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Original research paper

STUDENT MOTIVATIONAL PROFILES IN SCIENCE: TIMSS 2019 IN SERBIA*

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ABSTRACT

Understanding motivation for learning as a complex construct allows for education to be tailored to students' individual characteristics and needs. Although different combinations of motivational factors lead to different outcomes, there is still a remarkable scarcity of research on students' motivational profiles in science. To identify groups of fourth-graders characterized by different levels of intrinsic motivation and self-efficacy in science, we applied the person-centered approach. By conducting secondary analyses of data obtained via student questionnaires and science knowledge tests in TIMSS 2019 in Serbia, we examined motivational profiles' structure and relations to achievement as well as the membership of students of different genders and profile stability across two research cycles. The cluster analysis revealed four profiles characterized by different levels of intrinsic motivation, self-efficacy, and achievement. Students who reported higher levels of motivation and self-efficacy were more successful than students with lower scores on these variables. Students who reported the highest levels of self-efficacy and moderate levels of motivation demonstrated the highest achievement levels. This finding indicates that teachers need to use strategies for improving competencies and enhancing students' self-efficacy. It is necessary to examine contextual factors that might have contributed to the increase in the number of students who demonstrated low levels of intrinsic motivation and self-efficacy, and the lowest levels of achievement.

Key words:
motivational profiles, science, intrinsic motivation, self-efficacy, TIMSS 2019.

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INTRODUCTION

In the modern world, science and technology have become increasingly important and scientific literacy has come to be considered one of the key competencies to be developed in the process of education. It has been emphasized that a certain level of understanding of science is necessary for people to make decisions about themselves and the world in which they live. The concept of scientific literacy is complex and ambiguous. As such, it has been differently defined across the literature. Theoreticians who belong to what is known as the progressive movement in science education mostly hold a view of scientific literacy that emphasizes the application of scientific knowledge and skills in everyday situations (Bybee, McCrae & Laurie, 2009; DeBoer, 2000; Mullis, Martin, Ruddock, O'Sullivan & Preuschoff 2009; Sadler & Zeidler, 2009). Scientific literacy likewise implies an understanding of science as a form of human knowledge and enquiry as well as an understanding of the way science shapes the material and social world that people inhabit (Baucal & Pavlović Babić, 2010; OECD, 2006).

In addition to cognitive aspects, scientific literacy encompasses attitudes, beliefs, values, and motivational aspects. Attitudes towards science have a significant role in the acquisition of scientific and technological knowledge, the application of scientific concepts and methods in various real-life situations, and the establishment of a career in the field of science. Therefore, the key goals of science education do not only include the acquisition of knowledge and skills, but also the development of interest in science at an early age, along with a positive attitude towards the application of scientific methodology. Students in lower primary education are naturally curious about the world around them and their place in the world, which makes this age particularly suitable for learning the basic scientific concepts. Recent studies have shown that with adequate support and well-devised teaching strategies, students of this age can efficiently engage in conducting research, gathering and analyzing data, and evaluating simple scientific models. Consequently, they can gain an understanding of much more complex science concepts and processes (Enyedy, Danish, Delacruz & Kumar, 2012; Lehrer & Schauble 2006).

In spite of major efforts that many education systems have invested in the improvement of science education, the results of longitudinal studies warn about discouraging trends, including a decrease in student motivation for learning science over the course of education and students' waning aspiration to forge a career in this field (Alexander, Johnson & Kelley, 2012; Plenty & Heubeck, 2013; Potvin & Hasni, 2014; Zusho, Pintrich & Coppola, 2003). Hence, the identification of factors that contribute to the quality of learning and achievement in science has become one of the pressing research problems.

Student Motivation and Achievement in Science Education

Different motivational constructs such as student interest and enjoyment in learning are viewed as the main driving force of learning in the context of formal education (Fryer & Ainley, 2019; Pintrich & Schunk, 2002; Schunk, Meece & Pintrich, 2014; Wigfield & Eccles, 2000). Student interest is defined as a content-specific phenomenon that reveals why students are motivated to engage in a particular activity or learn particular subject content (Renninger & Hidi, 2011). Reasons for engagement can be extrinsic, such as the expectation to achieve the desired outcome, or intrinsic, such as finding a particular activity interesting and enjoyable. Researchers have devoted special attention to the study of self-concept and its contribution to achievement. Self-concept is defined as a multidimensional construct that is specific to school subjects (Marsh & Craven, 2006; Marsh, Hau, Artelt, Baumert & Peschar, 2006) and pertains to students' belief in their ability to complete a task and their expectations regarding the outcome of this activity (Bandura, 1997; Zusho *et al*., 2003). Self-efficacy constitutes a motivational belief in the sense that a higher perceived self-efficacy contributes to setting higher personal goals and affects the intensity of dedication to their realization. Setting challenging goals raises the level of motivation and increases the intensity of striving for achievement.

The relationship between motivation and achievement has been studied in the context of various school subjects, with researchers applying different theoretical frameworks and methodological outlines. Correlational and experimental studies and meta-analyses have shown that motivational characteristics are significantly linked to achievement, that is, that students who exhibit higher levels of self-efficacy and interest and highly value a particular subject achieve better learning outcomes (Cerasoli, Nicklin & Ford, 2014; Hattie, 2009; Lee & Shute, 2010). Furthermore, it has been confirmed that in comparison to other variables, self-efficacy correlates more significantly with achievement (Meece, Wigfield & Eccles, 1997; Richardson, Abraham & Bond, 2012; Stankov, 2013).

Motivation has been recognized as a crucial construct in the field of science education. Meta-studies offering overviews of the long research tradition in this field have revealed that students' motivational beliefs and self-efficacy are among the key factors influencing school achievement (Lavonen & Laaksonen, 2009; Osborne, Simon & Collins, 2003; Wang & Degol, 2013). Likewise, it has been shown that a sense of competence is a better predictor of student achievement compared to intrinsic and extrinsic motivation. For example, recent research conducted on samples of fifth-graders and sixth-graders has shown that students' self-efficacy consistently predicts different dimensions of affective, cognitive, and behavioral engagement in science, both in a school environment and in other contexts (Bae & DeBusk-Lane, 2019; Ben-Eliyahu, Moore, Dorph & Schunn, 2018). Furthermore, in a study involving students with the highest levels of achievement in science, Chen and colleagues determined that these students' dedication to learning and their self-efficacy had the greatest predictive power (Chen, Zhang, Wei & Hu, 2019).

The Person-Centered Versus the Variable-Centered Approach

Although numerous studies have identified positive relations between the components of student motivation and academic achievement, the obtained relations have mostly been weaker compared to other psychological and educational factors (Howard, Gagné & Bureau, 2017; Kriegbaum, Becker & Spinath, 2018). It has further been shown that different variables contribute to these effects (Marsh & Craven, 2006; Skaalvik, Federici & Klassen, 2015; Vesić, Džinović & Mirkov, 2021). These findings suggest that the relationship between student motivation and academic achievement is not unambiguous, which means that is necessary to examine potential limiting factors. In this sense, the crucial flaw of the variable-centered approach, which has been dominant in this research tradition, lies in the fact that it does not allow for the identification of subgroups of students with unique patterns of beliefs within a sample or between samples. Conversely, the person-centered approach offers the possibility to identify subgroups of individuals characterized by different configurations of motivational factors and beliefs about self-efficacy and examine more complex interactions between these components (Bergman & Trost, 2006). Within this approach, special techniques are used, including clustering and latent class analysis (LCA)[1], in order to isolate different profiles of participants giving similar answers in relation to motivational variables.

Studies that adopt the person-centered approach examine student profiles in science using motivational and other characteristics as identification measures. These can include students' self-efficacy and motivational beliefs, (Andersen & Chen, 2016; Bae & DeBusk-Lane, 2018; Bøe & Henriksen, 2013; Conley, 2012; Linnenbrink-Garcia, Wormington, Snyder, Riggsbee, Perez, Ben-Eliyahu & Hill, 2018), students' personal characteristics, motivation, and learning environment characteristics (Radišić, Selleri, Carugati & Baucal, 2021), epistemological beliefs (Chen, 2012; Kampa, Neumann, Heitmann & Kremer, 2016), and student engagement (Schmidt, Rosenberg & Beymer, 2018). The results of such studies have shown that students exhibit different combinations of motivational beliefs about science as well as that some profiles are more adaptive than others in terms of the key outcomes of science education, such as achievement on standardized tests, scientific literacy, and choosing to forge a career in STEM[2] (Snodgrass Rangel, Vaval & Bowers, 2020). Likewise, studies have consistently replicated the finding obtained in variable-oriented research that students' sense of competence more significantly contributes

1 LCA – *Latent Class Analysis*

2 STEM – *Science, Technology, Engineering, and Mathematics*

to student achievement in science education compared to intrinsic and extrinsic motivation (Chen, 2012; Chen & Usher, 2013; Ivanova & Michaelides, 2022).

The international comparative studies of TIMSS and PISA examine students' academic achievement and the contextual factors that explain this phenomenon, thus representing a valuable source of data for studying the relationship between motivation and achievement. Still, a relatively small number of studies have so far used these data to identify different student motivational profiles in science (Hofverberg, Eklöf & Lindfors, 2022; Radišić *et al.*, 2021; Shmidt *et al.*, 2018) and mathematics (Lalić-Vučetić, Ševkušić & Mirkov, 2021; Michaelides, Brown, Eklöf & Papanastasiou, 2019). The key advantage of these studies lies in the fact that they allow for the identification of different patterns of motivational beliefs among students on a representative sample as well as to monitor students' membership in motivational profiles and determine whether it is stable or changes from one cycle to another. These data could be an invaluable source of information for both educational policy and practice.

In our research, we adopted the person-centered approach in order to study students' motivational profiles in science in TIMSS 2019. Our findings have both theoretical and practical implications. The analyses conducted following this approach can contribute to the existing literature on motivation as a complex and dynamic construct and allow for a better understanding of factors that influence student achievement on the TIMSS science knowledge test. The identification of different student motivational profiles can help tailor science education to students' individual characteristics and needs and consequently contribute to higher-quality learning and achievement.

The aim of our research was to identify and describe student motivational profiles in science education based on differences in intrinsic motivation and self-efficacy. We examined motivational profiles among fourth-graders attending elementary schools in Serbia who participated in TIMSS 2015 and TIMSS 2019. Our study addressed the following research questions:

1. Which motivational profiles in science can be identified among students and what is the structure of these profiles?
2. What is the nature of the relationships between motivational profiles and students' achievement on the science knowledge test?
3. Are there any gender differences in student motivational profiles?
4. Are student motivational profiles in science education stable across the two research cycles, TIMSS 2015 and TIMSS 2019?

Based on the results of relevant person-centered studies (e.g., Ivanova & Michaelides, 2022; Michaelides *et al.,* 2019; Radišić *et al.,* 2020; She *et al.*, 2019), we expected to identify consistent profiles with similar (higher and lower) self-efficacy and intrinsic motivation scores. Furthermore, we expected to identify inconsistent profiles in which self-efficacy and intrinsic motivation would not have similar result distributions. In terms of relationships between motivational profiles and achievement, we assumed that students reporting a stronger sense of self-efficacy and higher levels of intrinsic motivation would demonstrate higher levels of achievement on the test compared to students with lower scores on these variables. Finally, we assumed that students with inconsistent profiles and the highest scores on self-efficacy would demonstrate the highest levels of achievement.

METHOD

The study was based on a secondary analysis of data obtained through student questionnaires and the science knowledge test within the TIMSS 2019 and TIMSS 2015 international assessment frameworks.

Sample

In TIMSS 2019, the sample comprised 4,380 fourth-graders from 165 primary schools in Serbia. In the sample, students of both genders were relatively equally represented (49% girls) and their average age was 10.60 years. In TIMSS 2015, the sample included 3,976 students from 160 primary schools, (49% girls), with the average age of 10.75 years.

Variables and Instruments

Since 1995, TIMSS has assessed student motivation for learning science using measures incorporated into student questionnaires. Over the cycles, the scales have been revised, motivation components have changed, and the selection of claims has gradually become more theoretically justified. Since 2015, authors have referred to self-determination theory to describe the motivation construct used in the TIMSS 2015 and 2019 assessment cycles (Hooper, Mullis & Martin, 2013; Hooper, Mullis, Martin & Fishbein, 2017). However, no clear explanation has been provided regarding the operationalization of statements in the scale of motivation based on this complex theory (Ivanova & Michaelides, 2022; Michaelides *et al.*, 2019), which has been empirically validated in numerous studies, across different cultural contexts in the domain of education (as cited in: Šarčević, 2015). For fourth-graders, the TIMSS motivation construct comprises two variables: students' attitude towards science and self-confidence in science. The first variable is interpreted as an indicator of intrinsic motivation, while the second variable constitutes an indicator of students' self-efficacy. In our research, these two measures were used for identifying student motivational profiles in science.

In both TIMSS cycles, the assessment of students' intrinsic motivation for learning science was conducted using a one-dimensional scale comprising nine statements used for obtaining students' self-perception of enjoyment and interest in learning science and affective attitude towards subject content (α = .90). The scale for assessing self-efficacy in the learning of science is likewise one-dimensional and contains seven statements pertaining to students' evaluation of their success and difficulties in learning science (α =.84). In TIMSS 2015, the reliability of the scale of intrinsic motivation was α =.88, while the reliability of the scale of self-efficacy was α = .83. Students expressed their degree of agreement with the statements using a four-point Likert-type scale (I completely agree, I agree, I disagree, I completely disagree). The statements are provided in Appendix 1.

To assess the factor structure of the two scales, we conducted a confirmatory factor analysis (CFA) using the JASP software (JASP Team, 2022), based on the analysis Ivanova and Michaelides conducted on the data obtained in TIMSS 2015 (Ivanova & Michaelides, 2022)[3]. The CFA revealed satisfactory fit indices for the scales in both research cycles (Table 1), especially after the inclusion of the factor of negative item formulation (i.e., *the negative wording factor*). The effect of this factor was highlighted in the aforementioned research as well as similar studies that confirmed the fit of the two-factor structure of the motivation construct among fourth-graders in different TIMSS cycles (e.g., Michaelides, 2019). Additional support for the use of motivational scales could be found in the results of analyses conducted on the data obtained in TIMSS 2019 for all participating countries, including Serbia (Reynolds, Khorramdel & von Davier, 2022)[4].

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3 The analysis assessed the factor structure of the scales of self-efficacy and intrinsic motivation on a sample of fourth-graders and eighth-graders from the US.

4 Scales measuring self-efficacy and intrinsic motivation were analyzed with the application of the IRT (Item Response Theory) approach. For both scales measuring the attitudes of fourth-graders and eighth-graders towards science and mathematics, the results showed that items were comparable in the majority of countries.

Table 1: The Fit Indices of the Scales of Self-Efficacy and Intrinsic Motivation

	χ2	df	CFI	RMSEA	SRMR
The structure of the motivation construct with the NWF (TIMSS 2015)	516.298*	95	.998	.035	.033
The structure of the motivation construct with the NWF (TIMSS 2019)	800.121*	95	.998	.044	.032

* $p < .001$.
NWF - *Negative Wording Factor*

Student achievement in science is operationalized as the mean of the five plausible values on the knowledge test (M = 500, SD = 100). The test measures student achievement in different domains of science content (life science, physical science, and Earth science)[5], within three cognitive domains: knowing, applying, and reasoning. The design of the research allows for students' average achievement to be interpreted in relation to international benchmarks that constitute indicators of four levels of knowledge: advanced (625 points), high (550 points), intermediate (475 points), and low (400 points).[6]

Analyses

To identify student motivational profiles, we conducted a two-step cluster analysis. Each set of data (TIMSS 2019 and TIMSS 2015) was analyzed separately. We chose this method because it allowed for a more direct comparison of our data with the results obtained in recent research conducted on TIMSS data with a similar goal (Lalić-Vučetić *et al.*, 2021; Michaelides, Brown, Eklöf & Papanastasiou, 2019). We used descriptive statistics for the analysis of cluster structure and conducted a one-way analysis of variance to determine whether differences in cluster membership were linked to students' achievement on the science knowledge test. Furthermore, we performed a chi-squared test to identify potential differences in the distribution of

5 According to the current curriculum for the first cycle of primary education in Serbia, science content represents an integral part of the mandatory subjects of The World Around Us (the first and second grades) and Nature and Society (the third and fourth grade).

6 For more detailed descriptions of competencies at different levels, see the methodological framework of TIMSS (Đerić, Gutvajn, Jošić & Ševa, 2021).

boys and girls across clusters and to determine whether the structure of motivational profiles differed across the two TIMSS cycles. Data processing was carried out using the SPSS 27 software package.

RESULTS

Characteristics of Motivational Profiles in Science: TIMSS 2019

Table 3 shows descriptive statistics for the two measures based on which motivational profiles were identified, self-efficacy and intrinsic motivation for learning science. The correlation between these two variables was relatively high ($r = .63$, $p < .001$).

Table 2: Descriptive Statistics for Motivational Variables (TIMSS 2019)

Variable	N	Min	Max	M	SD
Intrinsic Motivation	4,314	2.69	13.19	9.41	2.03
Self-efficacy	4,310	3.43	13.29	9.91	1.83

We conducted cluster analyses with the application of the procedure described in the research by Michaelides and colleagues (Michaelides *et al.,* 2019: 36). Considering that cluster analysis is an exploratory procedure, it is possible to extract and interpret different numbers of clusters, especially in a two-step cluster analysis. In this case, the number of clusters was limited to five and based on the criteria that each cluster includes at least 7% of participants and that the solution is good or at least acceptable (Kaufman & Rousseeuw, 1990). An overview of all cluster solution is provided in Table 3.

Table 3: Cluster Solutions Identified in Science (TIMSS 2019)

The Number of Isolated Clusters	Solution Quality	% of Participants in the Clusters
2	.6 (good)	39.4, 60.6
3	.5 (good)	21.4, 27.6, 51
4	.5 (good)	13.4, 27.8, 7.8, 50.9
5	.5 (acceptable)	13.4, 24.1, 7.8, 38.9, 15.8

Each cluster solution met the minimum requirements for being accepted as the final solution. For further analyses, we selected the four-cluster solution. The choice was based on cluster structure and relevant theoretical assumptions on the potential existence and effects of inconsistent profiles (Michaelides *et al*., 2019: 37). In comparison to two-cluster and three-cluster solutions, four-cluster and five-cluster solutions offered greater possibilities for interpretation, but the five-cluster solution did not provide any new information compared to the four-cluster solution.

Table 4 shows the structure of student motivational profiles in science. By structure we mean the distribution of students across clusters and the values of the variables of self-efficacy and intrinsic motivation. The first motivational profile encompassed students with high levels of intrinsic motivation and self-efficacy in science. The second profile included students with moderate scores on both variables. The third profile encompassed the smallest number of students, all of whom reported moderate intrinsic motivation, but had the strongest self-efficacy of all students across all profiles. The fourth profile comprised half of the sample and included students with a weak sense of self efficacy and low levels of intrinsic motivation for learning science. Therefore, the obtained results confirmed our assumptions about the existence of profiles that differed in terms of structure, with the identification of both consistent and inconsistent profiles.

Table 4: Distribution of Students Across Clusters, Descriptive Statistics for Intrinsic Motivation for Learning Science, Self-Efficacy, and Achievement on the Science Knowledge Test (TIMSS 2019)

Clusters	N	%	Intrinsic Motivation		Self-Efficacy		Achievement	
			M	SD	M	SD	M	SD
1	577	13.4	13.19	0.05	12.11	1.49	533.16	66.20
2	1196	27.8	10.00	0.92	10.25	.92	530.89	70.14
3	337	7.8	10.08	1.39	13.29	.04	555.90	61.63
4	2188	50.9	7.98	1.13	8.63	.88	514.29	77.86

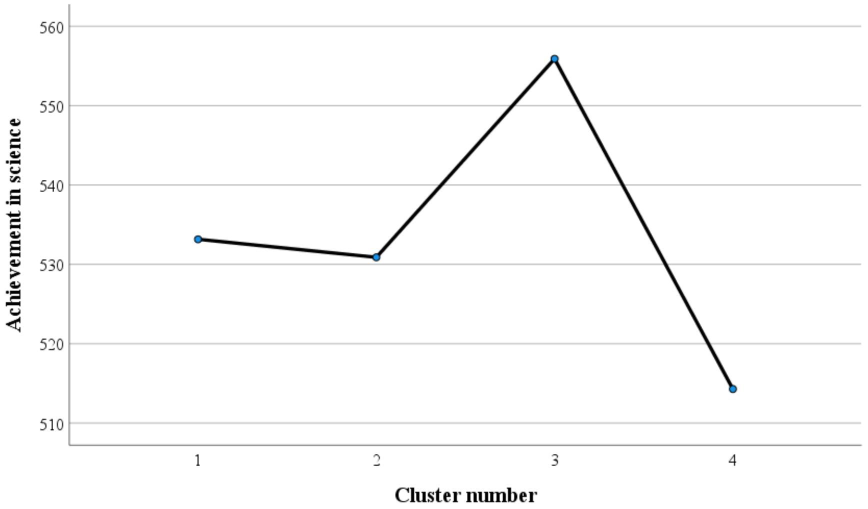
What Were the Achievement Levels of Students With Different Motivational Profiles?

The obtained results confirmed both of our assumptions related to achievement and different motivational profiles. Overall, students who reported higher levels of intrinsic motivation and self-efficacy demonstrated higher achievement levels compared to students with low scores on both motivational variables. Furthermore, students with the strongest self-efficacy and moderate levels of intrinsic motivation demonstrated the highest levels of achievement. As shown in Table 4, students encompassed by the third profile had the highest achievement levels. This *inconsistent* cluster (different scores on the variables of motivation for learning and self-efficacy) was significantly more successful than the first, in spite of its members exhibiting lower levels of motivation. Students included in the first and second clusters demonstrated similar levels of achievement, even though students in the second cluster exhibited significantly lower levels of motivation and self-efficacy compared to their counterparts in the first cluster. Students encompassed by the fourth profile had the lowest levels of achievement. The analysis of variance confirmed that between-cluster differences were statistically significant for both motivational variables (intrinsic motivation for learning, $F(3, 4294) = 4232.10$, $p < .001$, $\eta^2 = .75$; self-efficacy, $F(3, 4294) = 3726.83$, $p < .001$, $\eta^2 = .72$), as well as that cluster membership had a significant effect on achievement, $F(3, 4294) = 40.07$, $p < .001$, $\eta^2 = .03$. *Post-hoc* tests (the Tukey HSD test) revealed that the difference in achievement between the first and second clusters was not statistically significant ($p = .93$). Likewise, there was no statistically significant difference between the second and third clusters in terms of the variable of intrinsic motivation for learning ($p = .52$).[7]

Observing students' average levels of achievement across clusters in relation to the TIMSS international benchmarks, we noted that the score that the members of the third cluster achieved on the knowledge test (555.90) corresponded to the high international benchmark (Graph 1).

[7] We conducted three separate one-way analyses of variance for each of the three variables: intrinsic motivation for learning, self-efficacy, and achievement. Presented in the paper are only the post-hoc tests in which there were no statistically significant differences between the profiles, while all the other differences were statistically significant.

Graph 1. The Relation Between Motivational Profiles and Student Achievement on the Science Knowledge Test (TIMSS 2019)



The results of the analysis of gender distribution of students across clusters showed that there was no statistically significant difference ($\chi^2(2) = 2.73$, $p = .256$). In other words, boys and girls were approximately equally represented in each profile (Table 5).

Table 5: Gender Distribution of Students Across Clusters (TIMSS 2019)

Profile Number	Student Gender	
	F	M
1	292	285
2	611	585
3	174	163
4	1,055	1,133

Characteristics of Motivational Profiles in Science: TIMSS 2015

To address the question of whether the structure of motivational profiles in science was stable across the two TIMSS cycles, we conducted identical cluster analyses of data from 2015 (Table 6). For further analyses, we likewise selected the four-cluster solution.

Table 6: Cluster Solutions Identified In Science (TIMSS 2015)

The Number of Isolated Clusters	Solution Quality	% of Participants in the Clusters
2	.6 (good)	42.7, 57.3
3	.5 (good)	37.5, 32.6, 29.9
4	.5 (good)	26.2, 12.9, 30.9, 29.9
5	.6 (good)	15.5, 12.9, 13.8, 27.9, 29.8

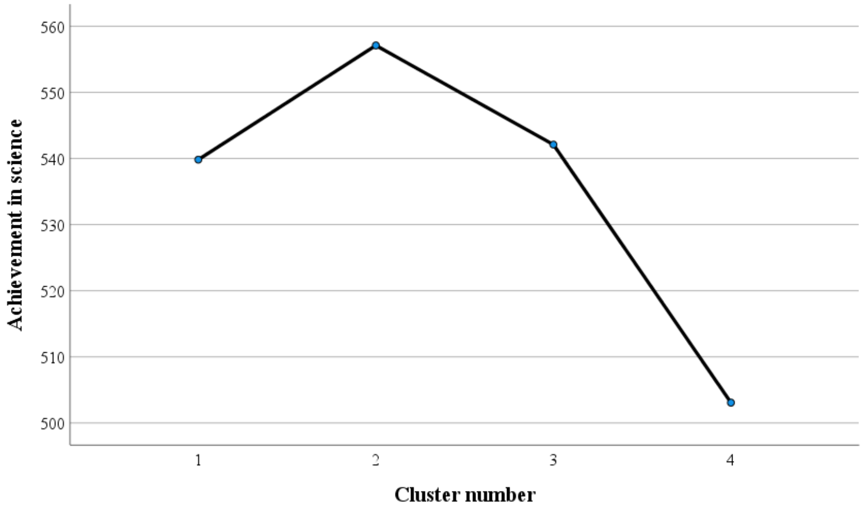
Table 7 shows the structure of motivational profiles and the achievement levels of students with different motivational profiles. The analysis of variance showed that all differences between clusters were statistically significant for both motivational variables (intrinsic motivation for learning: $F(3,3955) = 4905.20$, $p < .001$, $\eta^2 = .79$; self-efficacy: $F(3, 3955) = 3752.26$, $p < .001$, $\eta^2 = .74$) as well as that clusters significantly differed in terms of achievement, $F(3, 3955) = 104.69$, $p < .001$, $\eta^2 = .07$, with a single exception. Namely, post-hoc comparisons showed that the first and third clusters did not significantly differ in terms of achievement ($p = .86$), even though the first cluster exhibited high levels of intrinsic motivation and self-efficacy, while the third cluster obtained moderate scores on both variables.

Table 7: Distribution of Students Across Clusters, Descriptive Statistics for Intrinsic Motivation for Learning Science, Self-Efficacy, and Achievement on the Science Knowledge Test (TIMSS 2015)

Clusters	N	%	Intrinsic Motivation		Self-Efficacy		Achievement	
			M	SD	M	SD	M	SD
1	1039	26.2	12.61	.36	12.06	1.53	539.82	65.76
2	512	12.9	9.90	1.10	13.20	.06	557.10	60.85
3	1223	30.9	9.58	.94	10.15	.88	542.10	64.53
4	1185	29.9	7.84	1.17	8.27	.90	503.07	79.32

Students encompassed by the second (inconsistent) cluster demonstrated the highest levels of achievement. They reported moderate levels of intrinsic motivation, but obtained higher scores on the self-efficacy variable compared to students encompassed by the first and third clusters. As in the case of the third (inconsistent) profile in TIMSS 2019, the achievement of students with this profile (557.10) corresponded to the high international benchmark (Graph 2).

Graph 2: The Relation Between Motivational Profiles and Student Achievement on the Science Knowledge Test (TIMSS 2015)



Did the Structure of Motivational Profiles in Science Differ Across the Two TIMSS Cycles?

The difference between clusters isolated from the data collected in the years of 2015 and 2019 was tested via a chi-squared test, which showed that the structures of motivational profiles in the two TIMSS cycles were statistically significantly different ($\chi2(3) = 453.55$, $p < .001$). Subsequent z-tests of proportions confirmed that the number of students in each of the profiles significantly changed between the two assessments ($p < .05$). Namely, in 2019, the number of students in the first, second, and third profiles decreased significantly, while the number of students in the fourth profile increased significantly in comparison to 2015.

Observing the structure of the profiles, we noticed a trend of change in the two TIMSS cycles. Namely, in both TIMSS cycles, profiles no. 1 were characterized by similar, high scores on the dimensions of self-efficacy and intrinsic motivation for learning science. Another similarity between these profiles was reflected in students' moderate levels of achievement. However, the clusters differed in the number of students. Between the cycles, the size of the first cluster diminished by nearly a half, going from 26.2% of students in 2015 to mere 13.4% in 2019. Furthermore, profile no. 2 from 2015 was almost identical to profile no. 3 from 2019 in terms of scores on intrinsic motivation and self-efficacy. In other words, these profiles only switched places. Both profiles were characterized by moderate levels of intrinsic motivation for learning (around 10) and the highest scores on self-efficacy compared to other profiles. Students with these profiles demonstrated the highest levels of achievement in their respective cycles. The size of this, most successful profile was significantly smaller in the second research cycle, going from 12.9% of students in 2015 to 7.8% in 2019. The starkest change was observed in profile no. 4. In both TIMSS cycles, this profile was characterized by low scores on self-efficacy and intrinsic motivation for learning science. Both in 2015 and 2019, students with this profile demonstrated the lowest levels of achievement. This cluster significantly grew in size, going from 30% of students in 2015 to 51% of students in 2019.

DISCUSSION

Our research on motivational profiles in learning science among fourth-graders from Serbia revealed a relatively high correlation between students' self-efficacy and their intrinsic motivation for learning. In other words, a stronger sense of self-efficacy was accompanied by a higher level of motivation. Similar findings were obtained in the previous TIMSS cycle, in 2015 (Lalić-Vučetić & Mirkov, 2017; Vesić, *et al.*, 2021). Students reported somewhat higher levels of self-efficacy compared to levels of intrinsic motivation for learning science, which is aligned with theoretical assumptions of relations between the self-efficacy and motivation (Vesić, *et al.*, 2021; Zimmerman, 2000).

According to self-determination theory (Deci & Ryan, 1985), motivation is explained by a sense of competence, relatedness, and self-determination. Students who are certain of the competence invest greater efforts and exibit greater perseverance. Thus, beliefs about self-efficacy affect achievement (Patrick, Mantzicopoulos, Samarapungavan & French, 2008). Numerous studies have shown that students' self-perception and motivational beliefs affect learning by influencing the way students adapt to specific learning situations as well as their estimation of the proportionality between the efforts they invested and their success in completing the task (Seegers, Van Putten & De Brabander, 2002). Perceived progress reinforces the sense of efficacy, which further improves motivation. Students' motivation and self-efficacy in different subjects have been identified as predictors of achievement (Marsh *et al.*, 2006; Marsh *et al.*, 2013). In the face of difficulty, individuals with a strong self-efficacy keep thinking strategically, while persons who are less certain of their efficacy decrease the amount of effort invested.

The structure of motivational profiles identified in TIMSS 2019 showed that different groups of students reported different levels of intrinsic motivation and self-efficacy in science. In three out of four profiles, the level of intrinsic motivation was comparable to that of self-efficacy. The small number of students encompassed by the first profile reported high levels of intrinsic motivation and self-efficacy. The second profile encompassed around a quarter of the sample and included students with moderate scores on both variables. The largest number of students (approximately a half of the sample) reported low levels of intrinsic motivation and self-efficacy in learning science (the fourth profile). The third motivational profile constituted an exception. It encompassed the smallest number of students and was characterized by inconsistency between the scores on the two variables. Namely, students with this motivational profile were moderately intrinsically motivated, but had the strongest sense of self-efficacy in comparison to students with other profiles.

When it comes to the relationship between motivational profiles and achievement, our analysis showed that students with different motivational profiles significantly differed in terms of their achievement on the science knowledge test. Generally speaking, students with higher levels of intrinsic motivation for learning and a stronger self-efficacy demonstrated higher levels of achievement, while students with the lowest scores on both variables demonstrated the lowest levels of achievement in science. Similar results were obtained regarding the relationship between motivational profiles and achievement in mathematics in TIMSS 2019 (Lalić-Vučetić *et al.*, 2021) as well as earlier TIMSS cycles (Michaelides *et al.*, 2019). Furthermore, our analysis of the data obtained in TIMSS 2019 as well as TIMSS 2015 showed that the highest levels of achievement in science were demonstrated by students with inconsistent motivational profiles, that is, students who had the strongest sense of self-efficacy and moderate intrinsic motivation. Likewise, when observed in relation to international benchmarks, these students' scores on the test indicated that they possessed higher-quality knowledge compared to students with other motivational profiles. According to the description of competencies associated with the high international benchmark, these students were able to apply science knowledge in everyday situations, which is a crucial aspect of scientific literacy, according to contemporary theories of science education (Bybee *et al.,* 2009; Mullis *et al.*, 2009). This finding indicates that self-efficacy could be more important for achievement in science compared to intrinsic motivation for learning, as shown in similar person-centered research (Chen, 2012; Chen & Usher, 2013; Radišić *et al.*, 2021). Other studies have also suggested that a sense of competence is a more significant predictor of academic achievement compared to enjoyment in learning (Bong, Cho, Ahn & Kim, 2012; Džinović & Vujačić, 2017; Kriegbaum, Jansen & Spinath, 2015; Möller, Zitzmann, Helm, Machts & Wolf, 2020; Prast, Van de Weijer-

Bergsma, Miočević, Kroesbergen & Van Luit, 2018; Spinath, Spinath, Harlaar & Plomin, 2006; Vesić *et al.*, 2021).

In the context of contributions to achievement, studies have found that motivation for learning and especially intrinsic motivation, which is associated with the need for developing personal abilities and autonomy (Deci & Ryan, 1985; 1987), can be more significant for acquiring high-quality knowledge and realizing long-term academic goals (making academic choices, gaining a deeper understanding of the content, and long-term interest in a school subject) than for academic success and achievement on the test (Vesić *et al.*, 2021).

Analyses of motivational profiles identified in TIMSS 2019 revealed that girls and boys were approximately equally represented in each profile. Other studies have reported conflicting findings regarding the link between student gender and motivation (Chan & Norlizah, 2017; Pintrich & Schunk, 2002). Having in mind that studies have commonly reported gender differences in developmental changes in students' perceived competence and intrinsic motivation (Bouffard, Marcoux, Vezeau & Bordeleau, 2003; Wang & Degol, 2013).), further research is needed in order to illuminate the relation between gender and student motivation in science.

In terms of the stability of student motivational profiles over the four-year period, in-between the two research cycles, the obtained results showed that the structure of the clusters was highly similar. However, the number of students encompassed by each profile changed significantly. In comparison to the previous cycle, in TIMSS 2019, there were significantly more students with low levels of intrinsic motivation, who expressed a weak sense of self-efficacy and demonstrated the lowest level of achievement. At the same time, we observed a decrease in the number of students in other, more successful profiles. This negative trend in membership in student motivational profiles should be further investigated. In other words, it is necessary to examine the contextual factors that could have contributed to this trend, such as the quality of the curriculum and the quality and the number of hours invested in teachers' professional development (Ševkušić & Kartal, 2019). Having in mind that during the COVID-19 pandemic, the learning and teaching processes took place under different circumstances, it would be prudent to investigate whether these circumstances contributed to the negative trend in student motivation and learning outcomes.

CONCLUSION AND IMPLICATIONS

Motivational profiles identified in our research are aligned with the theoretical assumptions and findings of previous studies on student motivation for learning science at different ages. Our findings showed that students in lower primary education were relatively highly motivated for learning science, as evidenced in similar studies that applied the person-centered approach (Linnenbrink-Garcia *et al*., 2018; Wormington & Linnenbrink-Garcia, 2017). The obtained results further confirmed the results of other studies that found that students' belief in their own competency can be more significant than intrinsic motivation, not only in terms of their achievement in science but also in terms of the quality of their knowledge.

The examination of motivational profile stability over the four-year period revealed a downward trend in the number of students who were highly motivated for learning science, had a strong self-efficacy, and demonstrated high achievement levels on the knowledge test. Having in mind that studies have revealed that the intensity of student interest and motivation for learning science tends to decrease over the course of education (Karakolidis, Pitsia & Emvalotis, 2019; Patrick *et al*., 2008), it is essential for future research to apply the longitudinal approach in order to determine the stability of student motivational profiles throughout education.

Further research on different affective and motivational factors involving multiple indicators of achievement could improve our understanding of the role of motivation in learning science and point to favorable directions of changes in the teaching practice and the curriculum that would support the learning of science. The results of our research suggest that teachers should be aware of differences in student motivational profiles and apply teaching strategies that improve student competencies and their self-efficacy in the science education. Students' sense of competence is affected by peer comparison, which is why it is crucial for teachers to foster a less competitive learning environment and encourage students to focus on personal academic goals instead of comparing themselves to others. For students to develop an interest in school tasks and understand their value, teachers need to invest more time and effort into encouraging student autonomy and providing feedback. For students who exhibit a stronger sense of competence, teachers can devise more challenging tasks that would stimulate their desire to learn and allow them to make decisions independently during the process of learning. This way, teachers could promote intrinsically motivated learning. Research has also shown that teachers can help alleviate motivation problems among students in lower primary education by offering special support and assistance and developing a friendly atmosphere based on trust (Ng *et al*. 2016; Patrick *et al*., 2008).

Limitation-wise, our data were based on student self-reports and the obtained correlations between motivational variables and achievement did not reveal the direction of the relationships. Nonetheless, we believe that our research provides a contribution to the corpus of recent person-centered research by broadening our understanding of the role of motivation in learning and achievement in science. Generally speaking, these studies constitute an important step towards elucidating the complex patterns of motivation and its multifold relationship with achievement, as highlighted in theories of motivation. The obtained results contribute to the body of research on student motivation in lower primary education, which is still relatively scarce in spite of the potential far-reaching consequences of maladaptive motivational beliefs for the development of competences necessary for future learning and achievement in science.

Appendix 1
Statements in the Scales of Intrinsic Motivation and Self-Efficacy in the Learning of Science

The Scale of Intrinsic Motivation for Learning Science
I enjoy learning science. I wish I did not have to study science. Science is boring. I learn many interesting things in science. I like science. I look forward to learning science in school. Science teaches me how things in the world work. I like to do science experiments. Science is one of my favorite subjects.
The Scale of Self-Efficacy in Science
I usually do well in science. Science is harder for me than for many of my classmates. I am just not good at science. I learn things quickly in science. My teacher tells me I am good at science. Science is harder for me than any other subjects. Science makes me confused.

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