997; Howie et al., 2008).

Table 9.3 ***Factors significant at the school level***

Levels	Effective factors		Korea	South Africa
School	Quality	Curriculum management		
		Professional teaching force	Professional development	Professional teaching force Administrative duty Supervise & evaluate(-)
		School climate	All grades & Eight grades Community size Disadvantaged & Advantaged Educational ethos Frequency of bullying Severity of disrespect(-) Computers at school	Safe school(s) School environment(t) All grades & Eight grade Community size Absenteeism(-) Student still enrolled Disadvantaged(-) & Advantaged 1st language High expectation Parent involvement(-) Severity of low morale(-)
		Resources		Material resource(-) Facility resource(-)
	Time			
	Opportunity			

Note: (-) negative relationships with science achievement
(s) factor drawn from student questionnaire
(t) factor drawn from teacher questionnaire

In terms of student behaviour, it was documented that an orderly school atmosphere and a positive disciplinary climate, are conducive to student learning (Good & Brophy, 1986; Mulford, 1988). It is confirmed that schools in Asian countries are orderly with well-organized discipline. However, 'severity of disrespect' for teachers revealed a significant and negative impact on achievement in Korea. Considering the heritage of Confucianism, this might reflect Korean educational culture changing from a hierarchical system where teachers were regarded as high-educated individuals and respected by parents and student in the past.

With respect to professional teaching force, ‘professional development’ in Korea and principals’ leadership (administrative duty, supervision and evaluation) in South Africa were found as significant along with ‘professional teaching force’. It was documented that high-quality professional development changed teaching practices and improved student learning (Kahle et al., 2000; Supovitz & Turner, 2000; Desimone et al., 2002). In addition, education leadership was proved as significant in SER (Edmonds, 1979; Mulford, 1988; Scheerens & Bosker, 1997; Tate, 2001). These two issues will be discussed further in the second main research question.

Some findings identified mainly in developing countries are found in the South African results. Considering the negative association of absenteeism and the positive association of student enrolment (student still enrolled), attending school is a challenge to South African students. It was documented that students from educationally and economically poor-resourced homes tend to go to school later than supposed, or to drop out of school (Mzamane & Berkowitz, 2002, Fiske & Ladd, 2004). Resource-related and SES-related factors showed significance and discussion is presented in the second question.

As Fraser (1989) stated, student achievement is influenced by a number of factors rather than by a single dominant one. Tables 9.1, 9.2., and 9.3 (above) contrasted the factors identified in both countries to the research framework developed in Chapter 4. The next section elaborates on how different factors contribute to student achievement.

Question II: To what extent do the factors derived from the analysis explain the differences in the achievement of Korean and South African students?

The second main research question, given above, was divided into four sub-questions which were explored using correlation analyses as well as multilevel analyses. The results of multilevel analyses can be mainly examined as significant factors that improved the model, thus providing a much clearer picture in terms of differences between the two countries (Table 9.4, below):

Table 9.4 ***Predictor variables identified from multilevel analyses***

Levels	Effective factors		Korea	South Africa
Student	Time on task		Extutor, timafsch	Extutor(-)
	Opportunities used			
	Student characteristics	Aptitudes towards science		
		Attitudes towards science	Liksci	Selfcon
		Social context	Bokhom, edudad, edustu	Agestu(-), boncnty, languag, hompos, media
Classroom	Instructional quality	Science curriculum		Textuse(-)
		Teacher background		Agetch, 1stdeg
		Teaching practice		STS(-)
		Classroom climate	Hixpect	
		Physical resources		Phyres(-), clasize(-)
	Time for learning			
	Opportunity to learn			
School	Quality	Curriculum management		
		Professional teaching force	Prodeve	Admindt, supevdt(-)
		School climate	Schsize, disadva(-)	Disadva(-), lomoral(-), safschag(-)
		Resources		
	Time			
	Opportunity			

Note: (-) negative relationships with science achievement

As seen in Table 9.4, a single factor was found significant at the classroom level in Korea compared to many factors in South Africa. The student and the school levels also have more factors that are significant in South Africa than in Korea. Similarities and differences between the two countries are discussed below, corresponding to the answers of sub-questions.

1. Which factors influencing achievement are generic when comparing Korea and South Africa?

Some factors were generic in both Korea and South Africa. Firstly, at the student level, attitudes towards science (liksci, selfcon) are the strongest predictors of science achievement between individuals in both countries according to the results of multilevel analyses. This result also confirmed previous findings reported in the literature (Kahle et al., 2000; Shen & Pedulla, 2000; Papanastasiou & Zembylas, 2004; Chang & Cheng, 2008; Howie et al., 2008; Shen & Tam, 2008). In addition, it is consistent with Shen and Tam's finding (2008), that high-achieving countries tend to have negative attitudes and low-achieving country positive attitudes.

At the school level, percentage of disadvantaged students (disadva) is important in both countries. As for the relationship between SES and achievement, it has been well documented in SER that it is likely a stronger predictor at the school level than student level (Beaton & O'Dwyer, 2002). It was reported that the SES of a school (the proportions of students receiving free or reduced lunch was used as a proxy) influenced teaching practice more than either principal supportiveness or available resources influenced teaching practice (Supovitz & Turner, 2000). Therefore, students attending schools having more advantaged students can benefit in many ways. For example, the high expectations from the school, community, as well as home (Phillips, 1997) figure strongly. Students have more opportunity to learn content as the school offers more content and highly-qualified teachers than do ones in disadvantaged areas (Ramírez, 2006).

2. Which factors influencing achievement are specific to Korea?

At the student level, Korean data revealed that educational resources in the home influence student achievement. The results show that the father's education (edudad), school level expected by the student (edustu), books at home (bokhom), and computer use (comsue) are significant in contributing to the model. This is consistent with research that found home background, in particular educational resources offered in the home, a strong predictor of science achievement (Von Secker, 2004). Furthermore, international studies conducted by the IEA consistently showed that 'books at home' have a positive relationship with student achievement (Comber & Keeves, 1973; Postlethwaite & Wiley, 1992; Beaton et al., 1996; Martin et al., 2000; 2004).

With respect to time on task, out-of-school activities (timafsch) are significant as expected from the review in Chapter 3 in which more time on task is associated with student achievement. In particular, Korean parents force their children to take extra tutoring in private institutes, called '*Hakwon*', after school. Some of the students spend more time on extra tutoring than at school and it has been a very contentious issue in Korean society. Nonetheless, from a teaching and learning perspective, it is obvious that more time on task increases achievement (Carroll, 1963; Fraser, 1989; Šetinc, 1999).

At the classroom level, 'high expectation' (hixpect) remained significant, as seen in Table 9.4 (above). It is argued that teachers' high expectation towards students in class can be one of the ways that facilitate and raise students' self-concepts (Muijs et al., 2005). Research reported that a very low academic self-concept is likely to impair an individual's performance, while over-optimistic perceptions of one's performance resulting from low teacher expectations may reduce a student's devotion and subsequent performance (Stevenson et al., 1990; Stevenson & Stigler, 1992). It is clear that 'high expectation' can develop classroom climate which in turn develops a positive student attitude and thereby achievement, reflecting the zeal for education particularly in Korea.

At the school level, 'professional development' (prodeve), and 'school size' (schsize) are specific to Korea. From a policymaker's perspective, no alterable ingredient has impacted on student achievement except for professional development at the class/school level. High quality of professional development improves teaching and prepares teachers to meet the diverse needs of today's students, and subsequently closes achievement gaps (Kahle et al., 2000; Supovitz & Turner, 2000; Desimone et al., 2002). High quality of professional development in science can be guaranteed where providing intensively and steadily and immersing teachers in inquiry-based tasks. It also should involve concrete teaching tasks based on subject matter knowledge (Supovitz & Turner, 2000).

'School size' remained significant in Korea (Table 9.4, above). As was the case of 'class size', 'school size' should be considered in terms of educational expectations in Korea, as parents with higher zeal for education tend to move to more prestigious school areas, leading to large schools. Therefore, in Korea, a large school means students have more educational zeal. On other hand, generally, schools in urban areas tend to have more students than in rural areas in Korea. Therefore, it is understandable that larger schools performed better.

3. Which factors influencing achievement are specific to South Africa?

At the student level, 'student age' (agestu), 'language at home' (languag), 'home possession' (hompos), 'born-in country' (boncnty), and 'media' (media) are specifically significant in South Africa (Table 9.4, above). Whilst educational factors are important in Korea, ethnicity factors and SES factors are more significant in South Africa.

Some researchers documented that minority-ethnic groups performed less well than majority groups (Hamilton et al., 1995; Adigwe, 1997; Klein et al., 1997). This phenomenon is understandable as students from minority ethnic groups have to learn science knowledge in an instruction language that is different from mother tongue (Rollnick, 2000). The language barrier also holds true for South Africa, with 11 official languages and where language was found to be a strong predictor of student achievement (Howie, 2002). As the language of instruction is often different from the language spoken at home, it consequently prevents students from understanding subject content and hampers communication and thus teaching and learning. Given that reading ability had a strong relationship with achievement in science (Brookhart, 1997), it is evident that students who are not familiar with the language of instruction cannot understand knowledge taught in class.

According to Walberg's productivity model (1990), which includes learners' biological development as one of the effective factors, older students should perform better than younger ones as they are readier to learn. Student age in South Africa, however, has a positive relationship[18] with achievement. The older the students the less well they performed. Taking with home possession, which has a positive relationship with achievement, it might indicate students from educationally and economically poor-resourced homes do not attend school regularly or go to school later than supposed. As a result, they have less opportunity to learn and have to repeat grades because they failed to pass the standard demanded by the curriculum (Mzamane & Berkowitz, 2002, Fiske & Ladd, 2004).

Of relevance to this study is that 'media', representing 'watch TV or video' showed a positive relationship with science achievement in South Africa. This indicates that the mass media not only provides information related to science but also helps students improve their English. A similar result was found in Howie's study (2002) on mathematics in South Africa, where listening to the radio showed a strong relationship with student achievement. Walberg (1990) included mass media environment such as television or video in nine effective factors that influence student outcomes negatively.

The classroom level has even more significant factors specific to South Africa than does Korea, notably textbook use (textuse), teacher age (agetch), teacher qualification (1stdeg), 'STS'-based teaching, physical resource (phyres), and

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[18] Young students were assigned the higher score and the elder students the lower score. Therefore, the positive relationship indicates younger students performed better.

class size (clasize). With respect to the science curriculum, textbook use (textuse) is significant in South Africa, however the use of textbooks showed a negative relationship to performance. This was a surprising result, because in terms of opportunity to learn, textbooks can provide content of what should be taught in classrooms (Valverde & Schmidt, 2000) as well as the methods employed. In terms of resources, this might be an effective way to access scientific knowledge, particularly in developing countries (Fiske & Ladd, 2004). Most of the science teachers sampled in South Africa (92%) indicated that they used textbooks, with 63% using them as supplementary resources and 37% as primary resources. ‘Textbook use’ should have a positive effect as scaffolding to build scientific knowledge. The negative impact might be an indication that teachers used textbooks without reconstructing content for students to make meanings for themselves.

Another possible explanation might be that the outcome-based curriculum followed in South Africa, which does not prescribe content to be taught, but outcomes to be obtained by students, is not being implemented appropriately as pointed out by Rogan (2004). Furthermore, considering that teaching practice such as ‘practical work’, which is recommended for effective group learning by researchers (Harskamp & Ding, 2006; Odom et al., 2007), operates in an opposite way to general research findings, it is evident that outcome-based teaching and learning does not improve achievement at the classroom level. This may be related to inadequate preparation of South African teachers to implement the outcomes based curriculum.

Teacher qualification and age are significant in South Africa, with Heyneman and Loxley (1983) having found that teacher quality along with school quality was more important in developing countries. Teacher quality is also important in the light of ‘opportunity to learn’ (Ramirez, 2004). In terms of equity, as teachers tend to teach what they know, those who lack background in science are more likely to reduce coverage of content, which leads to difference in the implemented curriculum (Ruby, 2006). Specifically, the more disadvantaged students are taught by the least qualified teachers, hence perpetuating a vicious cycle of poor education in less developed countries such as South Africa (Howie, 1999; Ramirez, 2004).

Besides teacher qualification-related factors, resource-related factors (phyres and clasize) are significant in South Africa, confirming the findings of Fuller (1987) that material inputs are related to achievement in developing countries. As Scheerens (2001) put forward, material and human resource factors showed strong effects in developing countries such as South Africa compared to developed countries. It is proposed that the current finding also reflects the backlog resulting from unbalanced financing support under the apartheid regime. Although the disparate financing policy was diminished after the 1994 democratic elections, it is clear South African education is still struggling with ‘a cycle of mediocrity’, controlled by poor resources and under-qualified teachers (Howie, 1999).

At the school level, educational leadership (admindt and supevdt), safety in school (safschag), and student morale (lowmoral) are good predictors of student achievement in South Africa. Educational leadership has been proved to influence student achievement since it was identified within effective schools in early SER (Edmonds, 1979; Mulford, 1988; Scheerens & Bosker, 1997; Tate, 2001). South African results showed a school performed better when the principal was involved in administrative duty rather than supervising and evaluating teachers. According to previous findings (Creemers, 1994; Reynolds et al., 2002), it is evident that where educational systems are more decentralized, less engineered, and less ordered, principals’ leadership is more important than in centralised and better organised systems. It was found that South Africa schools were closer to the former.

As Harber and Muthukrishna (2000) suggested, SER should reflect a specific country’s educational, cultural, and social contexts. For example, non-violence is an issue in South Africa as the results revealed safety in school is significant.

According to the results of multilevel analysis, 'safety in school' is the strongest predictor of science achievement at the class/school-level, explaining the high variance between schools in South Africa. According to UNICEF (2000), quality education environments are healthy, safe, protective and gender-sensitive. It is clear that a secure environment is a prerequisite for high achievement.

Lastly, 'severity of low morale' was found significant in South Africa. It is possible that low morale of students reflects the culture of resistance to education, specific to South African history. Admittedly, the long period of Bantu education (40 years) contributed to the total collapse of the teaching and learning culture in South Africa (Fiske & Ladd, 2004). Although the new democratic government has made an effort to rebuild a positive perception of education, it still has a long way to go.

From the research, it is clear that factors specific to South Africa reflect the country's educational context accurately with regard to factors relating to ethnicity, teacher qualification, and resources. These findings are confirmed by the results of multilevel analyses. In particular, the results of the South African data are largely in accordance with previous findings that science achievement is more likely to be influenced by school and teachers than students' social status (Heyneman & Loxley, 1983).

4. How do these generic and specific factors explain the difference in the performance of the two countries?

Overall, Korean and South African students differ in terms of science achievement as well as in terms of the factors identified as strong predictors of it. According to multilevel analysis, the null model was used to partition the total variance in science achievement in each country into its within-classroom and between-classroom/school variance components. The Korean null model without any explanatory variables revealed that 93% of total variance in science achievement occurred at the student level, while only 7% of the total variance was attributable to the classroom/school level.

The student model, which has all student-level variables only, accounted for 31% of the achievement variance at the student level and 74% of the class/school-level variance, while the class/school model, in which class/school-level variables are added, explains 87% of the variance at the class/school level in Korea, where it is clear that the student-level variables explain a considerable amount of class/school-level variance.

The South African results of multilevel analysis show that 41% of the total variance in science achievement were assigned at the student level and 59% at the class/school level in the null model without any explanatory variables. The student-level model accounted for 20% of the variance occurring at the student-level and 54% of class/school-level variance, while the class/school model explains 89% of the variance occurring at the class/school level. Student-level variables do not explain as much of the class/school-level variance as in Korea.

In sharp contrast with the finding that, according to the null model, only 7% of the variance in student achievement was accounted for at the class/school level in Korea, more than half of the variance (59%) in achievement occurs among schools in South Africa. As a result, the model built in the research gave a different picture from the Korean picture. Some 59% of the variance is attributed to the class/school level in South Africa. This result is consistent with the research conducted previously in South Africa (Howie, 2002, Scherman, 2007), and the same finding is prevalent in developing countries.

The small percentage of between-classroom/school variance explained (7%) means that Korean classrooms or schools are homogeneous and have mixed-ability students, given that the amount of variability within- and between-classrooms/schools indicates the homogeneity of the classrooms (O'Dwyer, 2005). There is no tracking in lower-secondary school level (middle schools) in

Korea, while vocational or technical education runs parallel to an academic track in high schools. It was found that a substantial proportion of the variation among students occurred between schools in the study involving higher-secondary schools (high schools) in Korea, reflecting their being tracked due to achievement and SES (McGaw, 2005).

On the other hand, the large percentage of between-classroom/school variance explained (59%) indicates it might result from residential segregation due to race and SES, which is associated with variations in achievement (O'Dwyer, 2005).

The percentages of variance explained by the multilevel models demonstrate that the variables included in the models have varying capacities for predicting science achievement in different countries. The results show that in both countries the models are more powerful for predicting differences between classrooms/schools than for predicting differences within classrooms. In Korea, the final model explained 87% of the variance between classroom/school, and 89% in South Africa, compared to 31% of variance occurred within-schools in Korea and 20% in South Africa respectively.

Korea and South Africa differ in the context of education and culture, but some factors are similar, particularly in their apparent influence on science achievement, but with a subtle difference. For example, 'attitudes towards science' is the strongest predictor of science achievement at the student level in both countries. At the class/school level the percentage of disadvantaged students is the strongest predictor in Korea and safety in school in South Africa. In particular, student social context such as ethnicity, age, and language, and teacher background such as qualification and age are significant in South Africa. In many respects the results of the study are consistent with prior research, although there are some opposite results, including the negative effect of textbook use in South Africa.

9.3 DISCUSSION AND REFLECTION

This section summarises the discussion and reflection of the findings derived from the research. The research framework is discussed and reflected on (9.3.1), followed by a review of school effectiveness research (9.3.2). The methodology used in the research is discussed (9.3.3), the section concluding with the contribution to scientific and practical knowledge (9.3.4).

9.3.1 REFLECTION ON THE CONCEPTUAL FRAMEWORK

The current research began by building a conceptual framework based on previous studies and proposing a model for effectiveness of science education (Figure 9.1, below). The conceptual framework was based on a particular learning and teaching theory, initiated by Carroll (1963), and proposing five factors, namely students' aptitude, perseverance, ability to understand instruction, quality of instruction, and opportunity to learn. It has been argued that educational research and the findings do not fit teachers in the field because those findings are more likely to represent deep and micro aspects than the reality in which teachers work (Duit & Treagust, 2003). Furthermore, teachers not only need to consider learners from a micro level perspective, such as conceptual change, but also to take into account the environment surrounding students and themselves at the macro level, namely physical factors. For that reason, the model for effective science education should be based on teaching and learning theory as well as physical environments. Therefore, the conceptual framework for the study covers many aspects, such as human, material, and time, as shown in Figure 9.1 (below):

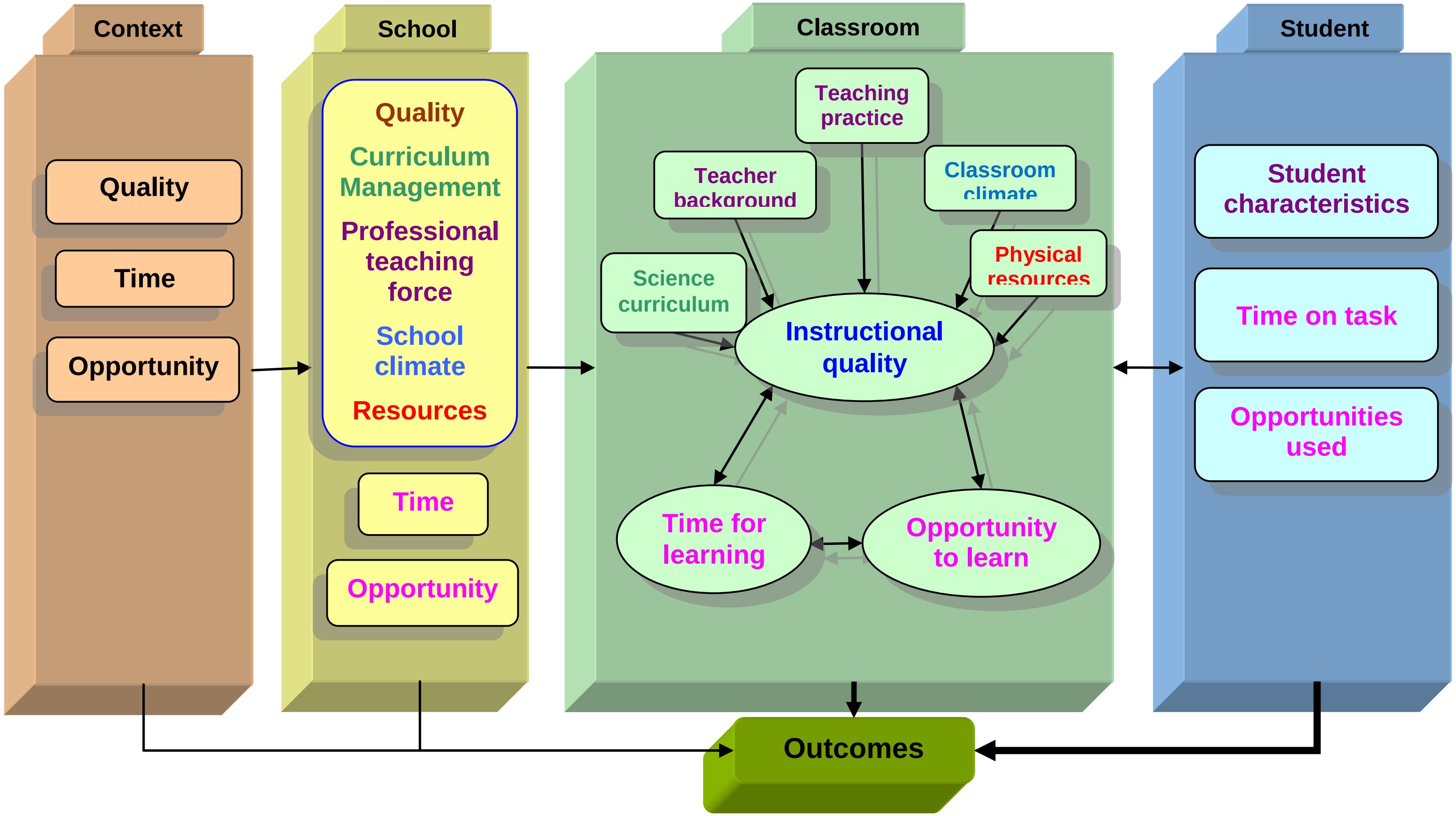

Figure 9.1 **A proposed model of effectiveness of science education**

Some modifications can be made on the model formulated from the conceptual framework according to the findings. Models modified for Korea and South Africa are illustrated in Figures 9.2 (below) and 9.3 (below) respectively. It should be noted that the model adapted from the analysis of the data was limited to the two countries and the research used a two-level hierarchical linear model (i.e., students nested within schools), as TIMSS tested only one class per school sampled.

The models shown in Figures 9.2 and 9.3 include variables (factors) identified as significant in the multilevel analyses. Compared to many factors (variables) examined at the beginning of the study, only a few have emerged as significant to student achievement in science, this being more likely the case in Korea.

The conceptual framework focused on three key factors influencing student achievement, namely time, opportunity, and quality. *Time* indicates students' time on task, teachers' time for teaching and learning, and instructional time allocated by school regulation. *Opportunity* covers learning opportunity used by students, teachers' opportunity to teach, and opportunity provided by school (Creemers, 1994). *Quality* includes student background, teacher and teaching background, and school support for teaching and learning (Reynolds & Walberg, 1991; Freedman, 1997; Mayer et al., 2000). From the results on the whole, and comparing them with the framework, in particular, time (extutor) at the student level was important. In contrast to time, although topic coverage was comprehensively asked of teachers at the classroom level, opportunities used or opportunity to learn were not identified as important at each level in Figures 9.2 or 9.3. Within the social context of students, attitudes towards science (liksci, selfcon) were significant in both countries, and with other social contexts, educational factors are important in Korea and ethnicity and SES – related factors matter in South Africa.

At the classroom/school level in the multilevel model, high expectation (hixpect) and teachers' professional development (profdeve) are vital in Korea, whilst teacher qualification (agetch, 1st deg) and physical resources (phyres) are important in South Africa, as expected from the previous studies. In addition, science curriculum (textbook use), principals' roles, safety in school, and students' morale are significant in South Africa.

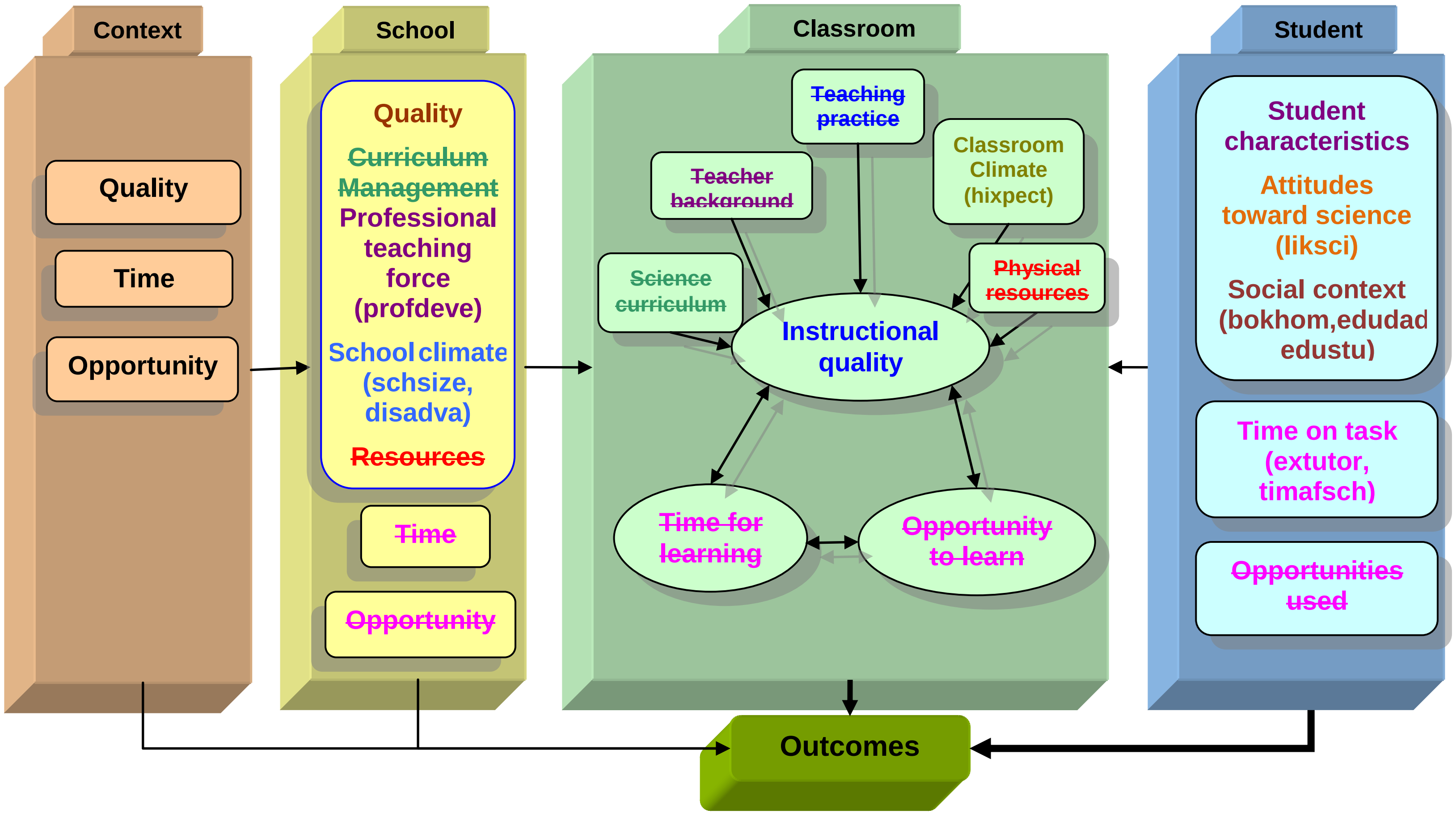

Figure 9.2 **A model of effectiveness of science education for Korea**

Note: Strikethrough font indicates factors which are not significant.

The Korean model differs from the South African one particularly in terms of instructional quality. South Africa has more factors overall that account for the variance in student achievement in science when comparing Figures 9.2 and 9.3. Such a difference is not surprising, taking account of the difference between the two countries in many aspects such as demography, culture, and history. It was documented that even though the same model is applied for other grades or subjects within one country, the results are different (Reynolds & Walberg, 1991; 1992). This is even more likely the case in different countries, where the major factors cannot hold for every one. Stevenson and Lee (1990) contend that factors predicting differences in performance within a given culture may not be the same as those that predict differences in individuals between cultures, and this appears to be true of the present study in light of differing educational systems.

Therefore, factors influencing student achievement should be considered, taking account of the status quo of an educational system or country. It is sufficient to note here that a spatial and temporal locality of the relationship applies to all the factors influencing student achievement as well as to attitudes towards science, as suggested by Papanastasiou and Zembylas (2004, p.259).

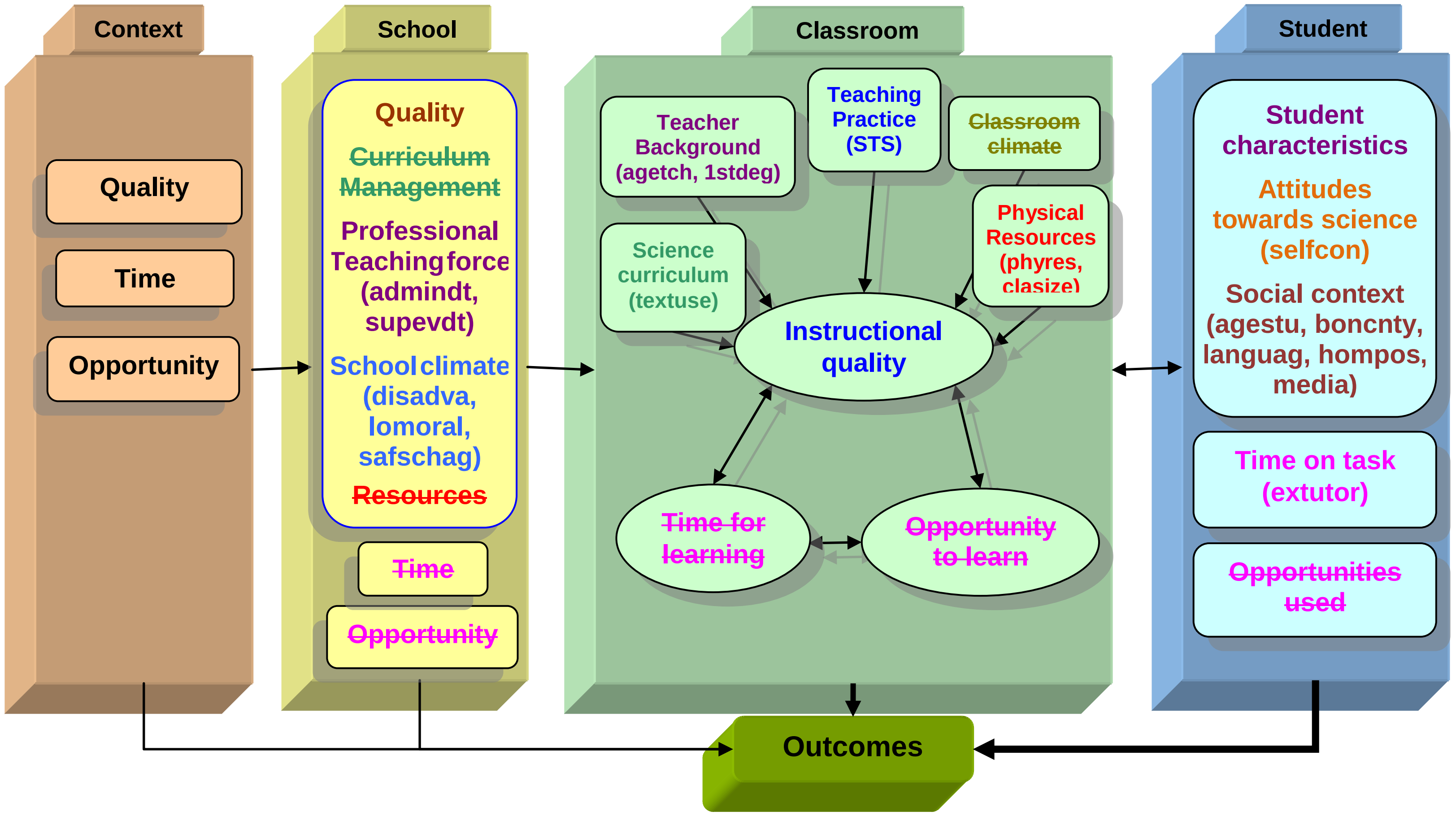

Figure 9.3 **A model of effectiveness of science education for South Africa**

Note: Strikethrough font indicates factors that are not significant.

9.3.2 REFLECTION ON SCHOOL EFFECTIVENESS RESEARCH

The results of the study can contribute to School Effectiveness Research (SER) from an economical development point of view, by comparing a developed and a developing country. SER has become one of the most important domains of education research during the past three decades (Teddlie & Reynolds, 2000). SER assumes that students' achievement represents the effectiveness of an education system, or to put it broadly, the quality of education. For that reason, stakeholders or policymakers tend to provide more input, such as budget or resources to improve their education system in terms of outcomes.

In contrast, many studies pertaining to students' outcomes have found home characteristics to be more highly associated with student achievement than school characteristics. As a result, a great deal of research has highlighted the need to examine the influence of students' background characteristics when examining student achievement. However, it does not hold true around the world, in particular in less-developed countries. As found in the study of Heyneman and Loxley (1983), it is often accepted that the economically developed countries show the pattern of larger influence by family SES with smaller school impact, and the reverse pattern in less-developed nations. The current research confirmed the Heyneman-Loxley effect empirically from the results of Korea and South Africa. As Scheerens (2001) stated, there are considerable differences between schools in South Africa, whereas the effect of school is minimal in Korea. In addition, material resources and teacher background are important in South Africa, unlike in Korean results.

Nonetheless, the results from the two countries should be viewed not only from an economical development perspective, but also from a cultural one, given that the current study involves one country from Asia and another from Africa. The two countries are different in many respects, such as economy, education, history, culture, and demography. Therefore, the differences between the results should be interpreted from a cultural perspective, and take into consideration unique contexts. Comparisons should be made to determine not which one is better but how each educational system works in different contexts. For example, high expectation in Korea can be explained from the heritage of Confucianism, which values highly educated individuals. Language and low morale of students in South Africa should be interpreted with the backdrop of an apartheid past which still hunts the education system.

However, if educational researchers or practitioners make interpretations without considering cultural differences and try to apply these to other contexts, and if policymakers and stakeholders intend to roll-out interventions which neglect cultural differences and simply try to implement what is developed elsewhere, they will make no improvement (de Feiter et al., 1995).

SER also recognized that school effectiveness varies across subjects. Nonetheless, SER tends to use language or mathematics as outcomes. By using science achievement the study made a contribution to the discussions based on literature. It is commonly accepted that science varies greatly in terms of curriculum, compared to mathematics which is more standardized across the countries. In terms of variance explained, the current study did not identify any findings that were different from the previous studies on mathematics conducted in Korea and South Africa. In lower-secondary school level, a larger portion of variance is explained at the student levels in Korea, but at the school level in South Africa, which are concurrent with the results of previous research. Specifically, some different factors were identified in each country, for example, computer use in Korea and educational leadership in South Africa. However, it should be noted that the above comparisons of studies are not exactly the same in terms of methods and variables selected.

On the other hand, the current research developed the conceptual framework from SER based on an economic input-output paradigm as well as classroom/school processes, which are regarded as a ‘black box’[19] (Black & Wiliam, 1998). The results of the study ascertained some factors significant at the classroom and school levels as follows: professional development, high expectation, educational leadership, school SES, instructional resources. Nonetheless, no factor was found in particular in terms of teaching practice, which is considered as influencing

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[19] It means literally the content remains unknown. Although learning and teaching take place actually in classroom, one do not know exactly what and how works for student outcomes.

student learning directly. It is assumed that impact of teaching practice needs to be approached by a micro-level framework under a macro–level model, such as the model adapted in the study. It might be too ambitious to expect one model to detect every factor.

9.3.3 REFLECTION ON METHODOLOGY USED

The research is a secondary analysis that used a large dataset of high quality collected in TIMSS 2003. Therefore, the researcher could save time and cost in collecting sufficient data and instead focus on data analyses. However, there are some disadvantages where a secondary analysis is used. The main limitation was that the researcher could not include everything necessary as the data had already been collected, and some factors that seemed significant from literature could not be explored because the data did not support it. Specifically, as TIMSS collected data in cross-section, the study could not use any on aptitudes (prior knowledge), which is proof of some variance in outcomes.

Although TIMSS provided information for the study, there are some risks to aggravating scales, as TIMSS collected information about some important factors by only a few items and survey. Admittedly, factors may not be measured in totality by one item (Bos, 2002). Another limitation, especially in survey research, is the issue of socially desirable responses where respondents answer in a manner expected, and which may not be reflective of their teaching practice (McMillan & Schumacher, 2006). In addition, for some factors the clustered sets of items differed in the two countries when constructing scales. A possible explanation for the differences is that cultural differences may result in different interpretations of the same questions between the two countries. As a result, differences in the reliability coefficient as well as of the clustered sets of items for some variables, implies that the power of comparability between the two countries might decrease (Bos, 2002). Therefore, there is a need to improve internal consistency and thus enhance the international validity of factors. In the process of the design of an international comparative study, a pilot test of background information should be prepared with more precision, and including more items could be another way to improve the validity of factors. Fundamentally, a conceptual framework firmly based on empirical and theoretical findings should guide the design of the study through all the processes.

On the other hand, the research was primarily exploratory in nature and was reflected in the research design, which consists of factor, reliability, correlation analyses, as well as multilevel analyses. However, only direct effects of variables on student achievement were taken into account, by examining the results of factor, reliability, and correlation analysis. The indirect effects can be provided by means of Partial Least Squares (PLS), one of the techniques used to estimate path models. PLS can be recommended in an exploratory study, where data from a complex context such as a school is involved (Howie, 2002). As PLS provides a researcher with the direct and indirect relationships among variables, and the strength, it can be used to make a decision for inclusion in further analyses, such as multilevel ones (Howie, 2002).

Nonetheless, the current study depended on the results of factor, reliability, and correlation analyses when selecting variables for multilevel analysis. As the research built a conceptual framework based on the comprehensive literature review, and the study aimed at contrasting Korea and South Africa, it is assumed that the indirect effects are considered beyond the scope of the current study, and thus PLS might be over-requisite processing. It should however, be noted that there is some risk that while variables assigned to the same factor in the conceptual framework might have slightly different meanings from a micro perspective they could have the same meaning from a macro perspective.

The purpose of the study was to investigate the reasons for differences between Korea and South Africa in terms of science achievement. Accordingly, multilevel analysis was used to explain the variance in achievement. Although multilevel analysis uses various levels of data simultaneously, only two-level models were built because TIMSS provides one set of class data per school tested. This means classroom and school cannot be stratified in terms of data collected, however at least two classrooms should be sampled per grade within a school in order to build a three-level model.

In a three-level model, the reliability of estimates of school effect depends on the extent to which teachers within a school are homogeneous in terms of their teaching practices. If between-teacher variability is substantial once student variability is controlled, a three-level model analyzing the instructional effect on students nested within classrooms, nested within schools, could provide a better estimation of the instructional influence on science achievement (Von Secker & Lissitz, 1999). Nonetheless, the TIMSS dataset used in the current research limited the study to a two-level model that compounds instructional effect with school effect.

9.3.4 CONTRIBUTION TO SCIENTIFIC AND PRACTICAL KNOWLEDGE

Scientific literacy is becoming more important as science and technology is the core of much industry, and consequently is the foundation of economic growth (Pillay, 1992; Thulstrup, 1999; Schofer et al., 2000; Baker et al., 2002; Hanushek et al., 2008; Murray, 2008). As such, scientific literacy has been given considerable attention for many reasons. From an economic perspective, modern societies need scientifically and technologically literate workforces to maintain their competencies. In a high-tech and democratic society, individuals need not only a basic understanding of science and technology to function effectively as individuals and consumers, but they also need to be able to reach an informed view on matters of science-related public policies and so participate in discussions and decision-making (Duit & Treagust, 2003).

Large-scale international comparative achievement studies such as TIMSS and PISA have played a valuable role in determining the extent of student scientific literacy. With many participating countries in TIMSS being concerned about the disappointing results of students, improving science achievement (which can be referred to as scientific literacy) has become a major issue and focus of science education research. As a result, many intervention strategies were developed during the 1990s, for example from a micro perspective and with the introduction of constructivist approaches to student learning.

However, educational research regarding the teaching and learning of science that has been dominated by basic research in cognitive psychology has been criticised as it seems that the findings are irrelevant to many teachers. Such studies are usually carried out in arranged settings in order to allow strict control of variables (Duit & Treagust, 2003), however, although the current study attempted to overcome such criticisms and to give some in-depth insights in particular to science teachers, the results seem not to directly inform science teachers of the actual practice of teaching and learning. Rather, they provide the higher education level of the two countries with some valuable findings. For example, from the correlation analysis, time scheduled per week has a positive relationship in both countries. This might mean the more emphasis on teaching and the lesson than on other duties, the better the outcomes. The point of importance here is making teachers dedicated to teaching rather than other types of duty. The South African results related to teacher background and teaching practice also show that improving content knowledge should accompany attempts to improve pedagogy, including effective textbook use.

On the other hand, stakeholders, policymakers, and school administrators demand that school science instruction become more effective in terms of school quality. Therefore, illustrating where the variance in achievement occurs can help policymakers better understand the status quo of the educational context in question and implement interventions to reduce the variance. In this vein, the current research can help policymakers find strategies that can increase teachers' ability to use resources such as textbook and students' engagement and interest in science and subsequently promote outcomes.

The current study developed a conceptual framework which mainly draws on the work of Creemers (1994), and Scheerens (1990), supported by a comprehensive literature review. To examine learning processes and outcomes between or among individuals, something must be known about the educational contexts. In this vein, the main idea of the framework was based on the assumption that student outcomes result from hierarchical structures where factors from different levels cooperate. The emphasis is put on time, opportunity, and quality from a perspective of teaching and learning theory. Therefore, the developed conceptual framework can help one examine and monitor educational systems and, subsequently, improve school or instruction effectiveness.

This research is a comparative study that compares achievement in science and effects of contextual factors at the student, classroom, and school levels in Korea and South Africa. The research purposed to provide insight and perspective in understanding the factors that increase learning and achievement in science in both countries. In addition, this research attempted to make explicit how indicators of effectiveness have been chosen and how it operated in the two countries that have different contexts in many aspects. Accordingly, to ascertain the determinants of cross-national variations in student achievement in the two countries is a very difficult task because students in each country are embedded in their own unique social, economic, and cultural contexts (Shen & Tam, 2008).

Nonetheless, the current research can serve vital functions, in line with Bos' (2002) argument that large-scale international comparative achievement studies have five major specific functions, viz., description, benchmarking, monitoring the quality of education, understanding of reasons for observed differences, and cross nation research. Amongst five functions, three can be supported by the current research, as described below.

The description function can be satisfied with describing similarities and differences derived from exploring the descriptive statistics and statistical analysis, as seen in Chapters 6 and 7. Understanding of reasons for observed differences can be met with postulating a model that accounts for the variance between and within schools, described in Chapter 8. The cross-national-research function can be accomplished by comparing predictable factors resulting from the research. Although the functions are fulfilled to a limited extent, useful recommendations can be made to improve science education in each of the two countries.

9.4 RECOMMENDATIONS

Recommendations were made mainly focusing on policies or interventions that can be addressed by policy-makers in the two countries. Recommendations on

Korean science education are put forward (Section 9.4.1), and recommendations made for South African science education (9.4.2). Recommendations on TIMSS are presented in Section 9.4.3 in particular in the light of the conceptual framework. The section concludes with recommendations regarding school effectiveness research (9.4.4).

9.4.1 RECOMMENDATIONS REGARDING KOREAN SCIENCE EDUCATION

In many countries, including Korea, it is likely that high economic growth has been accompanied by large investments in education. Admittedly, the education level of individuals is a good predictor of future socio-economic status in Korea. As such, educational aspiration is rising and becoming competitive. As a result, Korean students have performed better in international comparative studies such as TIMSS. However, although Korean schools performed well in terms of outcomes, they should not be satisfied with current status but rather seek out ways to improve quality of outcomes (Scherman, 2007). Therefore, some recommendations can be made for Korean science education.

Recommendation 1: Improving students' negative attitudes towards science at the context level

Students' negative attitude to science might be attributed to many causes. From a macro perspective the examination-driven university entrance system forces Korean students to work hard. Therefore, most spend time after school on taking extra tutoring to improve performance, more so than on other activities such as playing or sports. Too much time on task leads to students' burn-out and consequently negative attitudes towards learning (Papanastasiou & Zembylas, 2004; Murphy et al., 2006). Therefore, policymakers should develop a programme to reduce students' work while attending school. From a micro perspective, negative attitudes can result from teaching practice in the classroom. It was documented that transmissive pedagogy contributes to students' negative attitudes towards science (Lyons, 2006), and that more student-centred teaching methods can improve attitudes (Odom et al., 2007). Therefore, teachers need to change their practice, as elaborated on in the next recommendation.

Recommendation 2: Sustained and high quality of professional development for science teachers to change their teaching practice.

The research showed that 'professional development' at the class/school level influences student achievement. In addition, 'teacher interaction' based on 'discussions about how to teach a particular concept' or 'working on preparing instructional materials' showed a positive relationship with student achievement. Therefore, policymakers should develop a professional development programme or system reflecting such findings. While Korean science teachers are highly qualified in terms of content knowledge, they tend to use traditional teaching practices such as teacher- and lecture-centred teaching, which are not considered useful in developing higher-order thinking ability, although they do contribute to high performance. Therefore, in terms of quality of science instruction, Korean science teachers need to develop pedagogical content knowledge and change their practice to meet students' needs, namely to not only attain high achievement, but also to develop higher order thinking skills and positive attitudes amongst their students.

9.4.2 RECOMMENDATIONS REGARDING SOUTH AFRICAN SCIENCE EDUCATION

The research revealed that there are many factors in South Africa that should be considered simultaneously in terms of quality education to improve achievement. Policymakers should consider this point and ascertain which factors have higher priority, as well as considering the complex relationships between important factors. However, when educational issues in South Africa are highlighted, factors such as the budget or instructional materials are more likely to show up than factors such as safety, morale, and ethos. Recommendations made here are focused on factors, such as student and teacher background.

Recommendation 1: Improving the teaching and learning culture and environment.

The research revealed that students' low morale and lack of safety in schools accounted for some of the variance in science achievement in South Africa. There is a need to ascertain whether a culture of resistance to teaching and learning originating from the previous apartheid government still permeates teachers and students attitudes, even after the political changes in 1994, particularly as a safe and favourable atmosphere is a prerequisite for consistent schooling. A safe environment is one of the dimensions determining quality education (UNICEF, 2000), and 'safety in school' was a strong predictor explaining the variance at the class/school level in South Africa. Therefore, policymakers need to promote an ethos that being educated is valuable, necessary and compulsory in a modern and democratic society, hence a safe environment around schools should be cultivated.

Recommendation 2: Improving teachers' content knowledge

The research confirmed that the lack of qualified science teachers is significant in South Africa. It was pointed out that under-qualified teachers are at the core of factors blamed for poor performance of students, along with the poor infrastructure (Naidoo & Lewin, 1998; Howie, 1999). It is evident that a modern, high quality science curriculum and pedagogy cannot compensate for poorly trained teachers. OBE was introduced as an instructional method to redress deficiencies from the inadequate policies of the past government (Spady, 2008). Despite the high level of responses from South African teachers about science as conducting scientific investigation by many ways, practical work or STS work showed a negative relationship with student achievement. Pinto and Boudamoussi (2009) found the more familiar science teachers were with the underlying scientific knowledge, the more willing they were to take account of the diversity of scientific process such as describing, explaining and predicting scientific phenomena, understanding scientific investigation, and interpreting scientific evidence. Therefore, policy should be developed to improve content knowledge of teachers to improve the quality of science education.

Recommendation 3: Improving student fluency in the language of instruction.

Language is important in science education in the light of social constructivist theory, which contends that students can scaffold knowledge based on language-based social interactions (Staver, 1998). If learners do not have a good command of the language of instruction, outcomes intended cannot be accomplished. Therefore, the language of instruction needs to be taught from the beginning of schooling so that students can improve it before learning more complex knowledge-based subjects such as science. Furthermore, changing the language of instruction in the middle of primary schooling can cause confusion.

9.4.3 RECOMMENDATIONS REGARDING TIMSS

TIMSS is a large scale international comparative study of student achievement in mathematics and science. TIMSS results can provide participating countries or researchers with knowledge of the extent of progress in educational achievement of mathematics and science, suggesting reasons for differences by comparisons between countries, or improving evaluation of the efficacy of mathematics and science teaching and learning. Researchers and stakeholders are becoming more interested in TIMSS and intend to make use of data provided. Therefore, to benefit TIMSS it may be meaningful to give some recommendations based on the results of the research.

Recommendation 1: Suitability of topic coverage

TIMSS made considerable efforts to determine whether items of achievement tests are appropriate across countries, and thus to ensure their validity, as reviewed in Chapter 2. In terms of content coverage, the curriculum questionnaire, which was not covered in the current research, collected intended curriculum from experts who do not implement but plan curriculum. TIMSS addressed content coverage in teacher questionnaires, but these are not related directly to items tested. Keys (1999) pointed out that TIMSS failed to collect results on the implemented curriculum, which is referred to as opportunity to learn the contents of items tested. Instead, results were only collected on the intended curriculum, which is topic coverage. As a consequence, TIMSS results do not inform users whether or not content pertaining to any specific test item has been covered. As shown in Test-curriculum Matching Analysis (TCMA) addressed in TIMSS, South African students' poor achievement could be accounted for by inadequate opportunity to learn (OTL). For future research, it is recommended that a measure is added that covers this deficit. It is particularly necessary where the study intended cross-country comparisons, because it is very evident that opportunity to learn (OTL) influences achievement and accounts for differences in achievement across individuals and contexts.

Recommendation 2: Instrumentation issue

Besides OTL, if researchers aim to compare the influence of educational processes in different countries, it is more appropriate also to collect data on prior achievement, referred to as aptitude. This can be useful because cross-sectional studies that collect data at one point in time do not guarantee appropriate causal inferences (Bos, 2002). Students' aptitude, which is a strong predictor of achievement in SER, can be addressed by collecting information about prior achievement as well. It is expected that the unexplained variance in achievement at the student level can be better understood when factors potentially influencing achievement are added to a new conceptual framework and subsequently to the questionnaires.

On the other hand, TIMSS cannot increase the number of items unlimitedly in order to obtain information needed, due to the constraints of cost and time. To compensate for it, some items that represent the same construct can be removed. For example, there seem to be too many items pertaining to resources or teacher qualification and, among them, only a few items should remain. If some resource-related and teacher qualification-related questions are deleted and replaced by new and necessary ones, the number of questions that respondents should answer will decrease. Consequently, it would not raise the problem of time spent on answering too many questions. In terms of reliability and validity, selection issue was discussed further in the next recommendation.

Recommendation 3: Various data collection methods.

In contrast to a considerable number of variables derived from TIMSS questionnaires that were originally designed to find explanatory factors for science achievement, only a few variables turned out as statistically significant predictors. This could be attributed to survey research in which participants tend to respond with social desirability, undermining the reliability of the responses (Reeazigt et al., 1999). In particular, TIMSS questionnaires allocate a considerable number of questions to teacher instruction, but the data from the questions do not seem to offer plausible information about teaching practice in sampled classrooms. In order to build statistically and conceptually functional scales for the characteristics of the instruction, more items should be addressed, using a variety of methods, including observation (Kupari, 2006). Bos (2002) also pointed out that some of the constructs in the questionnaires should be elaborated on to ensure reliable scales.

9.4.4 RECOMMENDATIONS REGARDING SCHOOL EFFECTIVENESS RESEARCH

Since SER was initiated in the educational research field in the 1960s, it has contributed to evaluation and monitoring of education systems to improve the quality of education. SER involves other research areas, such as teacher effectiveness and school improvement, as there can be various approaches to improving the quality of education. For future SER, some recommendations are proposed below.

Recommendation 1: Multiple criteria as outcomes need to be measured.

Recently, multiple criteria as outcomes are demanded to determine the effectiveness of instruction and of schools. These include basic skills, higher cognitive outcomes, outcomes in different subject areas, and social and affective outcomes (Creemers, 1994). It should be noted that students not only learn cognitive skills but also other things, such as attitudes in their school. Therefore, estimation of school effectiveness by using one criterion shows only a part of all the aspects. It was documented that different kinds of outcomes are influenced by different factors (Hamilton et al., 1995). As the current study used science achievement as outcome, attitudes towards science can also be an outcome to be obtained by students. As quality education has many dimensions, such as learning environment, learning process or learning outcomes, SER needs to designate outcome criteria in many aspects.

Recommendation 2: Country-specific and subject-specific factors need to be considered.

SER should continue to explore generalisations on factors influencing achievement across countries as well as considering specific environments in which an educational system is nested. As shown from the results of the current study, some factors are common to both countries and others specific to a particular country. In particular, specific factors are more likely to reflect on the specific situation in which an educational system in question is placed. For example, watching television or video reduces time on task in Korea while it supports student learning in South Africa. In addition, taking into account that subject-specific factors such as computer use is important in Korea, SER should seek not only generalization but also specification across countries and subjects.

9.5 CONCLUSION

Having a first glance at TIMSS tables summarising mean achievement in science, it is clear that Korea outperformed South Africa in consecutive studies. However, before any interpretations or conclusions are made by the information illustratively presented in TIMSS only, it should be considered that countries such as Korea and South Africa examined here differ with respect to many social and educational contexts, such as culture, history, and demography. There is no doubt that these differences affect the amount of observed variability in science achievement among students in each context. It is against this backdrop that in-depth research such as the current study is necessary to fully utilise TIMSS data.

Cross-national studies in education, such as the current one, provide researchers with an opportunity to examine how students in both similar and different formal education systems perform in the same test, and give abundant information about the relationships between student achievement and the factors influencing them. Under the assumption that the two countries can learn from each other, this comparative study between Korea and South Africa purposed to provide valuable information for improving the prediction of students' science achievement in the two countries. However, in order to learn from other educational systems, one should keep in mind that there is no single education method that best suits all schools around the world. Where Korea needs to develop student-centred teaching practices to address negative attitudes to science, South Africa needs to address basic developmental issues such as improving teachers' subject knowledge, developing language skills, and fostering a culture of learning to improve performance. Therefore, what should be ascertained from the research is 'what is the best for one' and 'what is the best for the other'.

On the other hand, although societal values and conditions differ in Korea and South Africa, from a perspective of teaching and learning theory, it was valuable to find that the key factor such as time was important even in two extremely different countries. However, other key factors such as opportunity to learn and quality still could develop into a further study.

Some researchers found that nations that educate their populations in scientific and technical skills experience improved economic performance (Schofer et al., 2000; Murray, 2008). Although science education by itself is not sufficient condition of high economic development, scientific literacy cannot be separated from the national future development. In this vein, this study is poised to make valuable contributions to Korean and South African science education by examining differences between the two countries as well as the relationships between science achievement and background characteristics.

> *"Major transitions in life are often made mentally and emotionally before they are made physically. Persons facing such changes will usually make the mental adjustments before the physical ones are forced upon them. …Emotionally they saw themselves as part of the new, but they were physically located in the old. Yet each in its own way created circles of the new that existed within the old: small islands in a vast ocean. However, the circles expanded and new ones appeared, and together they constituted a powerful force.*
> *It has become possible for yesterday's distant dreams to become tomorrow's reality*." (Rogan & Gray, 1999, p384)