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Original research paper

## HOW DO EPISTEMIC CURIOSITY AND METACOGNITIVE ABILITIES SHAPE PHYSICS PERFORMANCE AND GENERAL SCHOOL PERFORMANCE\*

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### A B S T R A C T

Both curiosity and metacognition are considered to be crucial aspects of a student's school achievement and their motivation for learning. Many studies have explored these two concepts but very few have considered them simultaneously and by using the student's self-report measures. Understanding the factors that affect physics performance, physics being one of the most challenging school subjects, could enable teachers to establish better teaching conditions that would ultimately result in better student grades. Therefore, the purpose of this study was to explore the relationship between epistemic curiosity (specific and diversive) and metacognitive abilities (knowledge and regulation) on one side, and physics performance and general school performance on the other. Respondents were 270 7<sup>th</sup> and 8<sup>th</sup> grade school students (49.6% male). Multivariate general linear modeling (linear regression) showed that

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there is no significant effect of epistemic curiosity and its interaction with metacognition, while metacognitive abilities are significantly related to physics and general school performance. Metacognitive knowledge is positively related to all measures of students' performance, especially physics, while metacognitive regulation is negatively related to physics performance, without a significant effect on general school performance. Implications of these findings are further discussed.

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*Key words:*

epistemic curiosity, school performance, elementary school, metacognition, physics.

## ■ INTRODUCTION

Curiosity and metacognition are closely intertwined, with curiosity serving as both a precursor to and a product of effective metacognitive regulation. Conceptually, both curiosity and metacognitive regulation involve self-regulation and self-evaluation, influencing individuals' motivation and learning outcomes (Lauriola et al., 2015). Challenges in effectively utilizing these cognitive processes stem from the diverse levels of individual curiosity and significant cultural influences. Individual curiosity varies widely among learners, influencing their engagement and willingness to explore physics concepts deeply. Additionally, cultural factors shape learners' perspectives, attitudes, and approaches to learning, thus affecting their receptiveness to curiosity-driven inquiry and metacognitive strategies. For instance, student achievement in physics can be influenced by various factors such as socio-cultural background (Hakeem & Jimoh, 2020). Recognizing the relationship between curiosity and metacognition would provide valuable insights into the complexities of fostering curiosity and metacognition in diverse educational contexts and accordingly it can aid educators and learners in fostering curiosity-driven learning approaches, enhancing engagement and metacognitive growth.

There is no single definition of curiosity, and many consider it as a subtype of a broader category of behavior in search of information, and related terms include research, neophilia, desire for information, latent learning, etc. which illustrate the complexity of this phenomenon (Kidd & Haiden, 2015). In most of the studies, curiosity can either be observed as a personality trait or a motivational state/emotion that stimulates exploratory behavior (Litman & Spielberger, 2003). Also, curiosity could be seen as a metacognitive signal that indicates when there is an overlap between the learning material and the student's readiness to decipher it (Wade & Kidd, 2019). Metacognition represents our awareness about how we think and what we know (Litman, 2009) and curiosity largely stems from metacognitive judgment.

Physics is viewed as a complex and abstract discipline (Blickenstaff, 2010), since different representations of content, such as conceptual interpretations and explanation, mathematical terms, numbers and calculations, diagrams, sketches, experiments (Angell et al., 2004; Radulović, 2021) are present. For high physics performance, both mathematics and language competencies are necessary (Radulović & Stojanović, 2019). Consequently, a number of students achieve low physics performance. For instance, in the Republic of Serbia, students tend to finish elementary school with unsatisfactory functional physics knowledge. The low scores on PISA tests are one of the main indicators of this problem (OECD, 2019). However, physics deals with phenomena that students meet in everyday life and one would expect that students' curiosity is an important driver of students' inquiry (Luce & Hsi, 2014), therefore researching physics in schools is rather important, especially in terms of student's curiosity and metacognition because of the peculiarities of this subject. While learning and understanding physics content students should find answers to many "why" questions (Székely, 2011), so that one can work on encouraging students' curiosity through teaching physics (Luce & Hsi, 2014). For the purpose of this research, we observed curiosity as a personality trait and measured epistemic curiosity, explained in the sequel, since it was consistently tied to student learning, achievement, and cognitive development (Engel, 2011; Eren & Coskun, 2016).

## Curiosity

One of the forefathers of psychology, William James, described two types of curiosity: instinctual and scientific (James, 1890). Instinctual curiosity is a response that is triggered by novel stimuli while scientific curiosity encompasses the response to the gap in a person's knowledge. Berlyne (1954) stated that both types of curiosity, perceptual (PC) and epistemic (EC) curiosity, can be connected to James's classification (1890), where PC would be seen as instinctual while EC would be seen as scientific curiosity. There are several classifications of different types of curiosity considered as a trait (Litman, 2005; Litman & Spielberger, 2003). The most commonly mentioned typology of curiosity is by Berlyne (1954) that differentiates between epistemic (seeking new ideas, solving puzzles) and perceptual (seeking novel perceptual information) curiosity. As an epistemic emotion, curiosity occurs when there is a gap in knowledge, inducing the desire to acquire new knowledge and experiences (Muis et al., 2015). Litman (2005) states that there are two different ways in which a person can react to novelty: by developing a feeling of interest that is pleasurable, and by having aversive feeling of deprivation. Hence, he differentiates Interest (I) and Deprivation (D) type curiosity. I-type curiosity is "a motive to seek out information expected to be entertaining or aesthetically pleasing", while D-type curiosity "motivates seeking information that will resolve uncertainty and improve one's ability to

understand something” (Litman, 2009: 109). Since D-type curiosity is similar to an unsatisfied need-like state, it has a stronger stimulating impact that provokes trying to obtain information than I-type curiosity.

Peterson (2020) and Ahmad and Siew (2021) stated that curiosity can positively affect students’ learning. Curiosity can be seen as one of the main motivators to gain new knowledge and experience in exploring Science, Technology, Engineering and Mathematics (STEM). Peterson (2020) wrote that curiosity spurs student’s desire to learn, but also it is essential to develop curious individuals through education. In classroom, for example, an argumentation instruction can be helpful in learning science and also maintaining curiosity (Iwuanyanwu, 2023) and, also, hands-on and inquiry-based activities are shown to be useful for fostering curiosity (Delson & Lynch, 2023).

### Metacognition

The concept of metacognition can be defined as “cognition about cognition”, “knowledge about knowledge”, or “thinking about thinking” (Othman & Jaidi, 2012). Metacognition is an individual’s knowledge about their own cognitive processes, as well as achieving goals and everything related to them (Flavell, 1976). If properly understood, metacognition can answer questions about development in cognitive and affective domains. Besides, it helps in understanding all processes that involve self-regulation (Brown, 1987).

Metacognition consists of three separate metacognitive components: metacognitive knowledge, metacognitive experiences and metacognitive regulation (Efklides, 2006). According to Schraw and Moshman (1995), metacognitive knowledge is categorized into declarative, procedural and conditional knowledge. These three types of metacognitive knowledge refer to the knowledge about oneself as a learner (declarative), how to perform a particular strategy (procedural) and when a certain strategy should be applied (conditional) (Schraw & Dennison, 1994). Metacognitive experiences refer to different subjective feelings and judgments linked with monitoring of cognitive processes, such as learning (Koriat & Levy-Sadot, 1999). Metacognitive regulation includes elements that coordinate cognitive processes: planning, information management, monitoring, evaluation and debugging in the process of thinking and learning (Schraw & Dennison, 1994).

It has been shown that various factors are correlated with metacognition, such as motivation, conceptual understanding, critical thinking (Dessie et al., 2024), creative thinking, self-efficacy (Sun et al., 2022), and others. There are several studies that found a positive impact of metacognition on student’s performance in school and STEM subjects (e.g., Krebs & Roebbers, 2012; Singh, 2012). Besides, the use of appropriate metacognitive strategies increase students metacognition (Blajvaz et

al., 2022), physics performance (Akyüz, 2004; Gok, 2010; Koch, 2001; Mafarja et al., 2023; Yuruk et al., 2009), and even students' attitudes towards physics content (Dökme & Koyunlu, 2021).

### **Relationship between Curiosity and Metacognition**

Litman (2009) indicated that different metacognitive judgments are related to different types and intensity of curiosity. Namely, feeling-of-knowing and tip-of-the-tongue stimulate D-type curiosity, while a don't-know-feeling stimulates I-type curiosity.

Curiosity can be associated with metacognitive regulation, particularly processes of self-regulation and self-evaluation. However, there are still insufficient empirical studies examining the relationship between curiosity as a trait and metacognitive abilities, specifically knowledge and regulation. Although it was shown that there is a positive correlation between curiosity and metacognition (e.g., Chevrier et al., 2019; Litman et al., 2005; Loewenstein, 1994), based on relevant literature one cannot come to a firm conclusion if the curiosity precedes metacognition or if it is the other way around. It is possible that the inconsistency of findings, that is, the direction of impact between these two variables depends on which metacognitive components and which type of curiosity are examined. One can expect that metacognitive experience precedes curiosity, while curiosity can precede metacognitive regulation and knowledge. However, since there is no generally accepted theoretical model that explains the direction of influence between curiosity and metacognition, in this research we opted to treat them as equal without implying causation.

### **The Aims of the Study**

A physics course is generally viewed as difficult, and it often leads to low student performance, so understanding what cognitive factors contribute to it could help in improving physics teaching. Still, as far as the authors are aware, there are no available previous studies that have simultaneously explored the effect of metacognition and curiosity on the student's physics performance or for any other subject. Also, most of the studies have been done with older students, where metacognitive awareness is at a higher level of development. This research was conducted on students that are 13 and 14 years old, since in Serbian education system physics classes start from the 6<sup>th</sup> grade (12 years of age). This would mean that students of this age already have certain experience with physics. There are very few studies that explore factors that shape physics learning for this age group, which makes the results of this research noteworthy. Finally, there are no studies that explore the relationship between specific and diversive epistemic curiosity on one side, and metacognitive reg-

ulation and knowledge on the other. So, the aim of this study was to explore whether epistemic curiosity and metacognitive awareness relate to physics performance and general school performance measured by grade point average (GPA). Following the above-mentioned findings, several hypotheses can be proposed where both effects of curiosity and metacognition are observed in one linear regression model. The first hypothesis is that epistemic curiosity (both specific and diversive) affects physics and general school performance. We believe that higher epistemic curiosity leads to higher physics and general school performance. The second hypothesis is that metacognitive awareness (both knowledge and regulation) influences physics and general school performance i.e. higher metacognitive awareness is related to higher physics and general school performance. Finally, the third hypothesis is that specific epistemic curiosity and diversive epistemic curiosity are positively correlated with metacognitive knowledge and regulation.

## ■ METHOD

### Sample

The respondents of this study were 270 students of two elementary schools in Zrenjanin, Serbia, that attended two final grades, 7<sup>th</sup> and 8<sup>th</sup> grade. Both of these grades were represented almost equally (see Table 1). Similar could be said for the gender structure, which was almost balanced, with slightly more male students than female. Their physics performance, from the last semester and in the previous grade, as well as their GPA from the last semester and in the previous grade was measured. In the Serbian educational system, school performance is estimated on the 5-point grading scale (1 – insufficient to 5 – excellent). Average physics performance from the last semester was  $M=3.54$  ( $SD=1.15$ ), while in the previous grade it was  $M=3.63$  ( $SD=1.08$ ). As for their GPA, for the last semester it was  $M=3.93$  ( $SD=1.31$ ), and for the previous grade it was  $M=4.26$  ( $SD=.96$ ). Finally, their satisfaction with the physics classes was above theoretical average ( $M=4.13$ ,  $SD=1.02$ ).

**Table 1.** Sample characteristics

| Variable | Category                       | Total       |
|----------|--------------------------------|-------------|
| Gender   | Male                           | 134 (49.6%) |
|          | Female                         | 129 (47.8%) |
|          | Missing                        | 7 (2.6%)    |
| Grade    | 7 <sup>th</sup> (13 years old) | 136 (50.4%) |
|          | 8 <sup>th</sup> (14 years old) | 131 (48.5%) |
|          | Missing                        | 3 (1.1%)    |

### Instrument

The questionnaire consisted of three parts. The first part collected data regarding the socio-demographic characteristics of the sample (gender and grade), as well as their school and physics performance and satisfaction with physics classes. Performance and satisfaction were measured on a 5-point grading scale.

The second part measured metacognitive awareness by using the Serbian version of Jr. MAI Version B, which consists of 18 items that are rated on a 5-point Likert scale (Bogdanović et al., 2021; Sperling et al., 2002). It measures two major components of metacognitive awareness: *knowledge about cognition* and *regulation of cognition* (see Table 4 in Appendix). It is suitable for students from grades 6 through 9 since it includes more regulation related items which would be more developed in the older students. Alpha reliability of the original Jr. MAI Version B ranges from  $\alpha=.76$  for younger to  $\alpha=.82$  for older students while it is slightly lower for the Serbian translation  $\alpha=.70$  (Bogdanović et al., 2021).

The third part measured epistemic curiosity by using adapted Litman and Spielberger short 10 item EC scale (2003). Five items measure specific and five diversive exploratory behaviors (see Table 5 in Appendix). Alpha reliability of the whole scale is acceptable  $\alpha=.81$  (Litman & Spielberger, 2003). For the purpose of this study, the scale was back-translated into Serbian language and one item was adapted to correspond with physics classes (*New kind of arithmetic problem/enjoy imagining solutions* was modified into *New kind of physics problem/enjoy imagining solutions*).

Procedure

Non-probability data collection was used. The typical pen and paper study was carried out whereby the physics teacher distributed the questionnaire to students during class. The sample consisted of minors (13 and 14 years of age) and researchers acquired parental consent and the consent of the school board. Students were informed that the study was anonymous and that their responses would be used exclusively for scientific purposes. All respondents voluntarily participated in the study. Approximately 10 to 15 minutes were needed to respond to the questionnaire.

RESULTS

Before analyzing the data, we accounted for all missing values in the Jr. MAI scales (1.21%) and EC (.81%) using MVA and EM methods. We conducted two exploratory factor analyses to determine the acceptable and meaningful factor structure for both Jr. MAI and EC scales. In the initial analyses for Jr. MAI, two items were discarded (12. *I learn more when I am interested in the topic* and 15. *I occasionally check to make sure I'll get my work done on time*) since they had low communality (below .30). After this, 16 items remained. Alpha reliability of the whole scale (without items 12 and 15) is satisfactory ( $\alpha=.86$ ). As in the case of Jr. MAI, the original EC scale structure (Litman & Spielberger, 2003) was almost completely replicated in this study. Reliability of an entire scale is acceptable ( $\alpha=.86$ ).

Intercorrelations between metacognitive awareness and epistemic curiosity were calculated. Table 2 shows that there are significant positive correlations between these two constructs; however they are low to moderate (Cohen, 1988). This indicates that even though they are related phenomena, they do not overlap significantly.

**Table 2.** Intercorrelations between epistemic curiosity (diversive and specific) and metacognition (knowledge and regulation)

|              | Knowledge | Regulation |
|--------------|-----------|------------|
| Diversive EC | .48**     | .46**      |
| Specific EC  | .32**     | .48**      |

Note: \*\* Correlation is significant at the .01 level (2-tailed).

In order to examine the relationship between epistemic curiosity and metacognition on one side, and physics performance and general school performance on the other, multivariate general linear modeling (GLM, linear regression) was used. We tested

for interaction effects and there were none. Therefore, the final model included four covariates and four dependent variables (see Table 3).

**Table 3.** Multivariate GLM: Effects of epistemic curiosity (diversive and specific) and metacognition (knowledge and regulation) on physics performance and general school performance (df=1)

| Effects             | Type of performance                         | $\beta$ | $R^2$ | $F$   | $p$  |
|---------------------|---------------------------------------------|---------|-------|-------|------|
| <b>Diversive EC</b> | school performance from the last semester   | .02     | .11   | .05   | .82  |
|                     | school performance from the previous grade  | .04     | .15   | .27   | .60  |
|                     | physics performance from the last semester  | -.09    | .22   | 1.64  | .20  |
|                     | physics performance from the previous grade | .01     | .26   | .01   | .93  |
| <b>Specific EC</b>  | school performance from the last semester   | .03     | .11   | .16   | .69  |
|                     | school performance from the previous grade  | -.12    | .15   | 2.54  | .11  |
|                     | physics performance from the last semester  | .03     | .22   | .12   | .73  |
|                     | physics performance from the previous grade | -.04    | .26   | .27   | .61  |
| <b>Knowledge</b>    | school performance from the last semester   | .34     | .11   | 19.61 | <.01 |
|                     | school performance from the previous grade  | .46     | .15   | 36.50 | <.01 |
|                     | physics performance from the last semester  | .57     | .22   | 63.73 | <.01 |
|                     | physics performance from the previous grade | .60     | .26   | 76.26 | <.01 |
| <b>Regulation</b>   | school performance from the last semester   | -.04    | .11   | .30   | .58  |
|                     | school performance from the previous grade  | -.10    | .15   | 1.77  | .18  |
|                     | physics performance from the last semester  | -.11    | .22   | 2.42  | .12  |
|                     | physics performance from the previous grade | -.20    | .26   | 8.08  | .01  |

There was no significant relation between epistemic curiosity, diversive or specific, and physics and general school performance. However, knowledge about cognition is significantly positively related to all four dependent variables, while regulation of cognition is negatively related to only physics performance from the previous grade. This would mean that greater knowledge about cognition is followed by higher performance in school, especially in physics since beta coefficient is the largest in the case of physics performance (see Table 3). Interestingly, lower regulation of cognition is related to higher physics performance from the previous grade but not from the last semester.

## ■ DISCUSSION

The goal of this research was to investigate the effect of curiosity and metacognition on physics performance, and general school performance. We measured a student's curiosity as a self-reported personality trait. Focus was on epistemic curiosity since, compared to perceptual curiosity, it involves higher cognitive functions, such as fascination with new ideas and puzzles, and there are numerous studies that connect epistemic curiosity with school performance (Engel, 2011; Eren & Coskun, 2016). Elementary school students evaluated their general metacognitive awareness not related to any specific situation. As dependent variables, we measured physics performance and GPA from the last semester and previous grade. Besides using general school performance, we specifically explored physics performance since physics is one of the most complex subjects and yet it is strongly associated with real life problem-solving situations. Accordingly, it could be expected that a student's performance in physics has a strong relationship with metacognition and curiosity.

Following the previous research, we postulated three hypotheses. The first hypothesis, that epistemic curiosity is related to higher school performance and physics performance, was not supported by our findings. There is no effect of curiosity on any school performance which is rather surprising. The mean score on both types of epistemic curiosity is around the theoretical average, slightly above for specific i.e. physics oriented curiosity ( $M=3.32$ ) than for the diversive ( $M=3.06$ ). This shows that students possess a certain level of curiosity, but it would seem that it is not one of the crucial factors that predicts good school performance. For instance, our results indicate that metacognition influences school performance (see Table 3). However, there are numerous factors that were not included in this study, such as motivation (Broussard & Garrison, 2004), intelligence (Soares et al., 2015), and delay gratification (Bembenutty & Karabenick, 2004) which are often shown to affect school performance. In a highly stimulating environment, curiosity is also one of the important factors that shape school performance (Ahmad & Siew, 2021). Therefore,

it would seem that, in our research, a student's natural curiosity is not adequately stimulated in the school setting. This is not a new finding (Archer et al., 2017; Erdoğan & Tunaz, 2012; Jirout et al., 2018; Takase et al., 2019). Teaching is often conducted in a rote manner with strictly factual information, where students have very little time to think and question what they are being taught. Many school activities are not stimulating, which could explain the lack or even decrease in student's curiosity (Lalić-Vučetić, 2015). If student's curiosity is not adequately stimulated, students might get bored too quickly which could result in giving up on further research that is crucial for deep understanding of the subject and necessary for good school performance (Eren & Coskun, 2016).

The second hypothesis, that higher metacognitive awareness is related to higher physics performance and general school performance, is partially substantiated. Higher metacognitive knowledge is related to higher physics performance and general school performance but higher metacognitive regulation is only related to lower physics performance (from the previous grade). The effect of metacognitive knowledge is stronger for the last grade average than for the last semester grade average. The material from the beginning is the basis for the material at the end of the year, which is especially true for physics classes. Therefore, the performance at the end of the grade is more demanding for students because they need to know the material for the whole school year. Our finding about metacognitive knowledge is in accordance with previous studies (Bogdanović et al., 2015; Krebs & Roebers, 2012; Singh, 2012). If students have an awareness about being skilled or unskilled for performing particular strategies and also know how to select appropriate strategies (which include their acquired skills), their approach to a given task is likely to result in success. Declarative knowledge (e.g. "I know what the teacher expects me to learn") is well integrated into the everyday school practice because it is expected that students listen and act according to the teacher's instructions. Moreover, teachers often give examples of problem solutions and even explicitly instruct students to solve certain tasks in a certain way and approve and encourage memorization of algorithms for solving tasks. During the assessment (for grading), students are given tasks similar to those they worked on in class with their teacher (and follow practiced instruction step by step). Thus, procedural knowledge (e.g. "I try to use strategies that have worked in the past") is also appreciated in classes. Similarly, conditional knowledge is helpful for achieving higher school performance (e.g., the statement: "I use different learning strategies depending on the situation"). In order to be successful in physics, it is even more important that students use particular strategies for solving physics problems, performing experiments and similar. In accordance with all of the above stated, metacognitive knowledge has the strongest positive impact on physics performance and its application benefits students' engagement in physics classes. As for metacognitive regulation, previous studies show that it is important for school performance in general (Krebs &

Roebers, 2012), and science performance (Singh, 2012), particularly physics performance (Bogdanović et al., 2015). Our research findings surprisingly indicate that metacognitive regulation is not associated with school performance, while higher metacognitive regulation is related to lower physics performance from the previous grade. There was no effect of metacognitive regulation on physics performance from the last semester, which might be due to the difference in the content of physics classes and the level of difficulty that is higher for the end of the year. This unanticipated finding might be due to the school surroundings – we believe that the implementation of metacognitive regulation is not encouraged enough during school hours. Lippman Kung and Linder (2007) state that the quantity of metacognitive abilities is often not relevant if metacognitive abilities are not used. Extensive content planned in the curriculum might not leave time for teachers to nurture student's metacognitive regulation. Very high emphasis on grades and seeking the "right answer" could create a very discouraging atmosphere for the application of metacognitive regulation and consequently, it could discourage students from using this component of metacognition even when learning at home. We believe that in class, students who plan think over their work on solving a task, monitor the process, and look up for possible errors while working, do not manage to solve everything given to them and that leads to lower marks than expected.

Lastly, the third hypothesis that there is a positive correlation between metacognition and curiosity is confirmed. None of the previous studies have explored how metacognitive knowledge and metacognitive regulation are related to specific and diversive epistemic curiosity. Both aspects of metacognitive awareness are positively correlated with two measured types of epistemic curiosity. Specific EC has a slightly lower but significant correlation with metacognitive knowledge while the remaining three correlations are almost equal in strength. Students with high diversive EC always look for something interesting and generally have a tendency to explore while students with high specific EC would manifest curiosity mostly when there is an unsolved puzzle or a problem that is difficult to solve. This would indicate that students with high diversive EC would have both aspects of metacognition justly developed since they would constantly look for stimulation in order to escape boredom but for a student with high specific EC regulation might be more important to help in overcoming missing information. It is important to note that the correlation of EC and metacognition is significant but relatively weak. This implies that there are other factors that might moderate or mediate the relationship of these two concepts, such as personality traits, school climate, socio-demographic variables, etc. These variables should be explored in future studies.

Challenges persist in harnessing the full potential of curiosity and metacognition in physics education. Variations in individual curiosity levels, cultural influences, and instructional constraints may impact the efficacy of curricular interventions designed to promote metacognitive engagement. Accordingly, future inquiries should explore innovative instructional strategies and assessment methodologies that synergistically leverage curiosity and metacognition to optimize physics learning outcomes for diverse student populations. Since curiosity and metacognition are interrelated, if teachers stimulate one construct, the other would likely follow. If possible, teachers should provide a positive environment that would enhance both equally, e.g. more freedom and more time to learn at their own pace could benefit student's curiosity and metacognition.

Possible limitations of this study can arise due to the age of respondents. Both of our scales showed good alpha reliability and we used Jr. MAI that has consistently been used for younger adolescents and has had good metric characteristics in previous studies (Mastrothanais et al., 2018; Ning, 2019). As for the EC scale, we checked if the scale items are clear by using as judges several students that did not participate in the main study. To shorten the response period, several concepts that are of importance to the study area were not included, such as the feeling of boredom that might explain the lack of the effect of curiosity on school and physics performance. The main focus of this research was on physics but we believe that our findings can be of value to all STEM courses, whereby this certainly needs to be further investigated. Ideally, sampling should be random. There is a difficulty in acquiring random samples in the Serbian school system due to the rigid organization of the classes. Yet, we believe that our findings are generally of value to all, since they show the imperfections of the traditional teaching methods which are still present in many countries in the world. It would be interesting to compare the results in other countries since each education system has its own specificities. Moreover, data from this research was a student's self-assessment, which should be further supported by the teacher's observations, which might be more objective and strengthen our findings even more. Finally, school performance measures i.e. grades are general and sometimes crude estimates of student's knowledge that lack depth. Perhaps, acquiring additional measures of a student's levels of practical knowledge and theoretical understanding of the subject might yield new insight.

## ■ CONCLUSION

The goal of this study was to explore the effect of metacognition and epistemic curiosity on general elementary school and physics performance. Findings support the notion that metacognition is important; however, there was no effect of epistemic curiosity. This indicates that curiosity might be neglected in schools. Metacognitive knowledge has the strongest positive effect on performance, especially in the case of physics classes. Metacognitive regulation has a negative relationship with physics performance and no significant relationship with school performance. Traditional ways of teaching are more fitting for metacognitive knowledge while metacognitive regulation, in this context, is even detrimental for physics learning. There is a significant positive correlation between metacognition and curiosity. These results provide a novel insight which could be of benefit to the scientific community and school practice.

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## ■ APPENDIX

**Table 4.** Factor loadings for Jr. MAI scale

|                                                                                         | <b>Knowledge</b><br>( $M=3.86$ , $\alpha=.79$ ) | <b>Regulation</b><br>( $M=3.07$ , $\alpha=.77$ ) |
|-----------------------------------------------------------------------------------------|-------------------------------------------------|--------------------------------------------------|
| 3. I try to use ways of studying that have worked for me before.                        | .79                                             |                                                  |
| 4. I know what the teacher expects me to learn.                                         | .78                                             |                                                  |
| 1. I know when I understand something.                                                  | .67                                             |                                                  |
| 11. I really pay attention to important information.                                    | .63                                             |                                                  |
| 13. I use my learning strengths to make up for my weaknesses.                           | .54                                             |                                                  |
| 2. I can make myself learn when I need to.                                              | .53                                             |                                                  |
| 7. When I am done with my schoolwork, I ask myself if I learned what I wanted to learn. | .51                                             |                                                  |
| 5. I learn best when I already know something about the topic.                          | .49                                             |                                                  |
| 14. I use different learning strategies depending on the task.                          |                                                 | .78                                              |
| 6. I draw pictures or diagrams to help me understand while learning.                    |                                                 | .75                                              |
| 17. I ask myself if there was an easier way to do things after I finish a task          |                                                 | .63                                              |
| 16. I sometimes use learning strategies without thinking.                               |                                                 | .63                                              |
| 18. I decide what I need to get done before I start a task.                             |                                                 | .51                                              |
| 8. I think of several ways to solve a problem and then choose the best one.             |                                                 | .51                                              |
| 9. I think about what I need to learn before I start working.                           |                                                 | .48                                              |
| 10. I ask myself how well I am doing while I am learning something new.                 |                                                 | .41                                              |

Table 5. Factor loadings for EC scale

|                                                                                                        | Diversive EC<br>(M=3.06, α=.84) | Specific EC<br>(M=3.32, α=.75) |
|--------------------------------------------------------------------------------------------------------|---------------------------------|--------------------------------|
| 2. I am very interested in learning something new.                                                     | .93                             |                                |
| 1. I enjoy learning about new things.                                                                  | .84                             |                                |
| 4. When I hear something new, I like to learn more.                                                    | .79                             |                                |
| 3. I enjoy exploring new ideas.                                                                        | .69                             |                                |
| 10. I enjoy imagining a solution to a new problem when solving a physics problem.                      | .47                             | .34                            |
| 7. When I come across an unfinished thing, I like to imagine what it would look like if it were whole. |                                 | .84                            |
| 8. I like to discover how things work.                                                                 |                                 | .79                            |
| 6. When I see a complicated device, I like to ask how it works.                                        |                                 | .73                            |
| 9. When I encounter a puzzle, I like to think about possible solutions.                                |                                 | .60                            |
| 5. I enjoy discussing various concepts with friends.                                                   |                                 | .54                            |