

# **EXPLANATORY VARIABLES OF SCIENCE ACHIEVEMENT IN FINLAND: CULTURAL APPROACH**

*Pasi Reinikainen*  
University of Jyväskylä, Finland

## **Abstract**

This study presents Finnish explanatory variables of science achievement in TIMSS 1999. The methodological approach reflects the ideas of Bempechat et al., (2002), assumptions that educational outcomes, both cognitive and affective, are socially, culturally, historically, and institutionally situated and context-specific. The purpose of this study is to describe and highlight the wide spectrum of nuances of students' home-background, free and school-time activities, their motivational factors and affective outcomes of schooling, all of which are connected with students' science achievement. Attention is also given to social and cultural background issues and the historical context of each country. This ongoing study set out to find country-specific variables and establish national factors to describe the large variation of national and socio-cultural elements involved in student achievement within certain countries by using hierarchical linear models (HLM). Only 8% of the variation in Finnish science scores comes from school-level variables, whilst 92% is attributable to student-level variables. Regarding this study, only the statistically significant explanatory variables for science achievement are presented, and results are also illustrated in graph form that does not require specialist knowledge of HLM.

## **INTRODUCTION**

The science test in TIMSS 1999 included six content areas: earth science (about 15% of the score points); life science (27%); physics (25%); chemistry (14%); and environmental issues (9%) and the nature of science (8%), making a total of 153 score points for the science test items. TIMSS yielded estimates of average science achievement for the entire target population of (seventh or eighth grade) students in each country. The process also enabled consistent linkage between science achievement and student, teacher, and school background questionnaires. The TIMSS

data structure is hierarchical in nature. Students are nested within schools, which allows for analyses drawing on hierarchical linear models (HLM).

Several multilevel model analyses on TIMSS 1995 and 1999 data have been reported in recent years. While TIMSS 1995 and 1999 and most of the published multilevel studies on these data (e.g., Bos & Kuiper 1999; Fullarton & Lamb 2000; Howie 2002; Kupari 2003; Köller et al., 1999; Martin et al., 2000) focus mostly on mathematical achievement, this paper concentrates on factors associated with student achievement in science.

Martin et al., (2000) analysed the TIMSS 1995 data in order to identify effective schools in both science and mathematics. The aim of the present study, however, differs from that of Martin's and his colleagues' study in three ways. First, while Martin and his colleagues reviewed the questionnaires in the light of educational literature and accordingly selected variables that were likely to characterise effective schools, the present study used no such preconceptions in the selection of variables. Instead, the selection was based on the best explanatory variables from statistical analyses on each country's data. Secondly, while Martin and colleagues sought to combine individual variables into indexes more global and stable than the original variables, the present study set out to find country-specific variables and create national indexes to describe the large variation of national and socio-cultural elements involved in student achievement in each country. Thirdly, because of the different goals of these works, the results of the studies also differ. Most of the international explanatory variables in Martin's and his colleagues' country-specific HLM models had no statistical significance in relation to student achievement. In contrast, this study introduces only the significant explanatory variables. Country-specific results are furthermore reviewed and explained by education specialists in each analysed country.

The purpose of this study is not an international comparison of the countries. Rather, it is to describe and highlight the wide spectrum of nuances of students' home-background, free and school-time activities, their motivational factors and affective outcomes of schooling, which all are connected with students' science achievement. Attention is also given to social and cultural background issues and the historical context of each country.

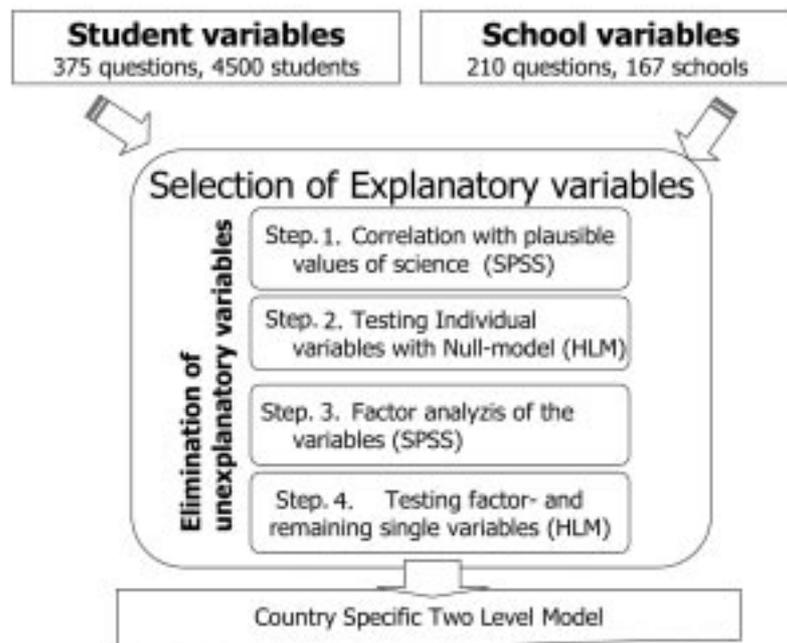
## **METHODS**

This study was designed to find country-specific variables and establish national factors to describe the large variation of national and cultural elements involved in student achievement within certain countries. That is why neither preconceptions, variables from existing educational literature nor international indexes were used in the selection of variables. Instead, the selection was based on the best explanatory variables from statistical analyses on country-specific data.

In TIMSS 1999, students are nested within schools, which allows for analyses drawing on hierarchical linear models (HLM). The statistical methods used in the selection of explanatory variables included rescaling of variables, studying the linear correlation between variables and the science score (five plausible values), testing

each individual variable against the null model, factorizing the variables, and constructing the final models. The process of identifying explanatory variables is illustrated in Figure 1.

Figure 1: Overview of Procedures and Methods



(All the variables used in this study can be found from TIMSS 1999 User Guide for the International Database. <http://isc.bc.edu/timss1999i/database.html>)

### Preliminary work - rescaling variables

The first step of the procedure was rescaling the variables to enable more facile interpretation of the final results. Reverse-scale values were used for Likert scale student's responses to the statements, so that after revision every response ranged from most negative to most positive, from least frequent to most frequent occasion, and from lowest level to highest level. For example, student response to the statement "Earth Science is boring", originally scaled: "Strongly Agree" = 1, "Agree" = 2, "Disagree" = 3, "Strongly Disagree" = 4, was rescaled to "Strongly Agree" = 4, "Agree" = 3, "Disagree" = 2, "Strongly Disagree" = 1. Student's sex was rescaled from "Girl" = 1 and "Boy" = 2, to "Girl" = 0 and "Boy" = 1.

Students' responses to the statement "How far did your mother go in school" and "How far did your father go in school" were recoded so that responses "I do not

know" = 8 were recoded with code 0 indicating the lowest level of education of parents. This variable was problematic, since the results show that majority of the students did not know the educational background of their parents.

For the statement "How far do you expect to go in school", the responses were recorded from 6 far "I do not know" to 0, indicating the lowest level of education.

### **Linear correlation**

First linear associations between science achievement scale scores (five plausible values) and the weighted variables of student and school background questionnaires were studied. Variables of student and school questionnaires were correlated with mean science achievement. Variables with Pearson's correlation coefficient larger than 0.09 or smaller than -0.09 were included in further analysis. In this study no internationally created indexes (such as Positive Attitudes Towards the Sciences or index of Students- Self-Concept in the Sciences) were used. Omission of such indexes was based on the belief that students' ways of expressing their attitudes are highly interconnected with their socio-cultural background. This hypothesis proved to be correct in subsequent analysis of the data.

### **Testing the individual variable with null model**

The purpose of this step of variable reduction was to select explanatory variables in null models of student and school levels. Each individual variable was tested separately against school and student level null-models with HLM 5.02 program. Only the variables with statistical significance were screened in further studies.

### **Factorizing variables**

The third step was a factor analysis. Its' purpose was to identify underlying variables, or factors, that explain the pattern of correlations within a set of remaining variables. Factor analysis was used in data reduction to identify a small number of factors that explain most of the variance observed in a much larger number of manifest variables. Using factors it is also possible to generate hypotheses regarding causal mechanisms and to screen variables for subsequent HLM-analysis. In factor analysis factor scores were produced by using varimax -rotation, and by suppressing absolute values below 0.4. There were no weights used during this operation. Remaining variables that did not load to any such factors were treated as individual variables in subsequent HLM-analysis. Factor analysis produced interesting results for this last model's components: It seems very evident that students' prior achievement, their attitudes and their self-concept form a cycle in which these components reinforce each other. For example Aunola et al. (2002) found a similar tendency when they studied the relationship between students' reading skills and self-concept.

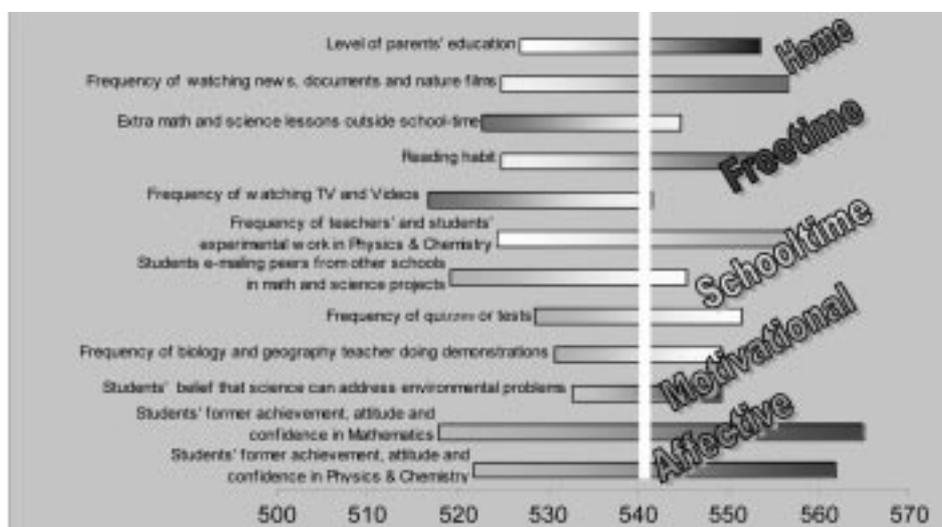
## Multilevel models

The final multilevel model consisted of five groups of student-variables. The order of the different models was affected by Sadler's (1979) statement: "In studying foreign systems of education, we should not forget that the things outside the schools matter even more than the things inside the schools, and govern and interpret the things inside.". Since educational policy issues and educational systems have at best minimal direct influence on student's home background and on the ways students spend their free-time, these factors were included in the first two models of explanatory variables. The third model consists of variables describing classroom activities from the students' point of view. The fourth model was construed from students' motivational factors and from their beliefs concerning science. The last model was then formed from student variables of prior achievement and affective outcomes of schooling (attitudes and self-conceptions in both mathematics and science subjects).

## RESULTS

Figure 2 presents the significant explanatory variables of this study for persons unfamiliar with HLM. For detailed findings, see Appendix 1 for descriptive statistics of variables and factors in the Finnish model, and Appendix 2.

Figure 2: Graphical presentation of explanatory variables of science achievement in Finland.



The white vertical bar indicates the average science score of the Finnish schools which were used in the model. The light colour at end of the bar indicates less values of variables or factors (for example, infrequent occasions, negative attitudes...) and the dark colour indicates correspondingly higher values of variables or factors (for example, frequent occasions, and positive attitudes). End points of the bars are determined separately for each variable and each factor, and they present the average score of the lowest and the highest fifths of the students.

One of the key findings of this study is that only 8% of the variation in Finnish science scores comes from the school-level variables, whilst 92% is attributable to student-level variables (see Appendix 2). With this approach 41 % of the total variance in science scores can be explained. It is noteworthy that without any statistically significant school level predictors, student level variables alone can explain as much as 55 % of between school variance.

The only significant explanatory variable of student home background was the educational level of parents. In Finland the number of books at students' homes was not a statistically significant explanatory variable, in contrast to many earlier studies (e.g., Fullarton & Lamb, 2000 and Bos & Kuiper, 1999). This discovery might be explained by studies of Finnish researcher Linnakylä (2002) who has studied reading literacy and habits in Finland. According to Linnakylä, Finnish students are the most active library book borrowers within OECD-countries, thus there is no need for large home-libraries in Finland.

Results from the student's free-time model indicate that it would be more fruitful to pay attention to the TV and video content watched by students rather than purely to the time spent on reading related activities. This result is consistent with previous findings of Köller et al., (1999), who obtained similar results in Germany.

Students' free-time results also show that positive reading habits support science achievement. This pronounced relationship between reading and science is well known from earlier studies. For example, Kjaernsli & Molander (2003) studied the relationship between reading, mathematical and scientific literacy in Nordic countries using PISA-data. They found that the correlation between scores in reading and scientific literacy in Finland was as high as 0.83 and even higher in Denmark, Norway and Sweden. However, in PISA items there was much more reading involved than in TIMSS 1999 items.

In Finland, it is primarily students who have some type of problems with science content who take extra mathematics and science lessons during free-time. This finding confirms the findings of Kupari (2004), who studied Finnish achievement in mathematics using TIMSS 1999 data.

Results from the students' classroom activities model show that experimental student work in physics and chemistry and also teacher-driven demonstrations of experiments foster high achievement in science. Finnish core curricula for comprehensive and secondary schools also strongly emphasize this experimental approach. Contrary to this result, however, this approach appears countereffective in biology and geography. There might be various reasons for this: First, in Finland biology and geography are not considered experimental by nature whilst physics and chemistry are. Secondly, the phenomena addressed in biology and geography may also be more difficult to demonstrate as changes occur over a long time frame.

Another very interesting finding was that students' e-mail-based cooperation with their peers in other schools on math and science projects had a negative effect on their science score. One possible explanation for this is that the tool (computer) itself is more interesting than the scientific phenomena to be studied.

The knowledge of real-life environmental hazards and understanding how these problems could be addressed by science contributed positively to the cognitive outcomes. Hence, real-life problems of both local and global magnitude seem to motivate students to study science.

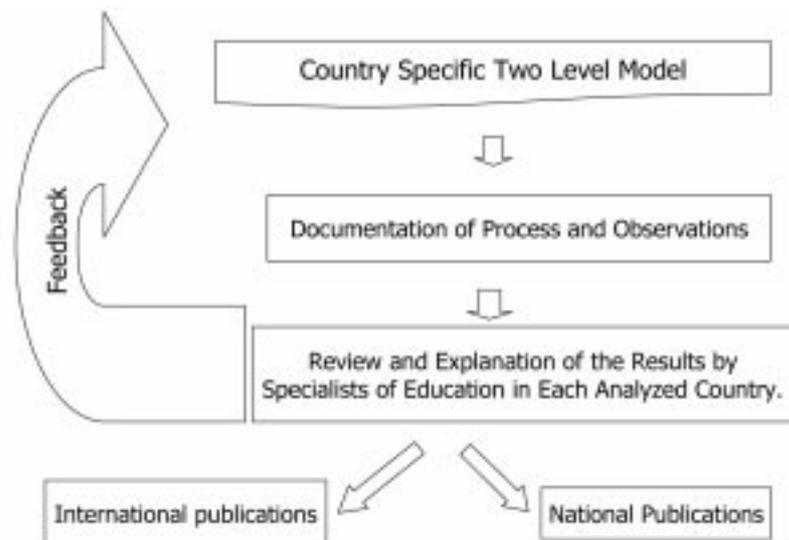
Prior achievement and affective outcomes in mathematics had a greater effect on student scores than those in physics and chemistry. It was interesting to note that similar factors for biology and geography had no explanatory value in this last model.

### CONCLUSION

The findings from this study have inspired discussion among Finnish educational researchers, teachers and educators. On one hand they have looked at the results with a critical eye, but on the other hand, they have proven to be very eager to provide possible explanations for the results. In most cases they have concluded that these results are very concrete and that they describe well the present school-life in Finnish comprehensive schools.

Because of the positive results and feedback of this research, the author of this paper has planned further studies of English, Hungarian, Japanese and Latvian TIMSS 1999 results using the same method. The research plan for these studies of country-specific explanatory variables of science achievement is illustrated in Figure 3.

*Figure 3: A plan for further research on explanatory variables of science achievement in different countries.*



A quote from Rogoff (1990) has convinced the author of this paper to rely on the studies of education specialists in each analysed country when analysing, reviewing and explaining country-specific results: "For researchers to attempt to understand development without considering everyday activities and skills in the context of cultural goals would be like attempting to learn a language without trying to understand the meaning it expresses." .

## References

- Aunola, K., Leskinen, E., Onatsu-Arviolommi, T. & Nurmi J-E. (2002). Three methods for studying developmental change: A case of reading skills and self-concept. *British Journal of Educational Psychology*, 72, 343-364.
- Bempechat, J., Jimenez, N. and Boulay, B. (2002). Cultural-Cognitive Issues in Academic Achievement: New Directions for Cross-National Research. In A. Porter & A Gamoran (Eds.), *Methodological Advances in Cross-National Surveys of Educational Achievement*. National Academy Press, Washington, DC, pp. 117-149.
- Bos, K. & Kuiper, W. (1999). Modelling TIMSS Data in a European Comparative Perspective: Exploring Influencing Factors on Achievement in Mathematics in Grade 8. *Educational Research and Evaluation*, 5(2), 157-179.
- Fullarton, S. & Lamb, S. (2000). Factors Affecting Mathematics Achievement in Primary and Secondary Schools: Results From TIMSS. In J. Bana & S. A. Chapman (Eds.), *Mathematics Education Beyond 2000*. Volume1, 258-266. Berth, Wa. Mathematics education research group of Australasia in corporate.
- Howie, S. (2002). English Language Proficiency and Contextual Factors Influencing Mathematics Achievement of Secondary School Pupils in South Africa. Thesis University of Twente, Enschede, PrintPartners Ipskamp.
- Kupari, P. (2004). Student and school factors affecting Finnish mathematics achievement. Will be published in S. Howie & T. Plomp (Eds.), *Context of learning mathematics and science: lessons learned from TIMSS*. Swets & Zeitlinger.
- Köller, O., Baumert, J., Clausen, M. & Hosenfeld, I. (1999) Predicting Mathematics Achievement of Eight Grade Students in Germany: An Application of Parts of the Model of Educational Productivity to the TIMSS data. *Educational Research and Evaluation*, 5 (2), 180-194.
- Linnakylä, P. (2002). Nuorten lukemisaktiivisuus ja lukuharrastus. In J., Välijärvi & P., Linnakylä. (Eds.) *Tulevaisuuden osaajat. PISA 2000 Suomessa. Finnish Results in PISA 2000*. pp 161-164. Kirjapaino Oma Oy., Jyväskylä, Finland. In Finnish. (Finnish results of PISA 2000)
- Martin, M., Mullis, I., Gregory, K., Hoyle, C. & Shen, C. (2000) *Effective Schools in Science and Mathematics*. IEA's Third International Mathematics and Science Study: TIMSS International Study Center, Boston College, Chestnut Hill, MA, USA.
- Rogoff, B. (1990) *Apprenticeship in thinking: Cognitive development in a social context*. New York: Oxford University Press.
- Sadler, M.(1979) Selections from Michael Sadler: *Studies in world citizenship*. Liverpool, England: DeJall & Meyorre.

## APPENDIX 1

*Descriptive statistics of variables and factors that were included in the Finnish model.*

<i>LEVEL-1 DESCRIPTIVE STATISTICS</i>					
<i>VARIABLE NAME</i>	<i>N</i>	<i>MEAN</i>	<i>SD</i>	<i>MINIMUM</i>	<i>MAXIMUM</i>
1. Plausible value of science	1495	545.54	74.86	201.25	810.23
2. Plausible value of science	1495	540.93	75.00	208.96	774.79
3. Plausible value of science	1495	545.10	74.08	116.53	866.30
4. Plausible value of science	1495	542.04	76.10	142.49	867.33
5. Plausible value of science	1495	540.87	75.05	171.74	842.57
Former achievement in physics /chemistry, attitudes and self-confidence	1495	-0.00	1.01	-2.40	2.19
Student need to do well in mathematics and in all subjects in science to get in school he prefers	1495	0.04	0.99	-2.47	2.15
Frequency of tests and quizzes in mathematics, physics, chemistry, biology and geography	1495	-0.02	0.98	-2.44	2.74
Believe that science can address environmental issues	1495	0.05	0.98	-2.79	1.44
Students doing experiments in physics and chemistry. Teacher doing demonstrations	1495	0.03	0.99	-2.88	1.56
Outside school time taking extra mathematics and science lessons	1495	-0.04	0.94	-0.36	8.37
Educational level of mother and father	1495	0.04	1.01	-0.82	2.49
Reading: habit and frequency	1495	0.06	0.98	-2.00	2.46
Biology and geography teachers doing demonstrations	1495	-0.02	1.00	-1.39	2.62
Frequency of watching TV and video outside school-time	1495	3.30	0.81	1.00	5.00
Number of books in student's home	1495	3.48	1.06	1.00	5.00
Home posses computer	1495	0.80	0.40	0.00	1.00
Frequency of students neglecting school work in mathematics lessons.	1495	2.42	0.69	1.00	4.00
Frequency of student goes to movies	1495	1.61	0.61	1.00	4.00
Former achievement in mathematics, attitudes and self-confidence	1495	0.04	1.01	-2.41	2.25
Frequency of student watching news, documentaries, nature- and science films	1495	0.02	0.99	-1.55	2.14
Frequency of student using internet with peers from other schools	1495	-0.06	0.93	-0.35	5.32
<i>LEVEL-2 DESCRIPTIVE STATISTICS</i>					
Community type	139	2.23	0.87	1.00	3.00

## APPENDIX 2

### Predictors of achievement in science, Finland

	Model 1 Students' Home Background		Model 2 Students' Outside School Time Activities		Model 3 Students' Classroom Activities		Model 4 Students' Motivational Factors		Model 5 Students' Self-Concept, Former Achievement affective Factors	
	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.	Coeff.	Prob.
Percentage of Between Students Variance Explained by Model	8,1	0,000	23,3	0,000	29,5	0,000	32,8	0,000	40,6	0,000
Percentage of Between School Variance Explained by Model	16,9	0,000	36,0	0,000	53,3	0,000	55,2	0,000	47,0	0,000
Total Percentage of Student & School Variance Explained by Model	8,3	0,001	24,3	0,000	31,4	0,000	34,6	0,000	40,9	0,000
Regression Coefficient Estimates (Significance of Levels)										
Intercept	541,1	0,000	541,3	0,000	541,4	0,000	541,4	0,000	541,5	0,000
Computer in students home.	27,2	0,016	28,1	0,014	26,5	0,021	23,2	0,032	—	—
Highest educational level of Mother & Father.	13,7	0,000	11,8	0,000	11,1	0,000	10,3	0,000	9,5	0,000
Number of books in student's home.	7,7	0,001	—	—	—	—	—	—	—	—
Frequency of watching nature, wildlife or history & new or documents on TV or video.	—	—	19,2	0,000	18,4	0,000	15,1	0,000	11,3	0,000
Frequency of taking extra Math/Science lessons Outside school time.	—	—	-13,7	0,000	-10,9	0,001	-11,4	0,000	-9,3	0,003
Frequency of going to the movies.	—	—	-13,5	0,001	-9,0	0,023	-8,2	0,031	—	—
Frequency of reading books.	—	—	12,5	0,001	9,1	0,009	8,0	0,017	9,5	0,005
Frequency of watching TV or Video outside school time.	—	—	-11,2	0,000	-10,5	0,000	-9,9	0,000	-7,5	0,003
Frequency of teacher giving demonstrations of an experiment & Students doing experiments in Phys/Chem class & in Chemistry lessons working in pairs or small groups.	—	—	14,7	0,000	14,7	0,000	12,4	0,000	11,6	0,000
Frequency of Students using e-mail to work with peers in other schools in Math/Science projects.	—	—	-9,6	0,001	-9,6	0,001	-10,1	0,000	-11,2	0,000
Frequency of having a quiz or test in Math & Phys & Chem & Earth lessons.	—	—	-8,5	0,021	-8,5	0,021	-8,0	0,028	-8,0	0,022
Frequency of teacher demonstrating an experiment in Bio & Earth lessons.	—	—	-6,5	0,002	-6,5	0,002	-7,6	0,000	-8,4	0,001
Frequency of students neglecting school work in mathematics lessons.	—	—	-6,0	0,033	-6,0	0,033	-6,2	0,029	—	—
Student believes that he needs to do well in do Math & Phys & Chem & Bio & Earth science to get into the school he/she prefers.	—	—	—	—	—	—	12,1	0,003	—	—
Student believes that science can address air pollution & Water Pollution & Damage to ozone layer & Problems from nuclear power plants.	—	—	—	—	—	—	7,0	0,001	5,8	0,003
Student does usually well in mathematics & Student has strong self-confidence in mathematics & Student has positive attitude towards Mathematics.	—	—	—	—	—	—	—	—	16,8	0,000
Student does usually well in physics & Student has strong self-confidence in physics and chemistry.	—	—	—	—	—	—	—	—	14,4	0,000