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Metacognitive Awareness Perceptions of Students with High and Low Scores on TIMSS-Like Science Tests

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Abstract: The current study explores the differences in metacognitive awareness perceptions of students who had high and low scores on TIMSS-like science tests. The sample consisted of 937 Omani students, 478 in Grade Five and 459 in Grade Nine. TIMSS-like tests were specially designed for both grade levels, and students also completed a metacognitive awareness perceptions inventory which explored their use of four main skills: planning, information management strategies, debugging strategies and evaluation. MANOVA was used to analyze the data. The findings indicated that students with high scores in the TIMSS-like test out-performed students with low scores in the test on all four metacognitive skills surveyed. This was true for all three performance areas analysed: performance in the TIMSS-like test as a whole, performance in lower-level test questions and performance in higher-level test questions. These findings highlight the extent to which students' metacognitive skills influence their performance in science tests. The study recommends that students be trained to improve their metacognitive skills, reviews several methods for doing this, and suggests that such training might better prepare them for taking science tests. However, it also notes that further research is needed to explore the impact of metacognitive training on student performance in specific science examinations such as TIMSS.

Keywords: debugging, evaluation, information management, metacognition, planning, science, TIMSS.

Introduction

Omani students have participated in the Trends in International Mathematics and Science Study (TIMSS) since 2007, but have consistently scored lower than the cut-off point throughout that time (Mullis et al., 2020). While little is known about the factors affecting Omani students' performance in TIMSS, internationally the TIMSS has gained the interest of a number of researchers (Kang and Cogan, 2020), resulting in a growing body of research exploring the factors associated with TIMSS test-taking (Chiu, 2012; Kang and Cogan, 2022; Ruthven, 2011; Tighezza, 2014; Wang and Liou, 2018). According to several studies, one of the main factors affecting student performance in science is metacognition (Casselman and Atwood, 2017; Hong, Bernacki and Perera, 2020; Oyelekan, Jolayemi and Upahi, 2019; Wang and Chen, 2014; Wang et al., 2014).

Metacognition has attracted a range of researchers since the term first appeared in the literature in the 1970s. The scientist who first developed metacognitive theory defined it as individuals' awareness of their mental and cognitive processes and the way they affect performance (Flavell, 1979); other researchers have described it as involving the ability to reflect on one's own thinking, and to monitor and control its progress in order to achieve the goals one desires (Brown et al., 1983; Efklides, 2011; Larkin, 2006; Tang et al., 2016). Metacognition has also been explained as the process of thinking about one's own thinking, a skill which is believed to promote higher-order thinking (Adey, 1999).

Research into the brain has shown that there is an executive control mechanism in the pre-frontal cortex; this is known as "inhibitory control" and is responsible for metacognition. This mental mechanism

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is believed to play a crucial role in inhibiting any initially ineffective or inappropriate response we might have and in guiding us to accept a more fruitful and powerful one (Larkin, 2010). The value of this ability to inhibit initial responses allows an individual to plan effectively. It does this by enhancing their capacity to assess prior knowledge retrieved from long-term memory, to mediate the construction of meaning in the working memory, and also to accommodate new knowledge into existing knowledge networks (Al-Harthy, 2016; Larkin, 2010; Wang and Chen, 2014).

The impact of metacognition on learning and academic achievement has been solidly established in research literature; it has been positively linked to improved levels of learning, intelligence, problem-solving, and decision-making (Al-Harthy, 2016; Balashov et al., 2020; Larkin, 2006; Lee et al., 2012; Mahdavi, 2014; Sari Faradiba et al., 2019; Was and Al-Harthy, 2015). Several studies argue that students with a high level of metacognition are able to decide what they need to learn, and can also control their thinking processes and act in ways that will help them achieve their intended goals. In addition, when a course of study or a topic area emphasizes different metacognitive practices from those they know, they are able to develop reflexive problem-solving strategies (Al-Harthy, Was and Hassan, 2015; Balashov et al., 2020; Rahman and Hussan, 2017; Efklides, 2011; Jaleel and Premachandran, 2016; Joseph, 2010; Lee et al., 2012; Liu and Liu , 2020; Mahdavi, 2014; Shubber, Udin and Minghat, 2015; Sutiyatno and Sukarno, 2019; Tok, Özgan and Döş, 2010). Metacognitive ability also makes students aware of their learning progress; they are thus able to reflect on what they have accomplished and decide how they need to go about completing their learning tasks, a process which requires the use of mental skills such as planning, monitoring and evaluation (Efklides, 2011; Wiley and Guss, 2007; Hong, Bernacki and Perera, 2020; Jaleel and Premachandran, 2016; Joseph, 2010; Miller and Geraci, 2011; Santelmann, Stevens and Martin, 2018; Sutiyatno and Sukarno, 2019).

A good deal of research has examined the relationship between students' metacognition and their attainment of academic goals, and has shown clearly that greater use of metacognitive skills is associated with an improved awareness of what students are studying. It has also been linked with greater attainment of their learning goals, improved reading comprehension, and enhanced independent learning skills (Al-Harthy, Was and Hassan, 2015; Coutinho, 2007; Jaleel and Premachandran, 2016; Rahman and Hussan, 2017; López-Vargas Ibáñez-Ibáñez and Racines-Prada, 2017; Meniado, 2016; Moir, Boyle and Woolfson, 2020; Shubber, Udin and Minghat, 2015; Sutiyatno and Sukarno, 2019; Zhao, 2014). As far back as 1983, Brown et al. (1983) had demonstrated significantly that several metacognitive strategies, including self-regulation, planning, evaluating, and monitoring, are relevant to reading comprehension. Baker and Brown (1984) argued similarly that anyone engaging in reading comprehension must be able to process their cognitive activities, and that most of this involves metacognition. Another interesting point arising from the research is that metacognitive scaffolding seems to lower the cognitive load during the time that an individual is involved in learning tasks (López-Vargas Ibáñez-Ibáñez and Racines-Prada, 2017); by the same token, experiencing learning anxiety during a problem-solving process might lead to metacognitive blindness (Sari Faradiba et al., 2019).

In science education, studies have indicated a positive association between metacognitive awareness and student achievement (Hong, Bernacki and Perera, 2020; Oyelekan, Jolayemi and Upahi, 2019). Metacognition has also been linked to improvements in problem-solving skills (Akben, 2020; Aurah, Cassady and McConnell, 2014), in reflective thinking skills (Antonio, 2020), in science inquiry learning (Tang et al., 2016), in comprehension of science texts (Wang and Chen, 2014; Wang et al., 2014), and in performance on exams (Casselman and Atwood, 2017). There have been other interesting findings; if metacognitive training is carried out continually throughout a semester, it is more likely to improve students' ability to assess their test scores (Al-Harthy, Was and Hassan, 2015; Casselman and Atwood, 2017), and the use of metacognitive prompts during test-taking improves student test scores (Aurah, Cassady and McConnell, 2014). Research also shows that students with high test scores are better able to accurately predict their scores, an important metacognitive skill, than are lower-performing students (Hawker, Dysleski and Rickey., 2016). While students are actually taking a test, they use a range of metacognitive strategies to answer test questions; these include eliminating incorrect options, underlining the clues found in the question text, and re-examining their answers. The metacognitive strategies used vary according to the nature and features of the test items (e.g. narrative, figures and graphics) (Diken, 2020). However, in spite of the growing body of research supporting the positive impact of metacognition on learning, some studies indicate that students do not regularly practice meta-cognitive skills while actually carrying out learning tasks (McCabe, 2011; Santelmann, Stevens and Martin, 2018; Siagian, Saragih and Sinaga 2019; Saenz, Geraci and Tirso, 2019). This could be partly because there is little focus on these skills within the classrooms where they study, and a lack of coverage of metacognition in the curriculum materials used (Jaleel and Premachandran, 2016; Joseph, 2010). Overall, though, research shows that metacognitive mental skills characterize high-performing achievers and more advanced students (Larkin, 2006). Other research also reports, interestingly, that metacognition develops with practice and also through interaction with others, and that it is these factors which impact individuals' consciousness of their cognitive processing (Balashov et al., 2020; Larkin, 2006).

There are several general learning theories which have a bearing on the role of metacognitive thinking, which is sometimes seen as a kind of private speech that takes place in children's minds. One of these is Vygotsky's sociocultural theory, which stresses the importance of private speech to the development of learning. Another is Piaget's cognitive theory, which emphasizes the importance of meta-thinking in the comprehension of abstract concepts and phenomena; this meta-thinking is a type of metacognition that happens in a later stage of a learner's development (Bates, 2019). A third theoretical perspective that helps to explain the association between learning and metacognitive skills is the cognitive acceleration theory proposed by Shayer and Adey (2002), and heavily reliant on the ideas introduced by Piaget and Vygotsky. A key principle of cognitive acceleration theory is the emphasis on asking learners to explain their thinking process to their peers, telling them how they solve the problems at hand. This lays the ground for the belief that social interaction accelerates learning (Shayer and Adey, 2002), with the group conversation allowing learners to articulate how they think, organize their thoughts, and benefit from others' techniques of tackling different problems, so that they come to visualize their thinking in a sophisticated way (Oliver and Venville, 2015). Other research also shows that the social construction of metacognition is best done while students are actually engaging in the task, rather than when reflecting on their thinking after the task has been completed (Larkin, 2010).

Purpose of study

Understanding the cognitive factors which affect Omani students' performance in the TIMSS has become particularly important to science education research in the country; metacognition is one of these factors, and, if investigated, will provide a better understanding of its role in student test performance in general. It is with this purpose in mind that the current study explores the differences in metacognitive awareness perceptions of students with high and low scores in TIMSS-like science tests. Also, although there have been a growing number of studies investigating student metacognition while they carry out learning tasks, studies investigating the association between student metacognition during test taking and their performance on tests have been very rare, especially in the area of science education. To the knowledge of the authors, there has been no study that explored the association between student metacognition and performance in TIMSS; the current study is an attempt to address this gap in the research literature.

The main research question of the current study is therefore:

What are the differences in the metacognitive awareness perceptions of students with high and low scores on TIMSS-like science tests?

Three sub-questions stem from this main research question:

1. Do metacognitive perceptions differ for students with high and low scores in TIMSS-like science tests for Grades Five and Nine?

2. Do metacognitive perceptions differ for students with high and low scores in lower-level questions of TIMSS-like science test for Grades Five and Nine?

3. Do metacognitive perceptions differ for students with high and low scores in higher-level questions of TIMSS-like science test for Grades Five and Nine?

Materials and Methods

Participants and Context

The participants were 937 Omani students, 478 in Grade Five and 459 in Grade Nine. The participants were from eleven schools located in three important governorates in Oman. The Omani school system is composed of three stages: Cycle I (Grades 1-4), Cycle II (Grades 5-10) and Cycle III (Grades 11 and 12). The study proposal went through an ethics checking review by both the funding body and the Ministry of Education. After their approval was obtained, the schools conducted their own ethics review before approving the participation of their teachers and students; they also obtained parental consent required for the students who would be in the study.

Instruments

Metacognitive awareness perceptions

The current study used the Metacognitive Awareness Inventory (MAI) created by Schraw and Dennison (1994), and a widely used research instrument. The MAI contains four sections, each of which addresses one type of metacognitive skill: planning, information management strategies, debugging strategies and evaluation. The original instrument contained 52 items, but this was reduced to 22 because the original was thought to be too lengthy for young children, and may have negatively affected the data collected.The shorter version had a balanced number of items in each section. The content validity of the selected items was validated by a panel of seven science educators and educational psychologists, who assessed its appropriateness to measure the metacognitive awareness perceptions of young school students. The items were then translated into Arabic, with the translation verified by two psychologists fluent in both Arabic and English. The modified instrument was then piloted on 120 students, and the calculated Cronbach Alpha coefficient was 0.95.

TIMSS-like tests

As our aim was to conduct the test in the study in the same way as the actual TIMSS test is conducted, multiple versions of the test were designed; the actual tests are administered using separate but matching booklets that are randomly assigned to students. We followed the TIMSS Framework (Mullis and Martin, 2017) and designed 18 versions of a TIMSS-like science test for Grade Nine and 20 versions of a Grade Five test. The tests were written by fifteen science educators who were trained by an international expert to design TIMSS-like questions. The tests were then reviewed by six local TIMSS assessment experts and by an international expert; they were then piloted on 1,163 students. The resulting Cronbach alpha reliability coefficients ranged between 0.661 and 0.885 with an average of 0.779 for Grade Nine, and between 0.655 and 0.885 with an average of 0.778 for Grade Five. These values were found to be acceptable when compared to the reliability values for the actual TIMSS science tests (Martin, Mullis and Hooper, 2016). More details about the construction of the test, its items, the validation of the matching versions, and other details can be found in Al-Balushi, Al-Harthy and Almehrizi (2022).

Data collection

The instruments were uploaded into a mobile application designed specially to collect the data needed for this study; the reader can find more details about this application elsewhere (Al-Balushi, Al-Harthy and Almehrizi, 2022). The mobile application, called the Trends in Oman Science Study (TOSS), was designed by the Sas for Entrepreneurship Center under the Omani Ministry of Transport, Communications and Information Technology; it was piloted on 120 students in order to ensure that there were no technical or administrative malfunctions. The study also hired twelve science teachers as research assistants; their role was to administer the study instruments in their classrooms in each of the selected schools. The administration of TIMSS-like test lasted for 40 minutes, while the administration of the metacognitive awareness perceptions instrument lasted for 10 minutes.

Data Analysis

We used means and standard deviations to describe participants' scores in the four sections of the metacognitive awareness perceptions instrument: planning, information management strategies, debugging strategies and evaluation. We also used the Multivariate Analysis of Variance (MANOVA) to answer the research questions and to discover whether there were any differences between high- and low-scoring students in the four sections of the metacognitive awareness perceptions instrument.

Results

Tables 1-4 illustrate the results of the study, and show significant Wilks' Lambda values for all MANOVA analyses conducted on the data. The findings also indicate that there were significant differences in metacognitive awareness perceptions between high- and low-scoring students, showing that, in both Grades Five and Nine, students with higher overall performances on the TIMSS-like test also had higher metacognitive awareness perceptions. When data was analysed separately for performance on lower-level and higher-level test questions, the results were found to be the same.

Table 1.
Means and standard deviations of metacognitive awareness perceptions for Grade Five

Metacognitive skill	TIMSS-like level	Total test score Low(n=235), High(n=241)		Lower-level questions Low(n=253), High(n=223)		Higher-level questions Low(n=243), High(n=233)	
		M	SD	M	SD	M	SD
Planning	Low	3.50	0.96	3.55	0.97	3.53	0.98
	High	3.80	0.93	3.78	0.93	3.79	0.91
Information management	Low	3.42	1.02	3.47	1.02	3.47	1.01
	High	3.77	0.93	3.74	0.93	3.73	0.94
Debugging	Low	3.35	0.97	3.40	0.98	3.39	0.97
	High	3.69	0.88	3.67	0.88	3.66	0.89
Evaluation	Low	3.44	1.00	3.49	1.00	3.50	0.99
	High	3.82	0.89	3.80	0.89	3.78	0.91

Table 2.
MANOVA results of between-subjects effects for metacognitive awareness perceptions and TIMSS-like total performance of Grade Five (df=1, 475)

Metacognitive skill	Effect	Total test score [a]			Lower-level questions [b]			Higher-level questions [c]		
		MS	F	*p-value*	MS	F	*p-value*	MS	F	*p-value*
Planning	performance	10.69	11.95	0.001	6.32	6.99	0.008	7.98	8.87	0.003
	error	0.89			0.90			0.90		
Information management	performance	14.10	14.89	0.000	8.94	9.33	0.002	8.20	8.55	0.004
	error	0.95			0.96			0.96		
Debugging	performance	14.26	16.58	0.000	9.23	10.61	0.001	9.17	10.53	0.001
	error	0.86			0.87			0.87		
Evaluation	performance	16.79	18.80	0.000	11.61	12.85	0.000	9.70	10.68	0.001
	error	0.89			0.90			0.91		

a: Wilks' Lambda= 0.96, F= 5.16, P= 0.000
b: Wilks' Lambda= 0.97, F= 3.44, P= 0.009
c: Wilks' Lambda= 0.97, F= 3.07, P= 0.016

Table 3.
Means and standard deviations of metacognitive awareness perceptions for Grade Nine

Metacognitive skill	TIMSS-like level	Total test score Low(n=217), High(n=239)		Lower-level questions Low(n=223), High(n=233)		Higher-level questions Low(n=217), High(n=239)	
		M	SD	M	SD	M	SD
Planning	Low	3.60	0.98	3.64	0.99	3.63	0.96
	High	3.97	0.69	3.94	0.68	3.94	0.74
Information management	Low	3.58	1.01	3.62	1.03	3.58	0.97
	High	4.04	0.67	4.02	0.64	4.04	0.71
Debugging	Low	3.50	0.98	3.58	1.01	3.52	0.96
	High	3.97	0.69	3.91	0.69	3.95	0.73
Evaluation	Low	3.51	1.00	3.53	1.02	3.54	0.98
	High	3.93	0.68	3.92	0.65	3.90	0.72

Table 4.
MANOVA results of between-subjects effects for metacognitive awareness perceptions and TIMSS-like total performance of Grade Nine (df=1, 454)

Metacognitive skill	Effect	Total test score [a]			Lower-level questions [b]			Higher-level questions [c]		
		MS	F	*p-value*	MS	F	*p-value*	MS	F	*p-value*
Planning	performance	15.27	21.49	0.000	10.69	14.83	0.000	10.70	14.84	0.000
	error	0.71			0.72			0.72		
Information management	performance	23.80	33.17	0.000	18.68	25.63	0.000	23.80	33.17	0.000
	error	0.72			0.73			0.72		
Debugging	performance	25.43	35.70	0.000	12.74	17.20	0.000	21.50	29.81	0.000
	error	0.71			0.74			0.72		
Evaluation	performance	20.46	28.57	0.000	17.01	23.50	0.000	14.56	19.97	0.000
	error	0.72			0.72			0.73		

a: Wilks' Lambda= 0.92, F= 9.73, P= 0.000
b: Wilks' Lambda= 0.94, F= 7.21, P= 0.000
c: Wilks' Lambda= 0.93, F= 9.06, P= 0.000

Discussions

The findings of the current study showed that the metacognitive awareness of the higher-performing participants in Grades Five and Nine was consistently and significantly higher than that of the lower-performing participants. This was the case for the overall test scores, as well as for the scores in lower-level questions and the scores in higher-level questions. These findings emphasize the importance of metacognitive awareness in student test performance on both lower-level and higher-level questions. These findings also confirm the existence of a undeniable association between metacognition and academic performance, which has been emphasized consistently by previous research (Efklides, 2011; Wiley and Guss, 2007; Hong, Bernacki and Perera, 2020; Jaleel and Premachandran, 2016; Joseph, 2010; Mahdavi, 2014; Miller and Geraci, 2011; Santelmann, Stevens and Martin, 2018; Sutiyatno and Sukarno, 2019; Tok, Özgan and Döş, 2010). This and other studies have come to a number of conclusions about the role of metacognitive thinking in test-taking. The findings of the current study indeed indicate that answering TIMSS test items is a cognitively demanding process, and that metacognitive thinking skills are essential for students taking these tests. Looking at the issue from a practical point of view, Zimmerman and Moylan (2009) have argued that such demanding contexts require test-takers to use their initiative and to be self-regulated, resourceful and persistent, all of which require the use of metacognitive skills. It has also been argued by proponents of the social cognitive model of self-regulation that test-takers engage in a three-phase cyclical mental process. These phases are the forethought phase, the performance phase and the self-reflection phase, and all require metacognitive abilities if they are to be successful. For instance, during the performance phase, test-takers must use self-observation strategies such as time management, imagery that enhances the processing of information into the memory system, and self-instruction; failure to mobilise these metacognitive strategies could result in poor test performance (Panadero and Alonso-Tapia, 2014). The current study provides added evidence that strong levels of metacognitive processing are an essential factor for students to perform well in the TIMSS science test; lack of these metacognitive skills is a key factor in reducing their ability to conduct the mental processes required to succeed in the test.

Science education literature offers little information about the link between students' metacognitive awareness and their performance in examinations, and we are aware of no study that has specifically investigated this association in the context of student performance in international science tests such as TIMSS. However, research in other areas might help to explain our findings, and their linking of the performance of high-achieving students to their metacognitive awareness. A number of previous research studies suggest that the possession of a high level of metacognitive awareness allows students to reflect on their thinking and monitor its progress; it also helps them to control their thinking processes and direct them towards achieving the goals for which they strive (Efklides, 2011; Jaleel and Premachandran, 2016; Joseph, 2010; Larkin, 2006; Mahdavi, 2014; Sutiyatno and Sukarno, 2019; Tok, Özgan and Döş, 2010). Thus, since researchers have widely reported a positive association between metacognition and both science achievement (Hong, Bernacki and Perera, 2020; Larkin, 2006; Oyelekan, Jolayemi and Upahi, 2019) and performance on science examinations (Casselman and Atwood, 2017), it is plausible to conclude that the high level of metacognitive awareness of the higher-scoring students in the current study contributed to their strong performance in the TIMSS-like science tests. Students with high metacognition have been shown to approach test questions by eliminating incorrect options, underlining the clues found in the question text, re-examining their answers, and using a range of metacognitive strategies to respond to the specific features of the test items, whether these involve narrative, figures or graphics (Diken, 2020); all of these features frequently characterise TIMSS test items (Mullis and Martin, 2017). Research also shows that metacognition helps learners better comprehend science texts (Wang and Chen, 2014; Wang et al., 2014), which would again help TIMSS test-takers, given that a number of the test items involve reading a short passage before answering related questions. In addition, students with good metacognitive skills are better able to assess the prior knowledge they retrieve from long-term memory during a test, and can mediate the construction of meaning in working memory (Wang and Chen, 2014), skills which gain them better results. Metacognition also increases the ability to conceptualize and think about a variety of abstract scientific concepts and phenomena, a skill which constitutes a major learning challenge for many novice learners, (Al-Balushi and Martin-Hansen, 2019). According to Piaget's theory of cognition, meta-thinking is a core metacognitive process and is also essential to comprehending abstract concepts and phenomena (Bates, 2019); students with high metacognitive awareness are therefore in a better position to process science test questions involving a high level of abstraction.

Conclusions, Recommendations & Limitations

The current study contributes to the literature by exploring the difference in metacognitive awareness perceptions between students with high and low scores on TIMSS-like science tests; this subject, and the important association between metacognition and TIMSS science test-taking, had not been specifically studied before. The current study reports that high-achieving students had a significantly higher level of metacognitive awareness than was present in their low-achieving counterparts. This very clear finding indicates that it is crucial for science educators to explore different ways to support student metacognition. Fortunately, there is already a significant body of research on the subject. A number of studies indicate that metacognition can be enhanced through practice, especially during social interaction with peers (Adey, 1999; Larkin, 2006, 2010; Oliver and Venville, 2015; Shayer and Adey, 2002). There are numerous examples of instructional methods that have been shown to enhance student metacognition, including cognitive acceleration through science education (CASE), thinking aloud, self-report checklists, interaction with peers, whole classroom dialogue, the Know-What-Learned (KWL) model, design-based science learning and reflection reports (Adey, 1999; Durley and Ge, 2019; Efklides, 2011; Wiley and Guss, 2007; Joseph, 2010; Miller and Geraci, 2011; Oliver and Venville, 2015; Tas, Aksoy and Cengiz, 2019; Whitebread, Grau and Somerville, 2018).

Other studies have addressed the question of how to improve student performance during actual test-taking; suggestions include the use of metacognitive prompts such as reflecting on test questions through self-monitoring, evaluation and explanation. Other types of prompts may include encouraging students to connect the current questions to their prior knowledge, to reflect on a problem before attempting to solve it, and to think of the best strategy to solve the problem being faced (Aurah, Cassady and McConnell, 2014). Metacognitive prompts may also be programmed and provided to learners electronically during tests through computer-based scaffolding (Shubber, Udin and Minghat, 2015; Tang et al., 2016). Another suggestion for enhancing metacognitive awareness is to continually request students to predict their test scores and to reflect on the accuracy of their predictions: this can be helpful because an individual's ability to predict their performance is seen as an important test of metacognitive monitoring (Casselman and Atwood, 2017; Hawker, Dysleski and Rickey, 2016).

Pre-test training has also been suggested to help students to perform better in tests. One method is to have students reflect – before the test - on their ability to solve questions related to the main topics on the course. Pre-test training has also been proved to be successful when an online medium is used to host metacognitive reflective prompts; this is done throughout the semester, and students respond to the prompts before taking any type of test, short quizzes as well as mid and final exams (Casselman and Atwood, 2017). Curriculum materials could also be redesigned to scaffold for better metacognition; one method is the use of refutation text structure, which has been shown to involve and develop metacognition (Tippett, 2010; Wang and Chen, 2014).

Overall, then, it is evident that metacognitive training needs to be embedded in science curriculum guidelines, instructional methods and learning materials, and we recommend that science teachers, as well as curriculum and materials designers, be made aware of the importance of including meta-cognitive training to support students' academic achievement. However, further research is needed to explore the impact of metacognitive training on student performance in specific science examinations such as TIMSS.

One limitation of the current study is the fact that it depends on a quantitative method for obtaining its data, namely a self-report metacognitive awareness perceptions inventory. Richer data could be provided by supporting this with qualitative data collection methods; these could include think-aloud protocols, portfolio analysis, and classroom observation, all of which could form part of a follow-up study of metacognition in science learning.

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Conflict of interests

The authors declare no conflict of interest.

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