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Factors Influencing Students' Achievements in the Content and Cognitive Domains in TIMSS 4th Grade Science and Mathematics in the United Arab Emirates

Asma Balfaqeeh [1], Nasser Mansour [2,*] and Sufian Forawi [3]

[1] Emirates National Schools, Abu Dhabi 44321, United Arab Emirates
[2] College of Education, Qatar University, Doha 9FFR+FC9, Qatar
[3] College of Education, The British University in Dubai, Dubai 345015, United Arab Emirates
* Correspondence: n.mansour@qu.edu.qa or n.mansour@hotmail.co.uk

Abstract: Trends in International Mathematics and Science Study (TIMSS) is a comparative international assessment study conducted by the International Association for the Evaluation of Educational Achievement (IEA). TIMSS aims to study how educational opportunities are provided for students and what factors are associated with these opportunities. The purpose of this study was to examine the student factors in the United Arab Emirates that have an association with grade 4 students' TIMSS 2015 results in the content and cognitive domains in the subjects of mathematics and science. The study adopted the quantitative research approach through the data analysis of TIMSS 2015 for grade 4 students in these subjects. The study sample consisted of 21,177 students enrolled in 372 UAE private schools and 186 public schools. The percentage of grade 4 girls who participated in the study was 48%, while the percentage of boys was 52%. A multiple linear regression analysis was conducted to examine the most influential student factors that impact on science and maths achievement. Structural equation modeling (SEM) was implemented to examine the relationships between student factors and the content and cognitive domains of mathematics and science in the TIMSS 2015 results. The findings showed that the student factors with a positive association with student achievement were having breakfast on school days, engaging teaching in mathematics lessons, liking learning science, and confidence in mathematics and science. There was a non-significant correlation between gender and mathematics and science achievement. A surprising finding was that "liking learning mathematics" had a negative association with student performance in that subject. There was a positive association between student engagement and mathematics achievement, while the association between the engagement in science lessons and student performance was found to be insignificant.

Keywords: Trends in International Mathematics and Science Study (TIMSS); content domains; cognitive domain; achievement; UAE

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1. Introduction

Trends in International Mathematics and Science Study (TIMSS) is a comparative international assessment study for more than 60 countries that is conducted by the International Association for the Evaluation of Educational Achievement (IEA) [1]. TIMSS has a quasi-longitudinal design, as grade 4 student cohorts will be assessed again after four years when they are in grade 8 [1]. The countries that participate in multiple cycles of the assessment can track students' progress, and can evaluate any changes that have been made in the country's education system (IEA, 2019). This design provides an early warning system for required curriculum reforms for grade 4, and allows us to measure the effectiveness of these reforms during grade 8 [1].

TIMSS results are highly valued by international policymakers and also by the government of the UAE. In 2010, H.H. Sheikh Mohammed bin Rashid Al Maktoum launched the UAE's Vision [2], which aims to make the country one of the top countries in the world when its celebrates 50 years of its union in 1971 [2,3]. One of the performance indicators of the vision is to be amongst the top fifteen performers in the TIMSS results. However, when looking at the UAE results in TIMSS 2015, it can be noted that grade 4 students need to improve by 20 ranks in both mathematics and science [4]. Therefore, the student factors that were associated with the UAE's student results need to be investigated in order to meet this national vision.

Most of the TIMSS analysis studies in the literature were conducted on European, American, or East Asian students. No published studies focused in depth on students in the UAE. This study, therefore, focused on the TIMSS 2015 results in the UAE, and investigated the factors associated with students' results.

Although several research studies have been conducted on student achievement based on TIMSS, most of these studies investigated the connections between student results as one variable, without taking into consideration the content and the cognitive domains. Camilli and Dossey [5] showed that investigating the content domain in TIMSS helps countries to develop a more strategic use of these test results. Looking back at the results of the TIMSS 2015 and 2011 research in the UAE, the challenges in the content and cognitive domains are similar [4]. Thus, the content and cognitive domains in TIMSS need to be investigated further, as the results have remained the same over two test cycles. In this study, the content domains in mathematics are Numbers, Geometry, and Data Display, while for science they are Life Science, Physics and Earth Science [1]. The cognitive domains of Knowing, Applying and Reasoning are the same across these subjects [1].

1.1. Student Factors

A number of researchers reported that there was a positive correlation of a healthy lifestyle and academic attainment [6–10]. Studies from the literature investigated the effect of a healthy diet on children's skills, and a healthy diet was found to improve students' cognitive functions for primary school students [6]. Burrows et al. [7] stated that balanced dietary behaviors are associated with better academic performance. For elementary students, an unhealthy lifestyle will lead to poor academic performance in English language and mathematics [11].

It is important for students to eat breakfast daily, as children who did not eat breakfast had lower scores in cognitive assessments [12]. Furthermore, students who eat school breakfast and lunch receive higher nutritional quality than the ones who obtain their meals from home because school meals have higher dairy-rich food with a limited number of calories and added sugar compared to home meals [13]. This is because schools need to follow school meal regulations, which include the amount of calories, fruits, vegetables and grains to be eaten [13].

Gender has been an interesting topic in educational research, in order to study the differences in academic performance between boys and girls [14]. A study of Saudi Arabia's TIMSS results concluded that the mathematics achievements of girls is stronger than that of boys, and this was indicated in three TIMSS cycles [15]. In Jordan, Innabi and Dodeen [16] concluded that in TIMSS 2015, boys were more likely than girls to correctly answer complex, unfamiliar, real-life situation mathematics questions, while girls were more likely to give the correct answer for familiar and less-difficult questions [16]. This shows the importance of contextualizing the problems in the curriculum and being relevant to the students [17–19]. A study of gender differences in the TIMSS assessment of Singapore concluded that girls performed as well as or better than boys in mathematics [20]. Other studies indicated that boys performed better compared to girls [14,21], while other authors concluded that there was no direct relationship between student gender and science achievement [22].

A number of studies found a strong relationship between student motivational beliefs and student academic achievement [23–25]. Liou [25] stated that there is a positive correlation between student motivational beliefs and academic performance. A TIMSS analysis study concluded that when students are motivated to learn, it will have a positive effect on their academic results [24]. A student's motivation is influenced by their beliefs, interests, and attitudes, which can have either a positive or negative impact [26].

Students' self-concepts are related to different aspects of their lives and how they perceive their abilities in different dimensions [23]. Academic self-concept and self-confidence are important concepts in motivation, as they have an impact on the students' academic achievement [27–29]. Students' science achievement depended greatly on student factors such as self-confidence [30]. A student's low level of math self-concept will lead to a decline in their interest in the subject [31]; when academic self-concept increases, students' interests in the subject increase [29], and there is a positive relationship between academic self-concept and standardized assessment results [28]. Liou [32] indicated that self-concept is positively associated with students' individual achievements in mathematics and science.

A common phenomenon that threatens student safety in schools is bullying [33–38]. Bullying exists in every school, and it affects academic performance for both the victims who suffer it and the bullies themselves [34]. Gietz and McIntosh [39] stated that a student's perceptions of their school's environment—such as safety, bullying experience and clear behavior expectations—are associated with their academic achievement. Similarly, Strom et al. [33] found that schools with a high rate of bullying show lower academic performance, and Sulak [40] claimed that a low frequency of school discipline issues is often associated with high academic performance. A study of the association between teasing and bullying with academic achievement indicated that a high number of students and teachers perceive these to be significantly associated with low academic achievement and classroom engagement [35].

Classroom engagement refers to practices in which the students are actively involved in the learning process [41]. House and Telese [42] indicated that there is a significant positive relationship between student engagement and academic achievement. Students' engagement could be promoted through collaborative learning, as this has a positive impact on student learning behaviors and academic achievement [43]. Teamwork engagement has a positive influence on students' personal success, learning and work satisfaction [44].

1.2. Conceptual Framework

The conceptual framework of the study consisted of the TIMSS curriculum model and Piaget's cognitive development theory. Figure 1 shows the TIMSS curriculum model, which consists of three parts [45]: (1) the intended curriculum refers to the mathematics and science learning expectations for students; (2) the implemented curriculum refers to classroom teaching practices; and (3) the attained curriculum refers to what the students learned, and their perceptions of learning mathematics and science.

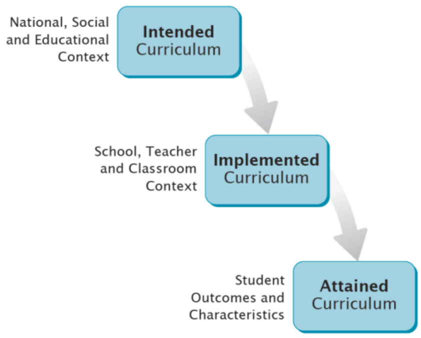

Figure 1. TIMSS curriculum model (from Mullis [45] (p. 5)).

As the focus of the study is on student factors and TIMSS results, it will be related to the attained curriculum. The attained curriculum refers to what the students have learned through the learning process. It is not measured only by student grades; it also involves student attitudes and characteristics that have been developed throughout the learning process [46]).

Piaget's [47] Theory of Cognitive Development focuses on the way in which humans construct and use knowledge based on their biological development and interaction with the environment. The focus of the study was on grade 4 students who were in the Concrete Operational Stage. This stage is considered to be the turning point of a child's cognitive development, language and fundamental skills, as it is the start of logical and operational thinking [48]. In TIMSS assessment, students need to be familiar with the content of mathematics and science, and they need to have acquired the cognitive skills to respond correctly to the questions [45]. The cognitive domains that are assessed in the assessment are Knowing, Applying, and Reasoning [45]. Referring to the skills that grade 4 students acquired in the concrete operational stage, students can use their Knowing skills in recalling and recognizing the information, their Applying skills in applying this knowledge in different contexts by the property of conservation and reversibility, and their Reasoning skills in solving problems in logical and rational ways.

1.3. Content and Cognitive Domains

The content domain focuses on the subjects or topics that need to be assessed [1]. Camilli and Dossey [5] showed that investigating the content domain in TIMSS helps the countries to gain more strategic use of the test results, obtain diagnostic information that helps to differentiate aspects of education on a national level, and to provide more supplementary information, as each country emphasizes a different aspect in the content domain. In the TIMSS assessment, the content domains for grade 4 in mathematics were Number, Geometry, and Data Display, while for science, these were Life Science, Physics and Earth Science [1]. Each content topic is divided into sub-topics. Daus and Braeken [49] showed that the varieties in the implementation of the content domains among countries in TIMSS since 2015 were because of some school's investment in teaching Biology, while others aimed for a balance between the three domains.

The cognitive domain refers to the thinking process and skills that are required in order to respond to the assessment items [1]. In TIMSS assessment, the question items cover students' thinking skills in three cognitive domains: Knowing, Applying and Reasoning [45].

The cognitive process in different domains requires the organization of the sequential information into an integrated structure [50]. A study of gender differences in TIMSS assessment according to the cognitive domain concluded that there is little difference in the three areas, which are Knowing, Applying and Reasoning, with boys outperforming girls in all of them [51]. Miscevic-Kadijevic [52] stated that cognitive achievement in the areas of Knowing, Applying and Reasoning were linked to self-confidence. Peduk and Ates [52] claimed that one of the most important reasons for nations not performing well in the TIMSS assessment is that the assessment and examinations that are implemented in these schools do not measure higher-order thinking skills. A study of Taiwanese TIMSS results concluded that Reasoning cognitive domain questions were more difficult than Applying and Knowing because Reasoning is considered a higher-order thinking skill that requires the analysis of information and judgment of its purpose [53].

1.4. Purpose and Research Questions

The purpose of this study was to examine the student factors that have an association with the grade 4 students' mathematics and science TIMSS 2015 results in the content and cognitive domains in the UAE. The content domains in mathematics are Numbers, Geometry, and Data Display, while for science, these are Life Science, Physics and Earth Science [1]. The cognitive domains of Knowing, Applying and Reasoning are the same across these subjects [1]. The research addressed the following questions:

1. What are the most influential Student Factors that have an impact on grade 4 mathematics and science achievement in TIMSS 2015 in the UAE?
2. What are the relationships between Student Factors and the content and cognitive domains of mathematics and science in TIMSS 2015 in the UAE?

2. Methodology

The approach of this study was purely quantitative. The study used secondary data analysis of TIMSS 2015 for grade 4 students in the subjects of mathematics and science in the UAE.

The sites of the study were public and private schools. The population of the study were all grade 4 students in the UAE. For the UAE TIMSS 2015 study, the grade 4 sample comprised 372 private schools and 186 public schools [4]. The total number of sample schools was 558 schools. The sample of grade 4 comprised 21,177 students [4]. The percentage of grade 4 girls who participated in the study was 48%, while the percentage of boys was 52% [54].

The data collection instruments were divided into two parts: assessment items and student questionnaires. The assessment items consisted of grade 4 mathematics and science TIMSS 2015 questions. Table 1 shows the percentages of the TIMSS 2015 assessment items for the content domains in mathematics (Numbers, Geometry and Data Display), content domains in science (Life Science, Physics and Earth Science), and cognitive domains (Knowing, Applying and Reasoning) in both.

Table 1. Percentages of the TIMSS 2015 assessment items for the content and cognitive domains (Mullis and Martin [45]).

Content Domains of Mathematics	Percentages	Content Domains of Science	Percentages	Cognitive Domains	Percentages
Number	50%	Life Science	45%	Knowing	40%
Geometry	35%	Physical Science	35%	Applying	40%
Data Display	15%	Earth Science	20%	Reasoning	20%

2.1. Selection of Variables

The variables were selected from students' TIMSS 2015 questionnaires, based on studies in the literature that identified them as the most critical variables that affected student performance. As there were many variables in the TIMSS questionnaires, these were reduced by combining them into composite variables. The study used the TIMSS 2015 background indices for the composite variables. The background index is a composite variable that assigns the participants' responses into one of three levels based on the data of the component variables [1].

There were seven composite factors in the student questionnaire that were selected for the study, and two ungrouped essential variables that were selected, which were gender and breakfast during school days. All of the student factors that are involved in the study are presented in Table 2. All of the items of the selected variables are presented in Appendix A (Table A1).

Table 2. Selected variables of the student factors.

Selected Variables (TIMSS Index)	Number of Items	Examples (TIMSS Index)
Student bullying (ASDGSB)	8	Someone spread lies about me (ASBG12C)
Engaging teaching in Mathematics Lessons (ASDGEML)	10	My teachers show me how to do better (ASBM02I)
Like learning mathematics (ASDGSLM)	9	I enjoy learning mathematics (ASBM01A)
Student confidence in mathematics (ASDGSCM)	9	I usually do well in math (ASBM03A)
Engaging teaching in science lessons (ASDGESL)	10	I am interested in what my teacher says (ASBS05C)
Like learning science (ASDGSLS)	9	Enjoy learning science (ASBS04A)
Student confidence in science (ASDGSCS)	7	I usually do well in science (ASBM03A)
Other variables of interest with no group		
Gender (ASBG01)		
Breakfast on School Days (ASBG09)		

2.2. Data Analysis

The TIMSS assessment used Plausible Values (PV), which are a computational approximation of the population characteristics in assessments, which are used when there are few items to provide a precise estimation of students' abilities [55]. The PVs were used in TIMSS assessment because they did not provide individual scores for students, but they estimated the population parameters such as average and variance. When analyzing TIMSS data, each PV variable needs to be considered during the analysis. These variables help us to achieve an accurate estimation of the average achievement for each domain.

TIMSS 2015 used Jackknife Repeated Replication (JRR) techniques that provide an accurate estimation of the sampling errors. The study followed recommendations from Rutkowski et al. [56] when calculating the sampling weight of the TIMSS analysis that included schools, classrooms and student factors.

Final Student Weight = (Student weight factor × Student weight adjustment) × (Class weight factor × Class weight adjustment)

An essential step in preparing the data for analysis was data cleaning, including correcting errors in the data, and correcting incoherent entries within and between instruments, etc. This process assisted us in handling potential errors before analysis (Chai 2020). The cleaning process in the study included making a gender variable 0, 1 (Female = 1, Male = 0) instead of 1, 2, as was indicated in TIMSS' original data set. Furthermore, it included rescaling questions to recode "Never" as 1 instead of 4, and "Strongly Disagree" as 1 instead of 4 for positive variables.

Due to the large sample size of the TIMSS assessment, some of the data were missing. For multivariate analysis, it is recommended to drop the cases of the missing data rather than to replace them [57]. Therefore, as the study used a multivariate analysis, such as multiple linear regression, the study used the deleting method. Allison [58] stated that listwise deletion leads to an unbiased estimation of regression coefficients, and that it leads to an accurate estimate of standard errors. As the study used regression and SEM analysis, it is essential to take into consideration the analysis method when selecting the deleting method of data analysis. Therefore, the study used listwise deletion.

The data analysis techniques were descriptive statistics, multiple linear regression, and Structural Equation Modeling (SEM). The pieces of statistical software that were used to conduct these data analysis techniques were IEA IDB analyzer and Stata. The study used the IEA IDB analyzer to combine the data in order to ensure that the data were merged with the correct variables, plausible values and weights. The merged data were then produced using the SPSS format. However, the SPSS program could not perform the required analysis using the plausible values for the mathematics and science results. Therefore, Stata/IC 16.1 was used to perform these analyses. Stata had specific commands for survey analysis that used plausible values (PV), Jackknife Repeated Replication (JRR), sampling weights, and specific controls for TIMSS data.

3. Results

3.1. Descriptive Statistics

The descriptive statistics for student factors are presented in Table 3. There are nine variables in Table 3; these are the TIMSS indices, except for gender and breakfast on school days. All of the variables had a three-point Likert scale, except for breakfast on school days and gender. The largest average and standard deviation in Table 3 were for the breakfast on school days variable (M = 3.27. SD = 1.03). This is because this variable had four values. The variable 'gender' had two values (Female = 1, Male = 0); the mean of 0.49 showed that the numbers of male and female students were almost equal.

The Most Influential Student Factors That Have Impact on Science and Math Achievement

In order to answer the first research question, "What are the most influential student factors that have impact on science and math achievement?", a multiple linear regression analysis was conducted. The selected variables of the student questionnaire were used to form the linear regression model of the student factors. The analysis was conducted for the five plausible values for the two subjects. Table 4 shows the regression analysis for student factors based on math achievement. The R^2 of the mathematics achievement model based on student factors was 0.12, which means that approximately 12% of the variability of mathematics achievement was accounted for in the variables of the model.

Table 3. Descriptive statistics of the student factors.

Variable	M	SD
Bullying	1.84	0.82
Like learning mathematics	2.44	0.68
Like learning science	2.56	0.62
Student confident in mathematics	2.11	0.71
Student confident in science	2.24	0.73
Engagement in mathematics lessons	2.63	0.59
Engagement in science lessons	2.68	0.57
Breakfast on school days	3.27	1.03
Gender	0.49	0.50

Table 4. Regression analysis results of the student factors with mathematics achievement.

Predictor	b	SE	t	*p*
Gender	−1.41	3.82	−0.37	0.71
Breakfast on school days	2.52 *	0.91	2.75	0.01
Bullying	−13.10 ***	1.60	−8.20	<0.001
Like learning math	−5.13 *	2.36	−2.18	0.033
Engaging teaching in mathematics lessons	11.5 ***	2.64	4.35	<0.001
Student confident in mathematics	41.07 ***	1.81	22.66	<0.001
Intercept	369.75 ***	8.12	45.52	<0.001
R^2	0.12			

* significant at the 0.05 level, *** significant at the 0.001 level.

The significant regression equation that predicted math achievement based on student factors was the following:

$$\begin{aligned} Y_i(Grade\ 4\ Math\ Achievement) &= 369.75 + +2.52(Breakfast)_i - 13.10(Bullying)_i \\ &-5.13(Like\ Math)_i \\ &+11.5(Engaging\ Teaching\ in\ Math\ Lessons)_i \\ &+41.07(Math\ Confidence))_i + \varepsilon \end{aligned}$$

Like mathematics achievement, the regression analysis for the student factors that were associated with science achievement was conducted, and the results are shown in Table 5.

Table 5. Regression analysis results of student factors with science achievement.

Predictor	b	SE	t	*p*
Gender	2.83	4.16	0.68	0.50
Breakfast on school days	2.20 *	1.01	2.19	0.032
Bullying	−16.69 ***	1.80	−9.26	<0.001
Like learning science	21.57 ***	2.33	9.26	<0.001
Engaging Teaching in science lessons	0.32	2.78	0.12	0.91
Student confidence in science	43.40 ***	1.97	22.01	<0.001
Intercept	327.37 ***	10.01	32.72	<0.001
R^2	0.16			

* significant at the 0.05 level, *** significant at the 0.001 level.

The significant regression equation that predicted science achievement based on student factors was the following:

$$Y_i(Science\ Achievement) = 327.37 + 2.20(Breakfast)_i - 16.69(Bullying)_i + 21.57(Like\ science)_i + 43.40(science\ Confidence)_i + \varepsilon$$

3.2. The Relationships between Student Factors and the Content and Cognitive Domains

In order to answer the second research question, "What are the relationships between student factors and the content and cognitive domains of mathematics and science TIMSS 2015 ?", a structural equation modeling (SEM) analysis was conducted with the selected variables of student factors and the content and cognitive domains of mathematics and science. Table 6 shows the SEM analysis of student factors with the content domains of mathematics. From Table 6, all of the student factors had statistically significant relationships with all of the content domains of mathematics. The model had a weak fit, as the Standardized Root Mean Square Residual (SRMR) was 0.42, and the Coefficient of Determination (CD) was 0.30. The model has a weak fit, as a perfect fit for SRMR is when it is close to 0, and for CD is when it is close to 1 [59].

Table 6. SEM analysis of the student factors model with the mathematics content domain.

Model	Coefficient	*p*
Model with Data Display		
Gender	2.54 *	0.047
Breakfast on school days	2.06 **	0.001
Bullying	−15.09 ***	<0.001
Like learning mathematics	−4.05 **	0.001
Engaging teaching in mathematics lessons	16.10 ***	<0.001
Student confident in mathematics	41.62 ***	<0.001
Model with Geometry		
Gender	3.58 **	0.005
Breakfast on school days	3.15 ***	<0.001
Bullying	−12.11 ***	<0.001
Like learning mathematics	−7.27 ***	<0.001
Engaging teaching in mathematics lessons	9.72 ***	<0.001
Student confident in mathematics	40.05 ***	<0.001
Model with Number		
Gender	−4.48 ***	<0.001
Breakfast on school days	2.23 ***	<0.001
Bullying	−11.97 ***	<0.001
Like learning mathematics	−4.29 ***	<0.001
Engaging teaching in mathematics lessons	9.33 ***	<0.001
Student confident in mathematics	42.54 ***	<0.001
Model Fit		
SRMR	0.42	
CD	0.30	

* significant at the 0.05 level, ** significant at the 0.01 level, *** significant at the 0.001 level.

In Figure 2, the latent variables of the model are Data Display, Geometry and Number. The observed variables were gender (ASBG01), breakfast on school days (ASBG09), bullying (ASDGSB), liking learning mathematics (ASDGSLM), being engaged in math lessons (ASDGEML), and confidence in mathematics (ASDGSCM). The factors that had a positive effect on the three latent variables were breakfast on school days, being engaged in math lessons, and students' confidence in mathematics; meanwhile, bullying and liking learning mathematics had a negative effect on the model. The gender variable had a positive effect on Data Display and Geometry, whilst also having a negative effect on the Number variable. This means that being a female student had a positive impact on Data Display and Geometry, whilst also having a negative effect on the Number content domain.

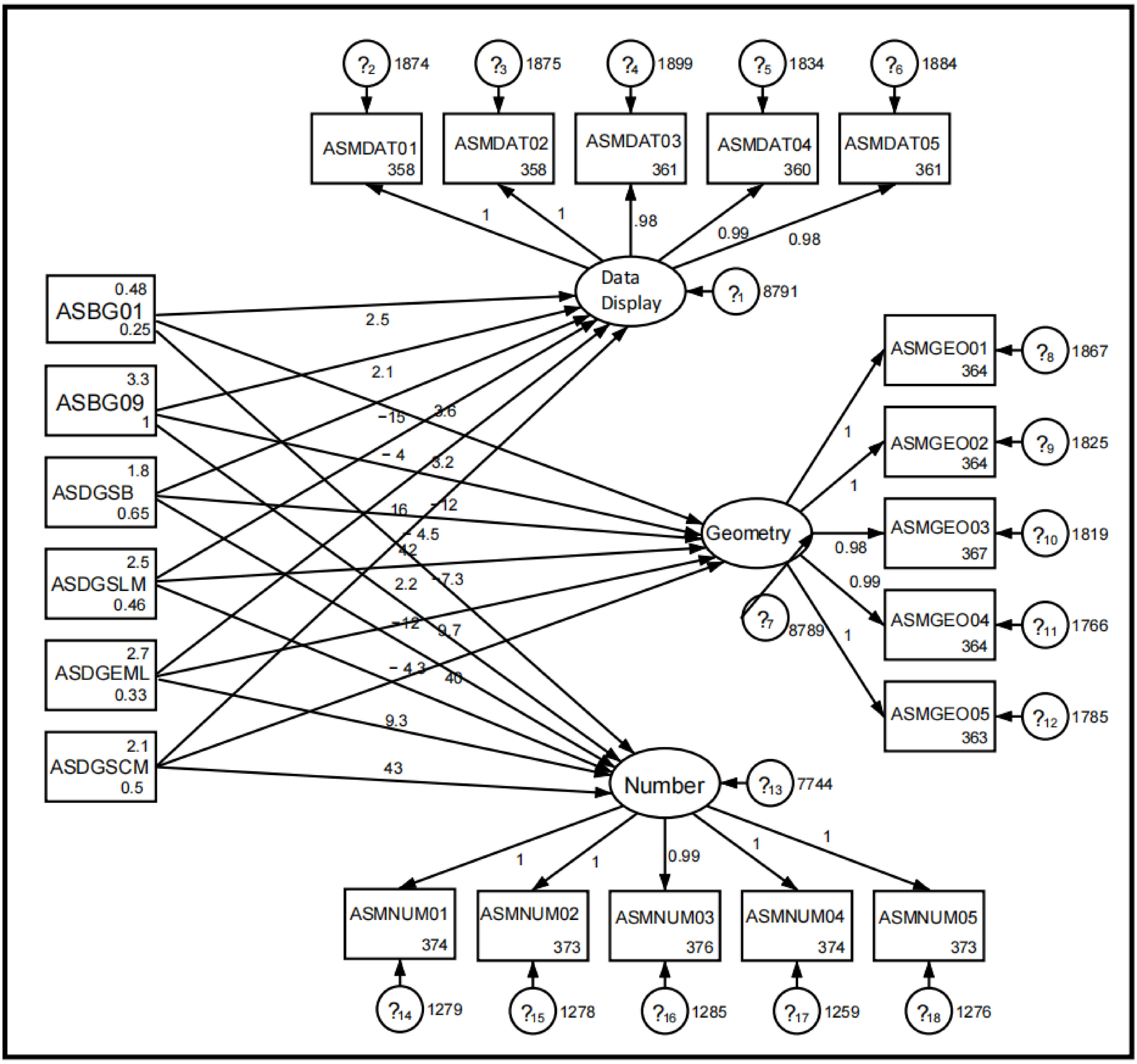

Figure 2. SEM model for student factors with the content domain of mathematics.

An SEM analysis was conducted with student factors, and the cognitive domains of mathematics and results are shown in Table 7. From the table, the model had a weak fit, as SRMR = 0.43 and CD = 0.32.

As shown in Figure 3, the latent variables of the model were Knowing, Applying and Reasoning. The observed variables were bullying (ASDGSB), engaging teaching in mathematics lessons (ASDGEML), liking learning mathematics (ASDGSLM), student confidence in mathematics (ASDGSCM), gender (ASBG01), and breakfast on school days (ASBG09). The observed variables that had a statistically significant positive effect with the three latent variables were breakfast, being engaged in math lessons, and student confidence in mathematics. The factors of bullying and liking learning mathematics had a negative effect on the three models of the cognitive domains. Gender had an insignificant effect on the cognitive domains of Knowing and Reasoning, while it had a statistically significant negative effect on the Applying model.

Table 7. SEM analysis of student factors with the cognitive domains of mathematics.

Model	Coefficient	p
Model with Knowing		
Gender	−3.09	0.075
Breakfast on school days	3.38 ***	<0.001
Bullying	−13.82 ***	<0.001
Like learning mathematics	−7.60 ***	<0.001
Engaging teaching in mathematics lessons	16.49 ***	<0.001
Student confident in mathematics	45.59 ***	<0.001
Model with Applying		
Gender	−3.78 *	0.025
Breakfast on school days	3.64 ***	<0.001
Bullying	−13.67 **	<0.001
Like learning mathematics	−7.89 ***	<0.001
Engaging teaching in mathematics lessons	13.22 ***	<0.001
Student confident in mathematics	43.34 ***	<0.001
Model with Reasoning		
Gender	0.085	0.959
Breakfast on school days	3.20 ***	<0.001
Bullying	−13.68 ***	<0.001
Like learning mathematics	−7.99 ***	<0.001
Engaging teaching in mathematics lessons	12.72 ***	<0.001
Student confident in mathematics	43.85 ***	<0.001
Model Fit		
SRMR	0.43	
CD	0.34	

* significant at the 0.05 level, ** significant at the 0.01 level, *** significant at the 0.001 level.

In the same vein as mathematics, an SEM analysis was conducted between the student factors and the content and cognitive domain of science. From Table 8, the SEM analysis model for the student factors with the content domain of science had a poor fit, as shown in the values SRMR = 0.40 and CD = 0.39.

Table 8. SEM analysis for student factors with content domains of science.

Model	Coefficient	p
Model with Earth Science		
Gender	−3.24 *	0.015
Breakfast on school days	2.05 ***	<0.001
Bullying	−15.03 **	0.002
Like learning science	19.20 ***	<0.001
Engaging teaching in science lessons	0.39	0.806
Student confident in science	44.22 ***	<0.001
Model with Life Science		
Gender	6.63 ***	<0.001
Breakfast on school days	2.04 **	0.003
Bullying	−16.74 ***	<0.001
Like learning science	22.614 ***	<0.001
Engaging teaching in science lessons	−1.41	0.382
Student confident in science	45.13 ***	<0.001
Model with Physics		
Gender	−2.74 *	0.041
Breakfast on school days	2.02 **	0.002
Bullying	−16.70 ***	<0.001
Like learning science	20.01 ***	<0.001
Engaging teaching in science lessons	1.32	0.396
Student Confident in Science	43.68 ***	<0.001
Model Fit		
SRMR	0.40	
CD	0.39	

* significant at the 0.05 level, ** significant at the 0.01 level, *** significant at the 0.001 level.

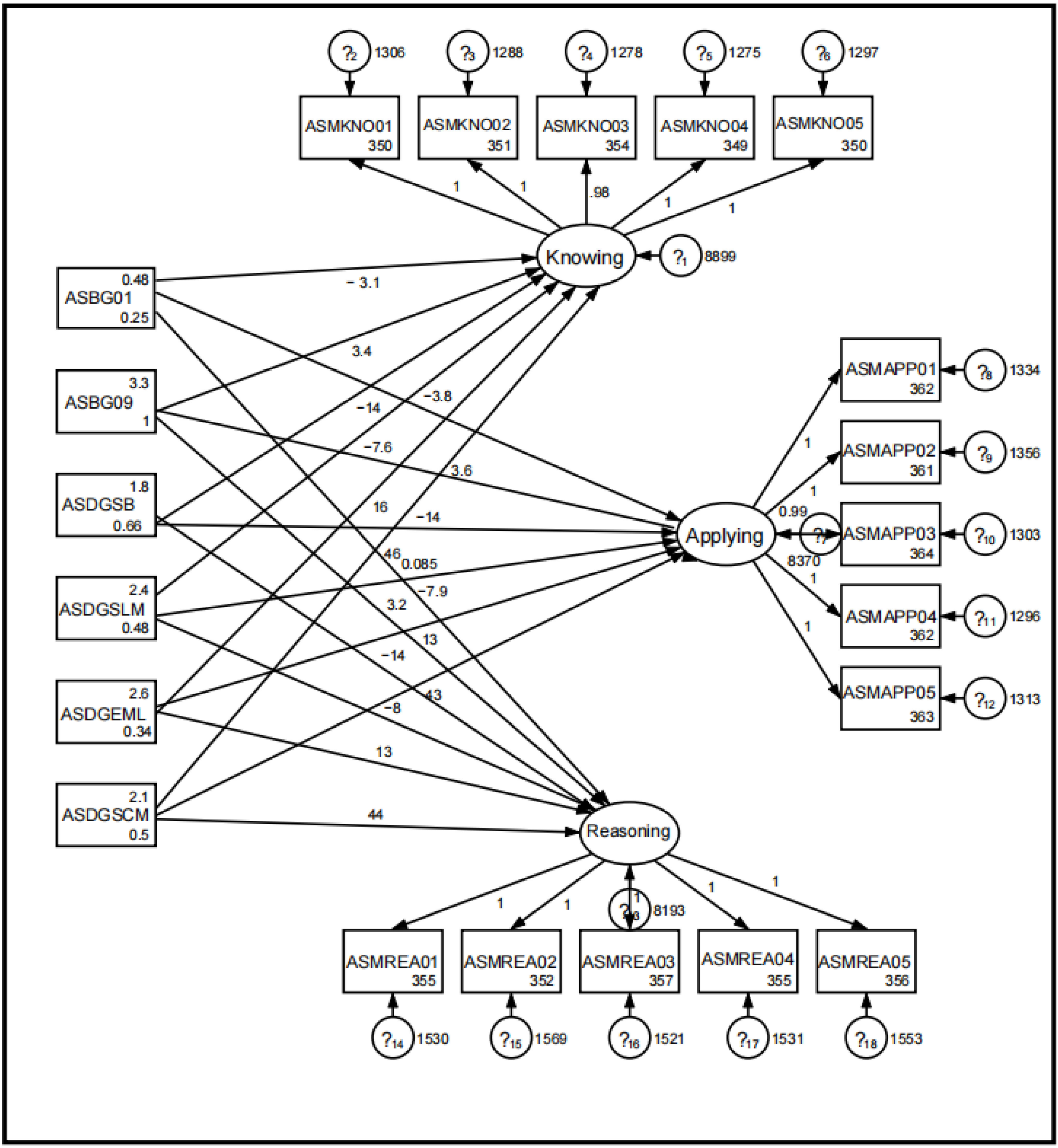

Figure 3. SEM model for student factors with the cognitive domain of mathematics.

From Figure 4, the latent variables in the model were Earth Science, Life Science and Physics. The observed variables were bullying (ASDGSB), engaging teaching in science lessons (ASDGESL), liking learning science (ASDGSLS), students being confident in science (ASDGSCS), gender (ASBG01), breakfast on school days (ASBG09). The factors that had a positive effect on the three latent variables were breakfast on school days, liking learning science, and student confidence in science, while bullying had a negative effect on the three models. Gender had a positive effect on Life Science and a negative effect on Earth

Science and Physics. Students' confidence in science had the largest effect on the three latent variables: Earth Science (b = 44.22), Life Science (b = 45.13), and Physics (b = 43.68).

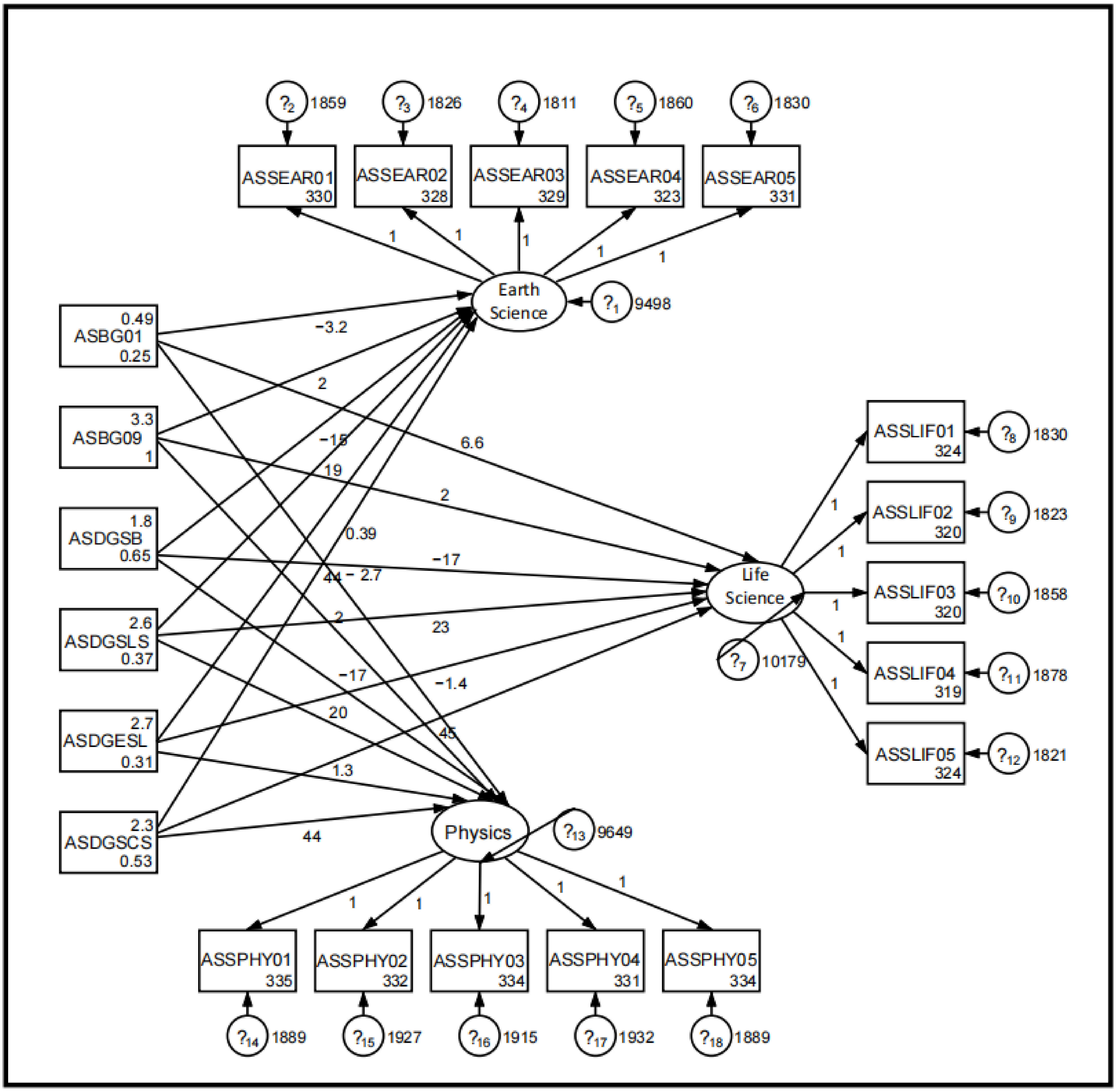

Figure 4. SEM model for student factors with the content domains of science.

An SEM analysis was conducted between student factors and the cognitive domains of science. From Table 9, the SEM analysis model for student factors with the cognitive domains of science had a poor fit, as the value of SRMR was 0.41, and that of CD was 0.39.

The model of SEM analysis between the student factors and the cognitive domains of science is illustrated in Figure 5. The latent variables were Knowing, Applying and Reasoning. The observed variables were bullying (ASDGSB), engaging teaching in science lessons (ASDGESL), liking learning science (ASDGSLS), students being confident in science (ASDGSCS), gender (ASBG01), and breakfast on school days (ASBG09). The factors that had a statistically significant positive effect on the three cognitive domains of science were breakfast on school days, liking learning science, and student confidence in science, while bullying had a statistically significant negative effect on the three models. Gender had a positive effect on Applying and Reasoning. Similarly to the model of the content domain, student confidence in science had the largest coefficient with the three latent variables.

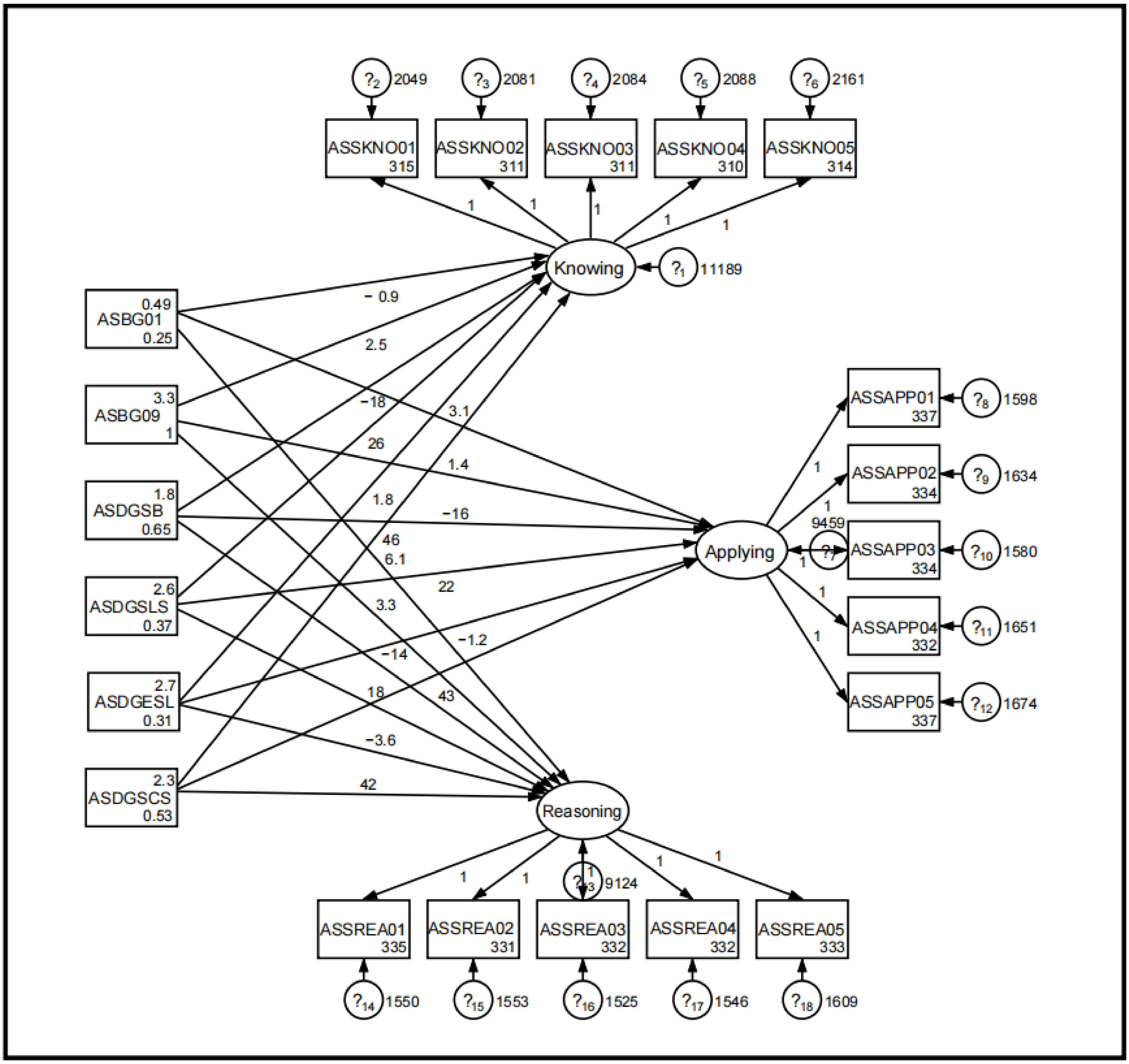

Figure 5. SEM model for student factors with the cognitive domains of science.

Table 9. SEM analysis for student factors with science cognitive domains.

Model	Coefficient	*p*
Model with Knowing		
Gender	−0.90	0.535
Breakfast on school days	2.48 ***	<0.001
Bullying	−18.23 ***	<0.001
Like learning science	25.98 ***	<0.001
Engaging teaching in science lessons	1.78	0.292
Student confident in science	46.29 ***	<0.001
Model with Applying		

Table 9. *Cont.*

Model	Coefficient	p
Gender	3.09 *	0.02
Breakfast on school days	1.45 *	0.025
Bullying	−16.07 ***	<0.001
Like learning science	21.50 ***	<0.001
Engaging teaching in science lessons	−1.23	0.433
Student confident in science	42.66 ***	<0.001
Model with Reasoning		
Gender	6.068 ***	<0.001
Breakfast on school days	3.32 ***	<0.001
Bullying	−14.29 ***	<0.001
Like learning science	17.94 ***	<0.001
Engaging teaching in science lessons	−3.58 *	0.019
Student confident in science	41.88 ***	<0.001
Model Fit		
SRMR	0.41	
CD	0.39	

* significant at the 0.05 level, *** significant at the 0.001 level.

4. Discussion and Implications

4.1. Student Factors That Have an Impact on Science and Math Achievement

The findings of the multiple linear regression model in Tables 4 and 5 showed that there is a non-significant correlation between gender and mathematics and science achievement. This finding is similar to Boz, Yerdelen-Damar and Belge-Can's [22], who stated that there was no direct relationship between student gender and science achievement. This finding is inconsistent with a study of Saudi Arabia, which found that the mathematics achievement of girls is better than that of boys [15]. Furthermore, it is not consistent with the Jordanian TIMSS results, as Innabi and Dodeen [16] indicated that girls performed better than boys in TIMSS 2015. A possible reason for the higher achievement of girls than boys might be that girls' confidence in learning is greater than that of boys [20], while boys may not show all their knowledge in exams [60]. Furthermore, girls study hard to understand the material of the subject, while boys only focus on their performance [61]. Another reason could be because women in the UAE have the same rights as men, and they have access to education, different careers, social benefits and government office [62]. Furthermore, the UAE National Agenda, Vision 2021, aimed to reduce inequality, including gender imbalance [4]. In UAE TIMSS 2019, there was a significant difference of 9 points in favor of UAE boys in mathematics. For science, in the TIMSS 2019, girls performed better than boys by 4 points [54]. This needs further study on the differences in gender in TIMSS 2019 and the factors that might cause these differences, and how we can improve our teaching pedagogies based on this understanding of the genders in TIMSS 2019. It was expected that having breakfast on school days would have a positive association with mathematics and science results. The results matched Hjorth et al. [12], who concluded that students who do not eat breakfast daily had lower scores in cognitive assessments. Furthermore, Burrows et al. [7] concluded that balanced dietary behaviors are associated with better academic performance. McIsaac, Kirk and Kuhle [11] stated that an unhealthy lifestyle for elementary students would lead to poor academic performance in mathematics. The healthy lifestyle could be linked to students' socioeconomic status. The economic affluence of homes was associated with student achievement [63]. Higher student achievement was associated with affluent students rather than the disadvantaged ones [64], and children from families with lower socioeconomic status performed more poorly in elementary schools than the children with higher socioeconomic status [65].

It was anticipated that bullying would have a negative association with mathematics and science achievement. The results were consistent with those of Al-Raqqad et al. [34], who stated that bullying had negative effects on students' academic performance. In the same vein, Strom et al. [33] concluded that schools with a high incidence of bullying show lowered academic performance.

The linear regression model showed that the factor of liking learning mathematics had a negative association with TIMSS 2015 mathematics student performance. On the other hand, as expected, the factor of liking learning science had a positive association with student performance. Liking learning is referred to as the students' desire to learn, which could be defined as motivation [66]. Students' motivation influences their beliefs, interest, and attitudes [26], which could result in a positive effect on student attainment. Students will learn better when they believe that subjects will benefit them, when they are interested in classroom activities, and when they have a positive attitude to learning in school.

Engagement in mathematics lessons demonstrated a positive association with student performance, while engagement in science lessons showed an insignificant association. The findings of the current study of the positive association between student engagement and mathematics achievement were similar to some studies in the literature. House and Telese [42] indicated that there is a significant positive relationship between students' engagement and their academic achievement in Korean TIMSS 2011 results. Furthermore, Moreira et al. [67] stated that higher-achieving students show higher cognitive engagement.

For the insignificant association between the engagement in science lessons and student performance, the explanations for these findings might be related to ineffective teaching strategies that were implemented in science classes. Littledyke [68] stated that students might have a negative attitude toward learning science when the concept is not linked to their experiences through the integration of the cognitive and affective domains.

The positive association with the confidence in learning and student achievement was similar to a number of studies in the literature. Mohammadpour, Kalantarrashidi and Shekarchizadeh [30] stated that students' science achievement depended greatly on student factors such as self-confidence, Guay et al. [69] stated that primary school self-concept had an impact on academic achievement, and Sewasew and Schroeders [28] noted that there is a positive relationship between academic self-concept and standardized assessment results.

A possible reason for the positive association between confidence in learning and academic performance is that it is linked to student motivation. Guay et al. [69] illustrated that academic self-concept was associated with student motivation. When students are interested in learning mathematics and science, they will be able to follow the classroom activities and understand the teacher's expectations.

4.2. The Relationships between Student Factors and the Content and Cognitive Domains of Mathematics and Science in TIMSS 2015

Structural Equation Modeling (SEM) analysis was conducted (see Tables 6–9 and Figures 2–5). The SEM analysis showed that there were differences between the genders in the performance in the specific content and cognitive domains. Girls performed better than boys in the content domains of Data Display and Geometry, while boys performed better in the Number and Applying questions. For science, girls performed better than boys in Life Science, Applying, and Reasoning questions, while boys performed better in Earth Science and Physics.

Studies in the literature indicated different findings from the current study in the content domains of mathematics. Stewart et al. [70] stated that there are no significant differences between male and female achievement in the areas of math calculation, geometric concepts, basic math concepts, and addition error factors. Furthermore, a study of the content domain of Data and Chance in the United States concluded that boys outperformed girls [71].

The current study concluded that there was an insignificant association between gender and the Reasoning cognitive domain questions. However, studies in the literature indicated that boys performed better in the Reasoning cognitive domain tasks. Stewart et al. [70] stated that boys outperformed girls in complex real-life problem situations. In Jordan, boys were more likely than girls to correctly answer complex, unfamiliar, real-life situations mathematics questions, while girls were more likely to obtain the correct answer for familiar and less-difficult questions [16].

It was difficult to find reasons for the differences in performance between genders in the specific content and cognitive domains. An argument provided by George and Robitzsch [51] about gender differences in specific content and cognitive domains stated that question items should be treated as a combination of both, rather than one domain by itself. The interaction effect of the content and cognitive domains could explain the significant differences between the genders which were not contemplated in a specific domain TIMSS analysis [51].

SEM analysis indicated that when the students had breakfast every school day it had a positive effect on the content domains and cognitive domains of mathematics and science. Having breakfast on school days improves students' abilities by maintaining a balanced dietary lifestyle, which is associated with better cognitive skills and academic achievement [10]. It is therefore very important to support healthy diet behavior in order to help improve students' academic achievement [11].

The study showed that when the students had been bullied in school, their achievement in the content domains and cognitive domains became lower. Students' ability to learn will decrease as a result of teasing and bullying. This will lead to lower student engagement in school, which might decrease students' desire to learn and perform well academically [35]. Furthermore, students who had been bullied were exposed to aggressive behavior that leads to lower performance in mathematics and science [72].

The findings of the SEM analysis indicated that when the students liked learning mathematics, their achievement in the content and cognitive domains became lower. For science, 'liked learning science' had a positive association with the content domains and cognitive domains.

It was difficult to explain the negative association between "liking learning mathematics" and student results, as well as in the content and cognitive domains. One possible explanation might be related to Ni et al.'s [73] indication that the desire to learn mathematics could be improved through high-cognitive-domain tasks, and building a positive relationship with the mathematics classroom. Furthermore, Slavin [74] stated that student motivation is influenced by previous experience in the school. High-achieving students might not be provided with high-cognitive-domain tasks that could make them like learning mathematics and have a positive relationship with the mathematics classroom. This might result in having a poor experience in mathematics lessons, and could affect their motivation negatively [75–77]. However, the negative association must be interpreted with caution because it had the lowest coefficient value in the multiple linear regression model, which was significant at the $p = 0.05$ level, while most of the other factors were significant at the $p = 0.001$.

Studies in the literature showed similar findings to the current study of the positive association between science motivation and student achievement, and in the content and cognitive domain. Liou [25], in a study of science motivational beliefs based on TIMSS data, concluded that there was a positive association between student motivational beliefs and academic performance.

The finding of the study indicated that when the students had a high level of engagement in mathematics lessons, their achievement in the content domains and cognitive domains became higher. For science, engaging teaching in science lessons had only one statistically significant negative effect with the latent variable 'Reasoning'.

The positive association between classroom engagement, mathematics content and cognitive domains might be because students were actively involved in the learning activities of the mathematics lessons [41]. When the students are actively involved in the learning activities, they will understand the mathematical concepts and will be able to respond to the question items that cover specific content and cognitive domains.

The last variable was confidence and self-concept in mathematics and science. The factor of confidence in learning mathematics and science had a positive association with students' results, as well as in the content and cognitive domains. The most interesting finding was that the factor of confidence in learning mathematics and science was the strongest student factor, as it had the highest coefficient in the regression model. This finding is similar to that of Miscevic-Kadijevic [52], who illustrated in an analysis study of TIMSS 2011 grade 4 results that cognitive achievement in the areas of Knowing, Applying and Reasoning was linked to self-confidence. Furthermore, in a study on Taiwan's TIMSS 2011, Liou [32] concluded that self-concept is positively associated with grade 4 students' individual achievement in mathematics and science.

Based on the findings of the study, there were some implications that need to be addressed in order to improve student performance. The current study concluded that bullying had a negative association with student achievement. Bullying had a negative influence on student wellbeing and safety [38], which could affect students' desire to learn and perform well in schools. Therefore, schools need to establish a strong discipline system that includes proper consequences for students' inappropriate behavior. Anderson, Ritter and Zamarro [78] stated that schools should develop prevention approaches rather than waiting for students to be involved in discipline issues. The prevention program could include lectures, assembly programs, workshops and competitions to raise awareness. Furthermore, teacher classroom management programs help to reduce behavioral problems and improve students' social competencies [79].

As the study concluded that having breakfast on a school day had a positive association with grade 4 performance, it is important to ensure that students do not miss this important meal during school days. It is recommended to provide this meal to students at school in order to make sure that the students eat healthy food regularly. Au et al. [13] stated that students who eat school breakfast and lunch receive a higher quality of diet than the ones who obtain their meals from home.

As the strongest student factor that was associated with academic achievement was students' self-confidence, it is important to maintain high self-confidence for students. School leaders should ensure that their students maintain high levels of self-confidence by following up with the classroom strategies that enhance this. These classroom practices include having a well-structured learning environment that helps students to feel confident enough to achieve their teachers' expectations [80]. Teachers' practices, experiences, and beliefs of learning and teaching related to TIMSS [80–82] and their needs to help the students achieve well in TIMSS content and cognitive domains need to be considered very well and comprehensively, in line with the development of the science and mathematics curricula [83,84]. The culture context of the students and teachers also need to be considered when thinking about changes and improvements in the learning environment [85].

5. Conclusions

The educational sector in the UAE considers Trends in International Mathematics and Science Study (TIMSS) to be a valuable indicator to trace educational improvements and to fulfill the country's National Agenda 2021. The purpose of this study was to examine the student factors that have an association with UAE grade 4 students' mathematics and science TIMSS 2015 results in the content and cognitive domains.

The analysis indicated that student factors had an association with mathematics and science achievement, as well as in the content and cognitive domains. There was insignificant association between gender and mathematics and science student achievement, and there were specific content and cognitive domains where boys outperformed girls. The factors that had a positive association with student performance were having breakfast, liking learning science, engagement in mathematics lessons, and student confidence in mathematics and science. The factors that had negative associations were bullying and liking learning mathematics. It is very interesting to note that student confidence in learning showed the strongest effect among the other factors in both the regression and SEM models.

The study had a few limitations. It was purely quantitative research, so it did not provide an in-depth understanding of the reasons behind student achievement in TIMSS

2015 in the content and cognitive domains. However, the fact that the instrument of the study was developed by experts in the assessment field and piloted in different countries provided more reliable and valid data that could be generalized to the whole cohort of grade 4 students in the UAE. The study used secondary sources of data that were not collected by the researcher; as such, the purpose of collecting the data might be different from the purpose of the analysis.

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Appendix A

Table A1. Items of selected variables for the study.

Variable	Description
ASDGSB	TIMSS Index: Student Bullying
ASBG12A	Someone made fun of me
ASBG12B	I was left out of games
ASBG12C	Someone spread lies about me
ASBG12D	Someone stole from me
ASBG12E	I was hurt by others
ASBG12F	Someone forced me to do something
ASBG12G	Someone shared embarrassing information
ASBG12H	Someone Threatened me
ASDGEML	TIMSS index: Engaging Teaching in Mathematics Lessons
ASBM02A	I know what my teacher expects me to do
ASBM02B	My teacher is easy to understand
ASBM02C	I am interested in what my teacher says
ASBM02D	My teachers give me interesting things to do
ASBM02E	My teacher has clear answers
ASBM02F	My teacher gives good explanation
ASBM02G	My teacher let me show what I had learned
ASBM02H	My teacher does a variety of things to help us learn
ASBM02I	My teachers show me how to do better
ASBM02J	My teachers listen to me
ASDGSLM	TIMSS Index: Like learning mathematics
ASBM01A	I enjoy learning mathematics
ASBM01B	I wish not to study math *
ASBM01C	Math is boring *
ASBM01D	I learn interesting things in mathematics
ASBM01E	I like mathematics
ASBM01F	I like schoolwork involving numbers
ASBM01G	I like solve math problems
ASBM01H	I look forward to math lessons
ASBM01I	Math is my favorite subject

Table A1. *Cont.*

Variable	Description
ASDGSCM	TIMSS Index: Student confidence in mathematics
ASBM03A	I usually do well in math
ASBM03B	Mathematics is harder for me than for others
ASBM03C	I am just not good in math
ASBM03D	I learn quickly in mathematics
ASBM03E	Math makes me nervous
ASBM03F	I am good at working out problems
ASBM03G	I am good at mathematics
ASBM03H	Mathematics is harder for me than any other subject
ASBM03I	Math makes me confused
ASDGESL	TIMSS index: Engaging Teaching in Science Lessons
ASBS05A	I know what my teacher expects me to do
ASBS05Bl	My teacher is easy to understand
ASBS05C	I am interested in what my teacher says
ASBS05D	My teachers give me interesting things to do
ASBS05E	My teacher has clear answers
ASBS05F	My teacher gives me clear explanation
ASBS05G	My teacher lets me show what I have learned
ASBS05H	My teacher does a variety of things to help us learn
ASBS05I	My teachers show me how to do better
ASBS05J	My teachers listen to me
ASDGSLS	TIMSS Index: Like learning Science
ASBS04A	Enjoy learning science
ASBS04B	I wish not to study science *
ASBS04C	Science is boring *
ASBS04D	I learn interesting things in science
ASBS04E	I like science
ASBS04F	I look forward to learning science
ASBS04G	Science teaches me how things in the world work
ASBS04H	I like to do science experiments
ASBS04I	Science is my favorite subject
ASDGSCS	TIMSS Index: Students Confident in Science
ASBS06A	I usually do well in science
ASBS06B	Science is harder for me than for others
ASBS06C	I am just not good at science
ASBS06D	I learn quickly in science
ASBS06E	I am good at science
ASBS06F	Science is harder for me
ASBS06G	Science makes me confused
Other variables of interest with no group	
ASBG01	Gender
ASBG09	Breakfast on School Days

* Reversed coded.

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