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Primary School Students' Self-Concept in Mathematics and Science: Findings from TIMSS 2019

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Abstract: A self-concept is an important construct that has been associated not only with academic achievement but with success in life in general. The self-concept can be general and domain specific. It is believed that by the end of Grade 4 students' understanding about their abilities is close to reality. Besides, by increasing the individuals' domain specific self-concept, also the achievement increases and vice versa. In this research, the authors explored the influencing factors of 4th graders' self-concept in Mathematics and Science from the IEA's TIMSS 2019 study. The factors were selected from the students' and parents' questionnaires. As the self-concept is typically associated with achievement, the students' achievement in Mathematics and Science was used as a reference. The purpose for this study was to examine whether achievement has the main influence on students' self-concept in Mathematics and Science and to find out other influencing factors. The research question was as follows: what factors influence the 4th grade students' self-concept in Mathematics and the students' self-concept in Science in the IEA's TIMSS 2019 study? The authors used a correlation and linear regression analysis to process the data from 8 countries around the Baltic Sea: Latvia, Lithuania, Poland, Germany, Denmark, Sweden, Finland, and the Russian Federation. The findings revealed that students' liking for the school subject was a more significant factor for students' self-concept in Mathematics and Science than their achievement. The achievement was only the second most influencing factor. It was discovered that students with higher self-concept understood their teachers better and were bullied less than their peers with lower self-concept in the domain subject.

Keywords: student's self-concept, academic self-concept, achievement, TIMSS.

Introduction

Sustainable development starts at the level of individual person (Fergusson et al., 2021) that is why sustainable development can't be viewed without education as one of the main instruments that is used to influence the human mind. Some authors even argue that Science, Technology, Engineering and Mathematics (STEM) education together with design and technology curriculum could provide the necessary bridge between sustainable development and education (Pitt, 2009). None can doubt that last decades had changed not only the way how we understand the education, but education itself and the curriculum. As educational curriculum and educational environment had significantly changed, it becomes more and more important to analyse the factors that influence a child's wellbeing in different educational environments and ability to learn successfully. Previous studies from the International Association for the Evaluation of Educational Achievement (IEA) had shown the importance of home and school factors on student's academic achievement (Mihno, 2015; Geske et al., 2020; Mullis et al., 2020), that is – on students' success at the school, as well as on students' academic self-concept in reading (Geske et al., 2021a; Geske et al., 2021b).

In the literature the term self-concept is widely defined, but most authors agree that it is a structured belief system, that a person has about oneself and that this belief system can be or not be related to reality (Berk, 2009; Pervin et al., 2013; Larsen et al., 2018). Academic self-concept is the belief one has about his/her academic success based on previous experience (Bong et al., 2003). For the purpose of this research authors assume that this belief system can be measured at the end of 4th grade as Bjorklund (Bjorklund, 2000) emphasizes that this is the age when it comes close to reality.

As academic self-concept is reciprocal in nature with the achievement of the academic domain (Pervin et al., 2013), and academic self-concept itself is one of the main predictors for achievement (Vesić et al., 2021), the authors selected the factors that could influence the academic self-concept because they were found to influence the academic achievement or self-concept in other studies (Denissen et al., 2007; Vesić et al., 2021): tiredness, absentness from the school, bullying, previous education

experiences, liking of the subject, engagement and the instructional quality of the teacher. Additionally, the authors decided to analyse whether or not an extra classes with a purpose to excel the overall class level could influence the students' self-concept in Mathematics or Science. The purpose for this study is to select the factors that influence the student's self-concept in Mathematics and Science and to analyse linear influence from these factors.

Methodology

The authors analysed the data from the TIMSS 2019 study, exploring the questionnaire of 4th graders and their parents, first, to find what factors from the students' and parents' questionnaires impacted the students' self-concept in Mathematics and Science, and second, to search for an explanation whether these factors impacted on the students' self-concept linearly in each domain. TIMSS 2019 was the seventh cycle of TIMSS Assessment. In total, approximately 330000 students of their fourth formal year of schooling and 310000 parents from 64 countries participated in the study. For every country the sample was representative and consisted of around 4000 students and their parents, 150 to 200 schools with Mathematics and Science teachers of the sampled classes.

Students were sampled in two stages: the first stage included the selection of schools with stratified random sampling methods; the second stage included the selection of a class or classes within the sampled school with random sampling methods. From every participant school one to three classes were sampled. Besides, all students of the sampled class were included in the sample, except for students with severe disabilities which prevented these students from ability to read, write or understand.

The Baltic Sea region countries, Latvia, Lithuania, Denmark, Finland, Germany, Sweden, and the Russian Federation, were chosen to compare the findings. These countries are located around the Baltic Sea, all of them apart from the Russian Federation belong to the European Union. The Russian Federation was included in the list of countries for comparison due to its historical similarities in educational system and traditions with Latvia and Lithuania. There were many Russian-speaking schools in Latvia and Lithuania which participated in the TIMSS 2019 study.

The purpose for this study was to find the factors that had a significant impact on students' domain specific self-concept. The data of each domain subject, that is, Mathematics and Science lessons for Grade 4, were analysed separately, thus the procedure was performed twice. First, the authors performed a correlation analysis to distinguish significant factors, then a liner regression analysis was done with identified significant factors. In the linear regression analysis, the students' self-concept in Mathematics and Science were chosen as the dependent variables, whereas independent variables were the following: tiredness, absentness, bullying, extra classes, early literacy, and numeracy tasks, liking for the domain subject (Mathematics, Science), engagement and achievement in the domain lessons.

In the TIMSS 2019 study, the students' self-concept was measured by Student Confident in the domain scale. This scale was constructed from the question of students' questionnaire "How much do you agree with these statements about <domain>?", followed by nine statement items for Mathematics and seven statement items for Science that were measured in the Likert-type scale. For Student Confident in Mathematics scale four statement items were coded directly and five – reverse coded. If the statement item was coded directly, then an answer "Agree a lot" got 1 point, "Agree a little" got 2 points; "Disagree a little" got 3 points and "Disagree a lot" got 4 points. If the answer was reverse coded, then "Agree a lot" got 4 points and "Disagree a lot" got 1 point. The statements for the Student Confident in domain subject were as follows (Yin et al., 2020): 1) I usually do well in <domain subject>, 2) <Domain subject> is more difficult for me than for many of my classmates (Reverse coded), 3) <Domain subject> is not one of my strengths (Reverse coded), 4) I learn things quickly in <domain subject>, 5) Mathematics makes me nervous (Reverse coded) (just for Confident in Mathematics scale), 6) My teacher tells me I am good at <domain subject>, 7) <Domain subject> is harder for me than any other subject (Reverse coded), 8) <Domain subject> makes me confused (Reverse coded), 9) I am good at working out difficult mathematics problems (just for Confident in Mathematics scale). For Student Confident in Mathematics scale and for Student Confident in Science scale the Cronbach's Alpha Reliability Coefficient for the countries of comparison varied from 0.86 to 0.90.

The students' tiredness was measured with a question from students' questionnaire: "How often do you feel this way when you arrive at school?". The student could mark one of the following responses: "Every day" (1 point), "Almost every day" (2 points), "Sometimes" (3 points) or "Never" (4 points).

The students' absentness was measured with a question from students' questionnaire: "About how often are you absent from school?". The students could mark one of the following responses: "Once a week" (1 point), "Once every two weeks" (2 points), "Once a month" (3 points), "Once every two months" (4 points) or "Never or almost never" (5 points).

The bullying was measured with the Student Bullying scale, which was created on the basis of students' responses to the questions "During this school year, how often have other students from your school done any of the following things to you, including through texting or the Internet?" and its 14 statements. All statements were measured in the four-item scale: "Never" (1 point), "A few times a year" (2 points), "Once or twice a month" (3 points) and "At least once a week" (4 points). All statements of this scale were as follows (Yin et.al., 2020): 1) Said mean things about my physical appearance (e.g., my hair, my size), 2) Spread lies about me , 3) Shared my secrets with others, 4) Refused to talk to me, 5) Insulted a member of my family, 6) Stole something from me, 7) Made me do things I didn't want to do, 8) Sent me nasty or hurtful messages online, 9) Shared nasty or hurtful things about me online, 10) Shared embarrassing photos of me online, 11) Threatened me, 12) Physically hurt me, 13) Excluded me from their group (e.g., parties, messaging), 14) Damaged something of mine on purpose. The Cronbach's Alpha Reliability Coefficient for the countries of comparison varied from 0.81 to 0.85.

The authors of this study chose to analyse whether there could be any impact on students' self-concept if one attended extra lessons, examining a question from the parents' questionnaire: "During the last 12 months, has your child attended extra lessons or tutoring not provided by the school in the following subjects?". Parents could point out that their child had attended extra classes in Mathematics and/or Science by marking one of the provided answers: "Yes, to excel in class", coded into a new variable to exclude other two options, "Yes, to keep up in class" and "No".

There were three scales in the TIMSS 2019 that measured ability to do school tasks before beginning of school. These scales were "Could Do Literacy Tasks When Beginning Primary School", "Could Do Numeracy Tasks When Beginning Primary School" and "Could Do Literacy and Numeracy Tasks When Beginning Primary School". In order to find any impact on students' self-concept, the authors chose to analyse the third scale. This scale was constructed from three questions in the parents' questionnaire. The first question "How well could your child do the following when he/she began the first grade of primary school?", followed by seven statements that were measured in the Likert-type scale from "Very well" (1 point) to "Not at all" (4 points). These statements were as follows (Yin et.al., 2020): 1) Recognize most of the letters of the alphabet, 2) Read some words, 3) Read sentences, 4) Read a story, 5) Write letters of the alphabet, 6) Write his/her name, 7) Write words other than his/her name. The second question was "Could your child do the following when he/she began the first grade of primary school?", followed by three statements that were measured in a four-item scale: "Up to 100 or higher" (1 point), "Up to 20" (2 points), "Up to 10" (3 points) and "Not at all" (4 points). The statements of this question were as follows (Yin et.al., 2020): 1) Count by himself/herself, 2) Recognize written numbers, 3) Write numbers. The third question was "Could your child do the following when he/she began the first grade of primary school?", followed by two statements that were measured with "Yes" (1 point) and "No" (2 points). The two statements of this question were as follows: 1) Do simple addition 2) Do simple subtraction. The Cronbach's Alpha Reliability Coefficient for the countries of comparison varied from 0.88 to 0.91.

To find whether there was any correlation between students' self-concept and liking for the domain subject, the authors used two scales "Students Like Learning Mathematics" and "Students Like Learning Science". Both scales were constructed from the question in the students' questionnaire "How much do you agree with these statements about learning <domain subject>?". Both questions had nine statements were students indicated the answer in the Likert-type scale from "Agree a lot" (1 point) to "Disagree a lot" (4 points). Some items in both scales were coded reversely. The items were as follows(Yin et.al., 2020): 1) I enjoy learning <domain subject>, 2) I wish I did not have to study <domain subject> (Revers coded), 3) <Domain subject> is boring (Reverse coded), 4) I learn many

interesting things in <domain subject>, 5) I like <domain subject>, 6) I look forward to learning science in school/I look forward to mathematics lessons, 7) Science teaches me how things in the world work/I like to solve mathematics problems, 8) I like to do science experiments/I like any schoolwork that involves numbers, 9) <domain subject> is one of my favorite subjects. The Cronbach's Alpha Reliability Coefficient for the countries of comparison varied from 0.90 to 0.94 for Mathematics and from 0.88 to 0.93 for Science.

Alongside liking for the domain subject, students' engagement was another important factor that predicted their achievement, but in order to find out whether the engagement was important for students' self-concept, this study included the "Instructional Clarity in <domain subject> Lessons Scale". The authors assumed that if the teacher's instructions were understandable for a child, then the child could engage in the lesson, whereas less clear instructions lowered students' engagement in lessons. The students could indicate their opinion by choosing one option in the Likert-type scale from "Agree a lot" (1 point) to "Disagree a lot" (4 points). There were six statements related to the clarity of teachers' instructions. They were as follows (Yin et.al., 2020): 1) I know what my teacher expects me to do, 2) My teacher is easy to understand, 3) My teacher has clear answers to my questions, 4) My teacher is good at explaining <domain subject>, 5) My teacher does a variety of things to help us learn, 6) My teacher explains a topic again when we don't understand. The Cronbach's Alpha Reliability Coefficient for the countries of comparison varied from 0.71 to 0.82 for Mathematics and from 0.76 to 0.83 for Science.

Based on the findings from the studies reviewed in the introduction, the authors created a new scale based on the statements that were included in the "Instructional Clarity in <domain subject> Lessons Scale" and "Students Like Learning <domain subject> Scale", they named this as "Engagement in the <domain subject> Scale". The students could indicate their opinion by choosing one option in the Likert-type scale from "Agree a lot" (1 point) to "Disagree a lot" (4 points). Statements that were included in the scale were as follows: 1) I know what my teacher expects me to do, 2) My teacher is easy to understand, 3) My teacher does a variety of things to help us learn, 4) I enjoy learning <domain subject>, 5) I learn many interesting things in <domain subject>. The Cronbach's Alpha Reliability Coefficient for the countries of comparison was 0.73 for Mathematics and 0.78 for Science.

The authors of this article performed data analysis in two parts: first, the correlation analysis was performed to find out the factors that had significant correlations. The second part consisted of linear regression models. In the linear regression models, the authors used the students' self-concept in the domain subject as a dependent variable but all other factors as independent variables.

Results and Discussion

The correlations between students' self-concept in Mathematics, Science and all other factors, including achievement, are summarised in Table 1.

Table 1

Correlations of Students' Self-Concept in Mathematics and Students' Self-Concept in Science with Eight Other Factors and Achievement

Country / Name of the factor		Latvia	Denmark	Finland	Germany	Lithuania	Poland	Russian Federatio	Sweden
Extra classes to excel in class	**M**	0.04	0.04	-0.10	-0.08	0.07	0.05	0.04	0.00
	S	0.01	-0.02	-0.03	-0.01	-0.03	0.03	0.02	-0.02
Tired at school	**M**	0.11	0.10	0.14	0.15	0.11	0.13	0.11	0.12
	S	0.06	0.06	0.07	0.14	0.05	0.10	0.11	0.11
Absent from school	**M**	0.20	0.19	0.23	0.16	0.19	0.17	0.18	0.26
	S	0.16	0.06	0.23	0.14	0.19	0.10	0.17	0.18
Student bullying	**M**	0.14	0.17	0.18	0.14	0.17	0.10	0.17	0.18
	S	0.17	0.11	0.15	0.14	0.13	0.08	0.19	0.15

Country / Name of the factor		Latvia	Denmark	Finland	Germany	Lithuania	Poland	Russian Federatio	Sweden
Early literacy and numeracy tasks	**M**	0.20	0.14	0.22	0.14	0.28	0.17	0.20	0.24
	S	0.08	0.05	0.09	0.04	0.17	0.11	0.15	0.11
Engagement in the domain subject lessons	**M**	0.50	0.56	0.51	0.50	0.49	0.54	0.43	0.52
	S	0.54	0.62	0.53	0.55	0.53	0.60	0.48	0.59
Student likes learning the domain subject	**M**	0.63	0.63	0.64	0.66	0.63	0.61	0.60	0.61
	S	0.64	0.68	0.60	0.63	0.64	0.66	0.60	0.65
Domain subject teacher's instructional clarity	**M**	0.33	0.45	0.36	0.33	0.30	0.47	0.28	0.39
	S	0.44	0.53	0.40	0.43	0.41	0.54	0.35	0.48
Achievement in the domain subject	**M**	0.51	0.47	0.43	0.47	0.48	0.45	0.38	0.36
	S	0.21	0.26	0.20	0.33	0.25	0.22	0.18	0.19

M – Mathematics, S – Science. All correlations are significant with $p < 0.05$ or less.

All values in Table 1 are significant at the level of $p < 0.05$. As one can see in Table 1, the strongest correlation for all countries of comparison was between students' self-concept in the domain subject and the fact that they liked the subject. The second strongest correlation between students' self-concept in Mathematics was with achievement in Mathematics in Latvia, but for other countries of comparison, the second strongest correlation was between the engagement in Mathematics lessons and students' self-concept in Mathematics. The second strongest correlation for all countries of comparison was between the engagement in Science lessons and the students' self-concept in Science. The Mathematics achievement variable correlated with the students' self-concept in Mathematics as the third strongest in Denmark, Finland, Germany, Lithuania, and the Russian Federation, whereas in Poland and Sweden the third strongest correlation was between the students' self-concept in Mathematics and the instructional clarity of teachers in Mathematics. In Latvia, the third strongest correlation was between the students' self-concept in Mathematics and their engagement in Mathematics lessons. The third strongest correlation with students' self-concept in Science was the teachers' instructional clarity for all countries of comparison.

From Table 1 it can be seen that not being tired, not being absent from school and being able to perform early literacy and numeracy tasks correlated more with self-concept in Mathematics than in Science. Whereas students that were bullied showed less correlation with the self-concept in Science but more in Mathematics. Table 1 shows that when engaging students in extra classes to exceed the class level negatively correlated with the students' self-concept in Mathematics in Finland and Germany, whereas students' self-concept in Science negatively correlated with extra classes for exceeding the class level in Science for Denmark, Finland, Germany, Lithuania and Sweden. In order to explain these negative correlations, one should know better the culture of these countries, but in Latvia these usually are special clubs and extra-curricular classes for talented students to prepare them for competitions in the domain subject.

The authors chose to analyse the factor linearity in two steps: first, all factors, except top three to exclude the influence from these on the students' self-concept in the domain subject and, second, all factors together to distinguish the ones that influenced the students' self-concept the most. It was done because it is widely researched and described in the literature that achievement and self-concept are reciprocal in nature. Moreover, Table 1 presented the factor "Student Like Learning the Domain Subject" and the factor "Engagement in the Domain Subject Lessons" had the strongest correlation with the students' self-concept in the domain subject. First, the authors built the linear regression model with six variables where the students' self-concept in the domain subject was dependent variable and the following six variables were independent ones: "Tiredness", "Absentness", "Bullying", "Extra classes" and "Early tasks. The result of this linear regression model is summarised in Table 2.

Table 2

Coefficient of Determination (R^2) for Linear Regression Model of Six Regression Equations Representing How Self-Concept in Mathematics and Science Is Affected by the Selected Factors

Name of the factor / Country		Latvia	Denmark	Finland	Germany	Lithuania	Poland	Russian Federation	Sweden
R^2	M	0.17	0.24	0.21	0.16	0.18	0.26	0.15	0.24
R^2	S	0.22	0.28	0.19	0.21	0.21	0.31	0.18	0.26

M – Mathematics, S – Science

As it can be seen in Table 2, the linear regression model explains better the students' self-concept in Science than in Mathematics. The mean average value for Mathematics is 0.20 but for Science – 0.23, it means that this model explains about 20% to 23% of the variance of students' self-concept in the domain subject.

In order to increase the explained variance of students' self-concept in Science and Mathematics, the authors added all other variables as independent together with achievement in the domain subject. In Table 3 one can see 10 linear regression equations where students' self-concept in the domain subject is a dependent variable, but "Tiredness", "Absentness", "Bullying", "Extra classes", "Early tasks", "Engagement in the Domain Subject Lessons", "Student Like Learning the Domain Subject", "Domain Subject Teachers' Instructional Clarity" and "Achievement in the Domain Subject" as independent variables together with a coefficient of determination for this model.

Table 3

Linear Regression Coefficients of Ten Regression Equations Representing How Students' Self-Concept in Mathematics and Science Is Affected by the Selected Factor and Coefficient of Determination (R^2) for This Linear Regression Model

Name of the factor / Country		Latvia	Denmark	Finland	Germany	Lithuania	Poland	Russian Federation	Sweden
Extra classes to excel in class	M	0.01	0.03	-0.02	-0.03	0.01	0.02	0.02	-0.02
	S	-0.02	-0.02	0.00	-0.01	-0.02	0.01	0.01	-0.02
Tired at school	M	0.02	0.00	0.04*	0.03	0.00	0.01	0.01	0.02
	S	0.02	0.01	0.02	0.05*	-0.02	0.04*	0.02*	0.05*
Absent from school	M	0.03*	0.02	0.01	-0.02	0.03*	0.00	0.05*	0.06*
	S	0.02	0.00	0.06*	0.05*	0.05*	-0.01	0.02*	0.06*
Instructional clarity	M	0.06*	0.14*	0.16*	0.11*	0.04	0.22*	0.05*	0.17*
	S	0.11*	0.13*	0.14*	0.13*	0.08*	0.13*	0.02	0.17*
Student bullying	M	0.02	0.02	0.04*	0.02	0.02	0.01	0.04*	0.02
	S	0.04*	0.02	0.06*	0.03	-0.01	0.02	0.07*	0.01
Student Like Learning the Domain Subject	M	0.51*	0.47*	0.58*	0.62*	0.52*	0.45*	0.54*	0.52*
	S	0.51*	0.49*	0.53*	0.50*	0.52*	0.49*	0.51*	0.51*
Early literacy and numeracy tasks	M	0.02	0.00	0.06*	0.02	0.07*	0.01	0.10*	0.08*
	S	0.03*	0.01	0.05*	0.01	0.08*	0.04*	0.12*	0.04*

Name of the factor \ Country		Latvia	Denmark	Finland	Germany	Lithuania	Poland	Russian Federation	Sweden
Achievement in the domain subject	**M**	0.36*	0.36*	0.28*	0.34*	0.37*	0.33*	0.24*	0.26*
	S	0.16*	0.17*	0.15*	0.23*	0.18*	0.16*	0.11*	0.14*
Engagement in the domain subject lessons	**M**	-0.01	0.02	-0.09*	-0.12*	0.05	-0.05	-0.03	-0.04
	S	0.08*	0.11*	0.01	0.02	0.09*	0.10*	0.09*	0.05
R^2	**M**	0,54*	0,55*	0,53*	0,56*	0,57*	0,50*	0,46*	0,50*
R^2	**S**	0,46*	0,52*	0,43*	0,47*	0,48*	0,50*	0,42*	0,50*

*M – Mathematics, S – Science, * Significant, $p < 0.05$*

Standardized regression coefficient statistically significant for confidence interval of 95%

As it can be seen in Table 3, the linear regression model explains on average 53% of variance from students' self-concept in Mathematics and 47% of variance from students' self-concept in Science. The strongest linearity exists between student liking for the domain subject and the students' self-concept, as well as with achievement in the domain subject and the students' self-concept; the third most linearly related variable was the clarity of instructions for the subject and the students' self-concept. Only in Lithuania the clarity of instructions was not significant for students' self-concept in Mathematics, and in the Russian Federation the clarity of instructions was not significant for students' self-concept in Science. For all countries of comparison, the attendance of extra lessons to excel in class was not significant for the students' self-concept in the domain subject. Surprisingly, the fact that students were engaged in Mathematics lessons was not significant for all countries of comparison and was negative in Finland and Germany. The linear regression coefficient for students' self-concept in Science was significant for the engagement in Science lessons in Latvia, Denmark, Lithuania, Poland and the Russian Federation, but in Finland, Germany and Sweden this coefficient was not significant. Only in Finland and the Russian Federation, a significant linearity was shown between the students being bullied and self-concept in Mathematics, but the self-concept in Science was significant in Latvia, Finland and the Russian Federation. Besides, the ability to perform early literacy tasks before beginning of school very little but significantly impacted on the students' self-concept in Science for Latvia, Finland, Lithuania, Poland, the Russian Federation and Sweden, but the self-concept in Mathematics as a variable was not significant for Latvia, Denmark, Germany and Poland. For other countries of comparison, the impact was small but significant. The fact that students were not tired at school and were not absent from school impacted more on students' self-concept in Science rather than in Mathematics. However, it was discovered that not being absent was more significant rather than not being tired, although these variables impacted on the students' self-concept in the domain subject very little. Only in Denmark there was a significant linearity for students' self-concept in Mathematics and not being tired.

Conclusions

As it has been described in other research papers, the students' self-concept in the domain is linearly related with the achievement and they are reciprocal in nature. In this study the authors discovered that both the self-concept in Mathematics and the self-concept in Science were more influenced by the students' liking for the subject rather than by the achievement itself, i.e., the students who liked Mathematics and/or Science had higher self-concept in Mathematics and/or Science and/or vice versa. Also, it was identified that students who understood their teachers' instructions had higher self-concept in the domain subject in comparison with their peers who did not clearly understand their teachers' instructions. The authors were surprised that the engagement in the domain subject lessons correlated a lot with students' self-concept, but it had no significance or even had a negative effect in the linear regression model when the achievement was included. This fact needs to be studied in detail to explore possible causes and effects. Besides, there is a need for further studies to find out whether

the fact that students like learning the subject is reciprocal in nature with the self-concept in the same way as the achievement in the domain subject and the self-concept in this subject.

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