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Self-regulation profiles across various levels of science performance in TIMSS

Ibrahim S. Al-Harthy[1], Rashid S. Almehrizi[2], Sulaiman M. Al-Balushi[3]

[1]*A'Sharqiyah University, Oman, ORCID ID: 0000-0003-0879-8750*
[2]*Sultan Qaboos University, Oman, ORCID ID: 0000-0001-7672-1451*
[3]*Sultan Qaboos University, Oman, Corresponding author, sbalushi@squ.edu.om ORCID ID: 0000-0002-4080-1203*

ABSTRACT
The research findings suggest that the academic achievements and learning processes of students are significantly influenced by their self-regulation and motivational factors. This study aimed to investigate the effects of four key self-regulation components, namely goal orientation, control of learning beliefs, rehearsal, and test anxiety, on the scientific performance of 5th- and 9th-grade students participating in the Trends in International Mathematics and Science Study (TIMSS). The research sample consisted of 776 students attending public schools in Oman, with self-regulation being assessed using the Motivated Strategies for Learning Questionnaire (MSLQ). To evaluate scientific proficiency, itemsresembling those found in TIMSS were developed and administered via a mobile application. The findings revealed noteworthy distinctions between students who performed well and those who performed poorly. High-achieving students exhibited greater levels of goal orientation, more effective control of learning beliefs, and a higher tendency to engage in rehearsal activities, while test anxiety did not exhibit a significant influence. These results were subjected to thorough analysis and discussion, with the study further offering insights into the potential implications for science education and the broader field of learning.

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Introduction

The performance of Omani students in the Trends in International Mathematics and Science Study (TIMSS) has recently garnered significant national attention. This attention stems from their consistent underperformance in science and mathematics, scoring below the established cutoff point in these subjects since 2007 (Mullis et al., 2020). Nevertheless, the Omani government's concerted efforts in the realm of science education have yielded some improvements in TIMSS scores, with regional comparisons indicating that Omani scores now exceed those of select Middle Eastern nations. Notwithstanding these improvements, Omani students' performance in TIMSS science assessments continues to fall below the established threshold.

It is worth highlighting that the Omani government's emphasis on this issue aligns with global endeavours to investigate various factors influencing students' performance in TIMSS assessments, as

evidenced by research conducted by Kang and Cogan (2020) and Wang and Liou (2018), which explore factors such as metacognition and motivation, as discussed by Michaelides et al. (2019).

Key Factors Influencing Student Science Performance in TIMSS

Student performance in TIMSS science assessments is shaped by a constellation of interrelated factors operating at the individual, parental, instructional, and systemic levels. At the individual level, affective characteristics such as positive attitudes toward science, enjoyment, high self-confidence, and low science-related anxiety are strongly associated with better achievement, as they enhance motivation and engagement (Balfaqeeh et al., 2022; Pongsophon, 2023; Topçu et al., 2016). Confidence in and liking of science also synergistically support performance across STEM domains (Balfaqeeh et al., 2022). Recent findings from Omani studies further point out the importance of cognitive and metacognitive factors in shaping science achievement. One of the main shortcomings in Omani students' performance in TIMSS was their difficulty in applying learned knowledge to unfamiliar contexts, along with challenges in interpreting shapes and graphs and connecting scientific concepts to everyday natural phenomena (Shahat et al., 2022). Al-Balushi et al. (2022a) reported that low-performing students exhibited significantly higher levels of mind wandering (MW) during science assessments than their high-performing peers, especially in grade 5, where attentional gaps remained consistent across the test. These attentional lapses suggest that attentional regulation—a key component of self-regulation—plays a critical role in test performance. In a complementary study, Al-Balushi et al. (2022b) found that Omani students who scored higher in a TIMSS-like science test outperformed others across four core metacognitive skills, including planning, monitoring, and evaluation. These findings highlight the pivotal role of metacognitive development in science achievement and point to the need for explicit instruction in these skills within the Omani context. From the parental perspective, parental education and involvement significantly contribute to academic success by fostering a positive learning environment and attitudes toward education (Mullis et al., 2020; Topçu et al., 2016). Instructional and classroom-level factors—particularly teacher specialisation, qualifications, and the use of inquiry-based pedagogies—have a positive impact on science achievement (Martin et al., 2016). Furthermore, the school disciplinary climate, availability of instructional resources, and an institutional emphasis on academic excellence contribute to favourable outcomes (Pongsophon, 2023). On a systemic level, disparities in socioeconomic status (SES), national education investment, urban-rural school differences, and curricular emphasis on science content shape achievement gaps across countries (Caponera & Losito, 2016; Mullis et al., 2020). A holistic approach that integrates psychological, pedagogical, and policy-level strategies is essential to address these multilayered determinants and to promote equity in science education globally.

Self-Regulation and Student Learning

Al-Harthy and Was (2018) conducted research indicating that students in grades 1-6 in Oman did not exhibit characteristics of agent learners, suggesting a lack of awareness and control over their learning progress. The study identified overconfidence in predicting their learning outcomes as a contributing factor to this phenomenon. It is important to note that metacognitive monitoring components, such as awareness and control, have been discussed in the context of self-regulation procedures in prior research (Al-Harthy & Was, 2013; Zimmerman & Moylan, 2009). Importantly, it has been found that students' awareness of task requirements, difficulty and value, as well as their control over goal and standards settings, attention focus, strategy selection, time monitoring, execution, feedback use and play, play a positive role in students' self-regulation. In addition to these findings, one recent study conducted by Fujita et al. (2024) reviewed the importance of self-regulation constructs

related to motivational approach. These constructs are goal-switching, goal pursuit, and feedback. It is important to note that in literature self-regulation has been conceptualised differently according to purpose and field of research. However, the research has emphasised the two broad components: cognition (e.g., goal settings) and motivation (e.g., effort regulation). In our study, these components are well incorporated into the self-regulation cyclical phases discussed below.

Self-regulation is a complex process in which learners utilise their cognitive and motivational capacities in academic tasks through a self-orientated approach (Billore et al., 2023; Suryawati et al., 2024). The literature of self-regulation has confirmed the positive impact self-regulation has in different contexts, such as academic performance (Ogbonneya & Nworie, 2024), problematic smartphone use (Xiao et al., 2025), learning online (Younis, 2024), critical thinking and problem solving (Zhou et al., 2024). Importantly, although the role of self-regulated learning has received attention in science education literature (e.g., Bene et al., 2021; Karaca et al., 2023; Tanti et al., 2018; Zheng et al., 2020), a research gap exists regarding the influence of students' self-regulation on their performance in the Trends in International Mathematics and Science Study (TIMSS), particularly when considering the cognitive levels of test items as clustering variables.

Relationship Between Student Science Performance and Self-Regulation Skills and potential research gaps in relation to TIMSS results

Self-regulation strategies play a crucial role in shaping students' performance in science assessments by promoting autonomy, goal-directed behaviour, and reflective learning. Numerous studies have confirmed that key self-regulatory processes—such as goal-setting, time management, planning, self-evaluation, and metacognitive monitoring—are significant predictors of academic achievement in science and mathematics (Aydin et al., 2019; Magsino, 2021; Mutawah et al., 2017). These skills enhance academic resilience and performance by linking motivation, particularly self-efficacy and intrinsic interest, with sustained learning efforts (Zheng & Li, 2016). While self-regulation is widely acknowledged as a driver of success, its direct role within the TIMSS framework remains underexplored, as current models tend to emphasise instructional and institutional variables over individual cognitive-behavioural traits (Panadero, 2017; Zimmerman, 2002). Early evidence suggests that students with high metacognitive awareness and strategic learning behaviours perform better in science, yet these factors are not systematically assessed in TIMSS analyses (Artelt et al., 2003). Moreover, cross-national studies indicate that the manifestation and impact of self-regulation vary by cultural and educational context, necessitating more context-sensitive and theoretically grounded approaches (Ker, 2017). To better understand the mediating role of self-regulation in science achievement, future TIMSS research should incorporate validated psychological instruments and multilevel analytic strategies that capture these nuanced learner-centred dimensions. Such efforts would not only enrich the explanatory power of TIMSS data but also guide evidence-based educational interventions aimed at fostering self-regulated learning in diverse student populations.

Despite growing interest in the psychological correlates of academic achievement, research directly examining the relationship between self-regulated learning (SRL) strategies and student performance on large-scale international assessments such as the Trends in International Mathematics and Science Study (TIMSS) remains limited. While SRL components—including goal setting, self-monitoring, and strategic resource management—are well established as predictors of academic success (Zimmerman, 2002), their integration into TIMSS-based analytical models has been minimal. Most TIMSS-related studies emphasise contextual and curricular variables, with limited exploration of cognitive-behavioural processes such as SRL. Moreover, cross-cultural analyses utilising TIMSS data rarely assess how SRL strategies may mediate science achievement across educational systems. This lack of mediation and multilevel modelling reflects a broader methodological gap. Studies such as those by Zimmerman (2002) and Panadero (2017) highlight the effectiveness of SRL in promoting academic success, yet these insights have not been fully operationalised in TIMSS datasets. Thus, incorporating validated SRL measures and using longitudinal or hierarchical models could yield a more

comprehensive understanding of science performance drivers in global educational contexts. Consequently, the present study posits that the subpar performance of Omani students in TIMSS science assessments may be attributed to their insufficient mastery of self-regulation strategies. As a result, they may resort to haphazard approaches that diverge significantly from effective methods of science learning. This study aims to offer insights into the correlation between self-regulation and the science performance of Omani students in TIMSS.

Research Focus

Understanding the mechanisms underlying students' science achievement in international large-scale assessments has become increasingly important for shaping evidence-based educational reform. This study investigates the role of self-regulation in shaping Omani students' performance in the Trends in International Mathematics and Science Study (TIMSS), with a particular emphasis on cognitive and motivational self-regulatory processes such as goal orientation, control of learning beliefs, and rehearsal strategy use. The persistent underperformance of Omani students in TIMSS science assessments has raised concerns about the quality of science learning and instructional support in the region, necessitating targeted inquiry into psychological and pedagogical contributors beyond structural factors.

Extensive literature confirms that self-regulation—a process by which learners plan, monitor, and reflect on their cognition, motivation, and behaviour—plays a vital role in academic performance, especially in complex and inquiry-based domains like science (Zimmerman, 2002; Panadero, 2017). This process includes both cognitive components (e.g., goal setting, metacognitive monitoring) and motivational elements (e.g., effort regulation, self-efficacy), which enable students to take agency over their learning (Billore et al., 2023; Fujita et al., 2024). Importantly, studies have shown that students with high levels of self-regulation perform better in both classroom settings and standardised tests due to their capacity to persist through difficult tasks and apply strategic learning techniques (Aydin et al., 2019; Zheng & Li, 2016).

Despite this robust evidence base, the role of self-regulation has been underexplored within the TIMSS framework, where analyses have traditionally prioritised instructional quality, socioeconomic status, and curricular coverage (Artelt et al., 2003; Mullis et al., 2020). Moreover, while TIMSS assesses science reasoning through cognitively demanding tasks, it does not directly capture the learner characteristics—such as motivational beliefs and metacognitive control—that may mediate student success. The situation in Oman adds another layer of complexity, as systemic issues such as rigid curricula and limited student agency have been identified as barriers to deeper science learning (Al-Harthy, 2016).

The current study addresses this critical research gap by linking self-regulation constructs to performance in TIMSS science items of varying cognitive demand. It offers a novel contribution by examining how specific components of self-regulation (goal orientation, control of beliefs, rehearsal strategy) relate to TIMSS outcomes within the Omani context, where performance profiles are stratified by grade level and item complexity. Furthermore, this research responds to calls for more context-sensitive educational models by accounting for cultural and assessment-specific factors, such as the low-stakes nature of TIMSS and the use of digital assessment formats (e.g., the TOSS platform), which may influence the manifestation of test anxiety and strategy use.

By synthesising insights across the domains of assessment, science learning, self-regulation, and TIMSS, this study advances a learner-centred perspective on international performance gaps and informs pedagogical and policy-level interventions aimed at fostering science achievement through self-regulatory development.

The social cognitive model of self-regulation, composed of distinct cyclical phases (Zimmerman & Moylan, 2009), affords a lucid comprehension of this impact:

1. During the *forethought phase*, students engage in task analysis, set standards and objectives, strategise for task execution, forecast outcomes, and adjust their learning task's values.

2. In the *performance phase*, students initiate the implementation of learning strategies and the utilisation of self-control tactics.
3. In the *self-reflection phase*, students continually evaluate their task performance against the standards and objectives initially set in the forethought phase.

Throughout the self-reflection phase, students encounter both positive and negative self-assessment emotions, which lead to either adaptive or defensive decision-making. In our study, self-regulation is operationalised as students' capacity to adapt their objectives, manage their beliefs, employ learning strategies via rehearsal, and cope with anxiety.

Self-regulation has been postulated to be inherently self-guided (Zimmerman, 2002), implying that the processes of science learning strategies rely on self-initiated implementation of the three self-regulation phases discussed above. Multiple studies substantiate this notion and emphasise the vital functions of students' learning goal orientation, task value, and self-efficacy in the domain of science learning (Kokkinos & Voulgaridou, 2018). Specifically, students' conception of learning in science correlates positively with their learning performance, and this self-perception influences their goal-setting and value adaptation. Consequently, students with low science performance tend to perceive themselves as lacking proficiency in science (Aurah, 2017). Such students are inclined to establish low-level goals (e.g., avoidance goals), place diminished value or interest in learning, and consequently resort to ineffective learning methods.

During the performance phase (phase #2), students frequently grapple with task-specific components such as science concepts and reasoning, often executing inefficient self-observation and self-control strategies as a result. To effectively manage these components, students necessitate ongoing and efficient self-instruction, visualisation, time management, and continual evaluation. Our hypothesis posits that students' ability to observe and regulate themselves hinges on their self-efficacy, objectives, and values established during the self-regulation phase (phase #1). Consequently, students with low-level objectives (e.g., avoidance goals) and limited appreciation for science learning are prone to struggle with self-instruction and exhibit ineffective self-control strategies. This struggle, in turn, manifests in various ways, including ineffective self-responses and defensive decision-making, such as attributing their poor performance to external factors. Additionally, these students may exhibit withdrawal behaviours, such as avoidance of science-related activities and limited class participation.

Cognitive abilities and scientific reasoning constitute critical determinants of students' academic performance. Scientific reasoning, entailing the formulation of hypotheses, experimentation, and evidence verification, represents a fundamental component of scientific inquiry and knowledge construction (Gillies et al., 2014; Saido et al., 2015). Saido et al. (2015) investigated the higher-order thinking skills of seventh-grade students based on Bloom's Taxonomy of the Cognitive Domain. Their findings revealed suboptimal performance in the domains of analysis, synthesis, and evaluation. The study underscores the necessity of higher-order thinking skills for comprehending science education. Hence, we assert strongly that active and constructive processes are imperative for the facilitation of scientific reasoning operations. From this standpoint, we hypothesise that self-regulation, as previously explicated, could constitute a significant contributing factor to students' scientific knowledge and reasoning performance.

Research Aim and Research Questions

Despite extensive evidence highlighting self-regulation strategies—such as goal-setting, time management, and metacognitive monitoring—as key predictors of science achievement (Aydin et al., 2019; Mutawah et al., 2017; Zheng & Li, 2016), their role remains underexamined within the TIMSS framework, with no prior research systematically investigating how these strategies differentiate between low and high-performing students in TIMSS science assessments (Magsino, 2021; Panadero, 2017). In light of this research gap, the present study has articulated two primary objectives. Firstly, it seeks to investigate the contribution of self-regulation to students' performance in TIMSS assessments.

Secondly, the study endeavours to explore this phenomenon in the context of the varying cognitive levels present in TIMSS test items, distinguishing between higher-order cognitive demands, which involve reasoning and inference abilities, and lower-order cognitive requirements, which focus on recalling facts and information. The findings of this study hold the potential to make substantial contributions to the enhancement of science education and the preparation for TIMSS assessments. Furthermore, the outcomes of this research are expected to lay the foundation for subsequent enquiries, including the development of intervention programmes targeted at improving science education and optimising TIMSS preparation. To address these overarching research objectives, the study is guided by the following research questions:

1. To what extent does the self-regulation of 5th- and 9th-grade students differ between low and high-performing groups in TIMSS-like science tests?
2. How does the self-regulation of 5th- and 9th-grade students vary between low and high performers across different cognitive levels of TIMSS-like science test items?

Method

Participants and Context

The study incorporated a total of 776 participants, drawn through a random selection process from 11 schools situated in socioeconomically middle-class regions across three governorates in Oman, specifically Muscat, AlDakhlia, and AlBatina South. The sample consisted of 342 fifth-grade students and 434 ninth-grade students, with the former consisting exclusively of girls and the latter of 60% girls and 40% boys. It is essential to note that Omani schools practise co-education for grades 1-4, wherein both male and female students coexist and are instructed by female teachers. However, from grades 5 through 12, female students attend segregated schools and are instructed by teachers of the same gender. The study proposal underwent meticulous ethical scrutiny by both the Ministry of Education and the funding organisation. Following the requisite approvals, the schools secured parental consent for their students to partake in the study, subjecting the study to their internal ethical reviews before granting permission for the participation of students and teachers.

Design and Procedure

The research design entailed the selection of 11 schools, from each of which two classes were randomly selected to partake in the study. Research assistants, who were science teachers and supervisors, were trained in administering TIMSS-like science assessments and the coordination of data collection procedures. In addition, a technical support team trained teachers to use the utilisation of a mobile application, namely the Trends in Oman Science Study (TOSS), developed by the research team. The technical team remained readily available to address any potential technical challenges encountered during the data collection process.

The TOSS application was installed on iPads, which were provided to each student. Furthermore, the students received login credentials and comprehensive instructions regarding iPad usage and the operation of the TOSS application. The study's objectives were elucidated to the participants by their teachers, following which they completed the TIMSS-like science assessments and answered the test items via the iPad interface. Notably, distinct versions of the TIMSS-like test were created for each grade level (5 and 9), and the assignment of a specific test version to participants was executed through a random allocation process.

Instruments

TIMSS-Like Tests

The development of TIMSS-like assessments was an intricate and meticulous undertaking, comprising multiple phases. Initially, the services of an internationally recognised expert in TIMSS assessments were enlisted to provide training to a cadre of 15 research assistants, all of whom were science teachers and supervisors. This training was specifically focused on the crafting of test items in accordance with the principles governing TIMSS assessments. Following the completion of training, a rigorous selection process resulted in the designation of nine science teachers for the actual development of test items.

In total, 20 equivalent test versions, each encompassing 24 items, were meticulously constructed for the fifth-grade level, while 18 corresponding test versions, comprising 27 items each, were designed for the ninth-grade level. The research assistants were entrusted with the responsibility of assembling the test versions, ensuring their strict alignment with the comprehensive TIMSS framework, as delineated in the work of Mullis and Martin (2017). This framework encompassed various science domains, including life sciences, physical sciences, and Earth sciences for the fourth-grade level, and biology, chemistry, physics, and Earth sciences for the eighth-grade level. The framework also encompassed the cognitive domains of the items, such as knowledge, application, and reasoning, in addition to the diverse item formats, which included textual, pictorial, multiple-choice, and short open-ended formats.

For the fifth-grade level, each test consisted of 24 items, comprising 11 items designed to evaluate knowledge and 13 to assess application and reasoning abilities. Similarly, for the ninth-grade level, each test contained 27 items, with 8 items tailored to gauge knowledge and 19 items dedicated to evaluating application and reasoning proficiencies. To ensure broad content coverage and minimise repetition effects, the 20 fifth-grade and 18 ninth-grade test versions were systematically assigned to students using a planned rotation across classrooms. Each student received only one test version, and care was taken to balance the distribution of test forms across schools and demographic subgroups. All test versions were constructed to be equivalent in terms of structure, content domains, cognitive demands, and item formats, as guided by the TIMSS framework. Throughout the development process, emphasis was placed on maintaining parallel item specifications and balanced difficulty distributions across versions. Expert reviews at multiple stages helped ensure that the test forms were functionally comparable, allowing for meaningful aggregation and interpretation of student performance data across the different versions.

The development of the TIMSS-like tests adhered to a rigorous protocol. The process commenced with the introduction of an international TIMSS expert to train 15 science teachers and supervisors, who served as research assistants, in the formulation of test items congruent with the TIMSS framework. Subsequently, nine individuals were meticulously selected to craft the actual test items. In total, 20 test versions, each comprising 24 items, were meticulously constructed for the fifth-grade level, while 18 corresponding test versions, comprising 27 items each, were designed for the ninth-grade level. These items were methodically aligned with the TIMSS framework in terms of science domains, cognitive domains, and item types. A subset of items necessitated the creation of illustrative materials, which were expertly crafted by five graphic designers. Following the initial item development, a comprehensive review was undertaken by six science assessment experts, who had undergone specialised training in the realm of TIMSS item design. Subsequently, a second review was conducted by a seasoned international TIMSS expert.

The TIMSS-like assessments were subsequently pilot-tested on 1,163 students, across two classrooms per test version. Items exhibiting suboptimal reliability were subject to revision, resulting in the final versions of the tests, which demonstrated commendable Cronbach's alpha reliability coefficients ranging from 0.65 to 0.88 (with an average of 0.77) for both the fifth and ninth-grade levels. In addition to assessing internal consistency through Cronbach's alpha, the development process of the

TIMSS-like assessments incorporated multiple layers of expert-driven content validation and quality control to ensure the robustness of the instruments. Item construction was guided strictly by the TIMSS assessment framework, with explicit alignment to its cognitive and content domains. All test items underwent iterative review and refinement by trained science educators and TIMSS specialists to evaluate their clarity, alignment, and representativeness of the intended constructs. Furthermore, through pilot testing across two classrooms per test version, items with low reliability were identified and revised, a process through which aspects of item discrimination and content coherence were indirectly captured. Taken together, a comprehensive foundation for content validity was provided by these steps, and the overall interpretability and fairness of the final test forms were enhanced.

Self-Regulation

The central theme of the present investigation was self-regulation, and for the purpose of this study, the Motivated Strategies for Learning Questionnaire (MSLQ) (Duncan et al., 2015; Pintrich & de Groot, 1990) served as the foundational instrument. The original MSLQ comprises 55 items categorised into five distinct subscales. However, in the context of this study, a judicious selection of 20 items was made, specifically tailored to the level and context of the students' science learning. These 20 items, in turn, were employed to assess four fundamental sub-scales: goal orientation (6 items), control of learning beliefs (5 items), rehearsal (6 items), and test anxiety (3 items). To enhance content validity, it underwent a comprehensive review by seven esteemed faculty members, and their invaluable feedback was thoughtfully incorporated. Subsequently, the adapted instrument was subjected to a pilot test, involving 630 fifth-grade students and 542 ninth-grade students, culminating in commendable Cronbach's alpha coefficients of 0.93 for the fifth-grade level and 0.91 for the ninth-grade level. Table 1 illustrates the inter-domain and domain-to-total correlations for the self-regulation instrument across grades 5 and 9, providing evidence for its construct validity. The high correlations between each domain and the overall self-regulation score (e.g., grade 5: Goal Orientation = .940, Rehearsal = .931; grade 9: Goal Orientation = .943, Control of Learning Beliefs = .912) suggest that each domain contributes meaningfully to the overarching construct of self-regulation. This supports the relevance and representativeness of each domain, aligning with principles of content validity. Moreover, inter-domain correlations are moderate to high, particularly between cognitively related domains such as Goal Orientation and Rehearsal (grade 5: .842, grade 9: .852) and Control of Learning Beliefs and Rehearsal (grade 5: .722, grade 9: .778). These findings indicate conceptual coherence without redundancy, a desirable trait in multidimensional constructs. Test anxiety, while still positively correlated with self-regulation (grade 5: .599, grade 9: .605), shows relatively weaker associations with other domains, which is theoretically justifiable. It reflects an affective regulation component that is related but distinct from metacognitive strategies, further supporting construct differentiation within the instrument.

Table 1

Inter-domain and domain-to-total correlations for the self-regulation instrument by grade level (grades 5 and 9)

Dimension	Goal Orientation	Control of Learning Beliefs	Rehearsal	Test Anxiety	Self-Regulation
Goal Orientation	—	0.763 (G5)	0.842 (G5)	0.590 (G5)	0.940 (G5)
Control of Learning Beliefs	0.811 (G9)	—	0.722 (G5)	0.526 (G5)	0.875 (G5)
Rehearsal	0.852 (G9)	0.778 (G9)	—	0.532 (G5)	0.931 (G5)
Test Anxiety	0.534 (G9)	0.617 (G9)	0.516 (G9)	—	0.605 (G5)
Self-Regulation	0.943 (G9)	0.912 (G9)	0.936 (G9)	0.599 (G9)	—

Note. Upper triangle values represent grade 5 correlations. Lower triangle values represent grade 9 correlations. All values are Pearson correlation coefficients between dimensions and total self-regulation score.

To categorise the 776 participants into low and high achievers, their performance on the total score and on both lower-level and higher-level items from the TIMSS-like science test was employed. Median scores were strategically utilised to establish cut-off thresholds, effectively demarcating individuals as low- or high-performing (see Table 2). These cut-off scores were instrumental in the classification of participants into low and high-performance categories based on the total score, lower-level items, and higher-level items of the TIMSS-like science test for both grade levels.

Table 2

Number of items and cutoff scores of low and high performance in the lower-level, higher-level items and total score of the TIMSS-like test for the two grade levels

Grade	Lower-level items		Higher-level items		All items	
	Number of items	Cut-off score	Number of items	Cutoff score	Number of items	Cutoff score
Five	11	4	13	4	24	8
Nine	8	3	19	8	27	11

Results

This section presents an overview of the findings related to self-regulation in each grade level, alongside the independent variables, namely TIMSS total score, lower-level items, and higher-level items. The descriptive statistics, including means and standard deviations, are displayed in Table 3 for the four MSLQ subscales concerning the two performance levels and the three TIMSS-like measures for fifth-grade students. Additionally, Table 4 furnishes the results of the one-way Multivariate Analysis of Variance (MANOVA) concerning the equality of these means.

The results elucidated significant disparities in the four self-regulation variables across the two performance levels in relation to the TIMSS total score, lower-level items, and higher-level items. To expound, the findings indicated that for fifth-grade students, Wilks's Λ was 0.95, yielding $F (4, 487) = 6.46$, $p < .001$, and $\eta^2 = 0.05$ in the case of the TIMSS total score. Similarly, Wilks's Λ was 0.98, resulting in $F (4, 487) = 3.05$, $p < .017$, and $\eta^2 = 0.024$ for lower-level items, and Wilks's Λ was 0.96, with $F (4, 487) = 5.00$, $p < .001$, and $\eta^2 = 0.039$ for higher-level items. Furthermore, the between-subjects tests unveiled that fifth-grade students who performed at a higher level across all three measures of TIMSS-like tests exhibited more robust self-regulation concerning goal orientation, control of learning beliefs, and rehearsal, as compared to their lower-performing counterparts. However, both higher and lower performers displayed no significant differences in test anxiety, indicating comparable levels of anxiety in both groups.

Subsequently, we present the results for ninth-grade students. Table 5 furnishes the descriptive statistics for the four MSLQ subscales concerning the two performance levels for the three measures of TIMSS-like assessments (total, lower level, and higher level), while Table 6 presents the outcomes of the one-way MANOVA examining the equality of these means.

The outcomes unveiled noteworthy differences in the four self-regulation variables across the two performance levels, specifically in the context of the TIMSS total score, lower-level items, and higher-level items. Specifically, for ninth-grade students, Wilks's Λ values were 0.91, 0.94, and 0.91 for the TIMSS total score, lower-level items, and higher-level items, respectively. These values corresponded to $F (4, 452)$ values of 10.70, 7.36, and 11.04, with p-values of less than 0.001 for all three measures. Furthermore, the subsequent analysis revealed that ninth-grade students who performed at a higher level across the three TIMSS-like tests displayed enhanced self-regulation with regard to goal orientation, control of learning beliefs, and rehearsal, as compared to their lower-performing peers. Nevertheless, there were no significant differences between both groups concerning test anxiety, signifying equivalent levels of test anxiety among both high and low performers.

Table 3

Descriptive statistics of self-regulation for fifth-grade students

Self-regulation skills	Performance in TIMSS-like	Total test score Low(n=230), High(n=262)		Lower-level items Low(n=249), High(n=243)		Higher-level items Low(n=238), High(n=254)	
		M	SD	M	SD	M	SD
Goal Orientation	Low	3.37	0.98	3.45	0.98	3.40	1.00
	High	3.79	0.88	3.74	0.91	3.77	0.87
Control of Learning Beliefs	Low	3.42	1.00	3.52	0.98	3.43	1.01
	High	3.82	0.93	3.74	0.98	3.81	0.92
Rehearsal	Low	3.44	1.04	3.52	1.01	3.49	1.04
	High	3.87	0.91	3.82	0.95	3.84	0.91
Text Anxiety	Low	3.12	0.68	3.15	0.65	3.15	0.69
	High	3.29	0.62	3.26	0.65	3.26	0.61

Table 4

Multivariate analysis of variance (MANOVA) results exploring between-subjects effects for self-regulation and grade five TIMSS-like performance (df = 1, 490)

Self-regulation skills	Effect	Total test score			Lower-level items[b]			Higher-level items		
		MS	F	*p-value*	MS	F	*p-value*	MS	F	*p-value*
Goal Orientation	Performance	21.11	24.11	0.000	9.46	10.41	0.001	16.90	18.92	0.000
	Error	0.88			0.90			0.89		
Control of Learning Beliefs	Performance	17.52	18.50	0.000	5.14	5.29	0.02	15.95	16.79	0.000
	Error	0.94			0.97			0.95		
Rehearsal	Performance	22.06	23.19	0.000	10.50	10.77	0.001	15.07	15.61	0.000
	Error	0.95			0.97			0.96		
Text Anxiety	Performance	2.85	6.99	0.008	1.02	2.50	0.11	1.13	2.75	0.098
	Error	0.40			0.41			0.41		

Note. [a]: Wilks' Lambda = 0.95, F = 6.46, P = 0.000, [b]: Wilks' Lambda = 0.97, F = 3.05, P = 0.017, [c]: Wilks' Lambda = 0.96, F = 4.99, P = 0.001

Table 5

Summary of descriptive statistics concerning self-regulation in the ninth grade

Self-regulation skills	Performance in TIMSS-like	Total test score Low(n=221), High(n=236)		Lower-level items Low(n=225), High(n=232)		Higher-level items Low(n=223), High(n=234)	
		M	SD	M	SD	M	SD
Goal Orientation	Low	3.55	0.92	3.58	0.95	3.55	1.00
	High	3.94	0.69	3.91	0.66	3.93	0.87
Control of Learning Beliefs	Low	3.61	0.89	3.65	0.89	3.60	1.01
	High	4.04	0.72	4.02	0.72	4.05	0.92
Rehearsal	Low	3.62	0.96	3.66	0.95	3.66	1.04
	High	4.07	0.66	4.05	0.69	4.04	0.91
Text Anxiety	Low	3.19	0.63	3.17	0.59	3.21	0.69
	High	3.21	0.51	3.23	0.55	3.20	0.61

Table 6

Multivariate analysis of variance (MANOVA) results exploring between-subjects effects for self-regulation and grade nine TIMSS-like performance (df = 1, 455)

Self-Regulation	Effect	Total test score			Lower-level items[b]			Higher-level items		
		MS	F	*P*	MS	F	*P*	MS	F	*P*
Goal Orientation	Performance	17.02	25.94	0.000	12.79	19.22	0.000	16.23	24.67	0.000
	Error	0.65			0.66			0.65		
Control of Learning Beliefs	Performance	21.74	33.34	0.000	16.01	24.08	0.000	23.76	36.68	0.000
	Error	0.65			0.66			0.64		
Rehearsal	Performance	22.47	32.85	0.000	17.52	25.22	0.000	16.97	24.39	0.000
	Error	0.68			0.69			0.96		
Text Anxiety	Performance	0.00	0.00	0.94	0.29	0.92	0.33	0.12	0.39	0.53
	Error	0.32			0.32			0.32		

Note. [a]: Wilks' Lambda = 0.91, F = 10.70, P = 0.000, [b]: Wilks' Lambda = 0.93, F = 7.35, P = 0.000, [c]: Wilks' Lambda = 0.91, F F= 11.04, P = 0.000

Discussion

The present study has unveiled several noteworthy findings. Firstly, the self-regulation variables, encompassing goal orientation, control of learning beliefs, and rehearsal, exhibited significant discrepancies across diverse levels of TIMSS-like science test scores, which include total scores as well as itemsof both lower and higher cognitive levels. Secondly, these findings were consistent across both fifth and ninth grades. In particular, students achieving higher TIMSS scores in both grades demonstrated a more robust goal orientation, superior control of learning beliefs, and a more extensive use of learning strategies through rehearsal.

The present study reinforces the critical role of self-regulation in explaining student performance differentials in the TIMSS science assessment. Our findings indicate that students who perform at higher levels tend to demonstrate stronger mastery and performance-approach goal orientations, suggesting they are more likely to engage in goal-directed, self-monitoring behaviours that are conducive to academic success. This aligns with the broader self-regulation literature, which emphasises the interplay of cognitive (e.g., goal-setting, planning, feedback use) and motivational (e.g., self-efficacy, effort regulation) components in academic performance (Fujita et al., 2024; Billore et al., 2023). Students with mastery and performance-approach goals were also more likely to rate themselves as persistent and to maintain task focus—behaviours linked to sustained goal pursuit and strategic effort application (Aydin et al., 2019; Zheng & Li, 2016). In contrast, students adopting performance-avoidance orientations displayed lower persistence and self-belief, which corresponds with prior evidence that such goals are often associated with anxiety and disengagement in academic settings (Ker, 2017).

Moreover, this study extends the literature by applying self-regulation theory within the underexplored context of TIMSS, where individual-level cognitive-behavioural factors are frequently overshadowed by structural variables, such as teacher quality or school resources (Panadero, 2017; Zimmerman, 2002). Our findings suggest that incorporating validated self-regulatory constructs—such as feedback responsiveness, time management, and metacognitive awareness—into future TIMSS analyses could significantly enhance the explanatory power of international assessments. Importantly, the identification of performance profiles based on self-regulatory traits offers a promising avenue for tailored interventions. These findings emphasise the necessity of culturally responsive and theoretically grounded educational practices that foster goal-setting, autonomy, and reflective learning in science classrooms worldwide (Artelt et al., 2003; Mutawah et al., 2017). In doing so, educational systems may

better equip students to thrive not only in assessments but also in lifelong scientific inquiry and problem-solving.

The results of our study align with the cyclical self-regulation model informed by social cognitive theory, which emphasises goal setting, self-monitoring, and adaptive regulation across task phases (Zimmerman, 2002; Panadero, 2017). Specifically, we found that students with higher TIMSS science performance were more inclined to elevate their academic goals and perceive greater control over their learning processes. This pattern held true across both low- and high-cognitive-demand items, suggesting that high achievers consistently apply metacognitive strategies and regulate effort in response to task complexity. These findings echo the broader literature, which emphasises that self-regulated learners actively monitor their performance and modify their goals based on task evaluations (Billore et al., 2023; Fujita et al., 2024).

Furthermore, our analysis points out the importance of controlling learning beliefs in differentiating TIMSS performance. High-performing students reported greater belief in their capacity to influence learning outcomes—a construct strongly tied to academic confidence and emotional regulation. This aligns with research showing that a strong sense of control is positively associated with adaptive academic emotions like enjoyment and pride and inversely related to anxiety and shame (Ker, 2017; Zheng & Li, 2016). Emotional engagement, fuelled by these beliefs, likely enhances test performance by reducing cognitive overload and promoting sustained effort (Garn et al., 2017). In light of these findings, it is plausible that high-achieving students possess not only cognitive advantages but also motivational dispositions—such as optimism and strategic perseverance—that enable them to maintain effortful engagement during assessments.

Finally, our results reinforce the established connection between self-regulation, goal orientation, and academic learning strategies. Specifically, high-achieving students in our sample exhibited greater use of rehearsal, a surface-level strategy often employed to maintain attention and prepare content for deeper processing (Akyol et al., 2010). While rehearsal alone may not yield profound understanding, its integration within a broader self-regulatory framework—particularly when paired with goal-setting and feedback use—can serve as a scaffold for higher-order learning strategies (Mutawah et al., 2017; Aydin et al., 2019). Given the complexity of science reasoning required in TIMSS items, these findings suggest that even foundational strategies like rehearsal can play a critical supporting role when embedded within effective self-regulation cycles.

Our findings suggest that the effective use of learning strategies—particularly rehearsal—is intricately linked to students' self-regulatory capacities, especially their ability to set adaptive goals and manage emotional responses to academic tasks. Rehearsal, typically classified as a surface-level strategy, plays a preparatory role by facilitating attention and retention, which are foundational for the deployment of deeper cognitive processes such as elaboration, summarisation, and inferencing (Akyol et al., 2010; Billore et al., 2023). This aligns with the view that goal setting and emotional regulation, as key components of self-regulation, provide the motivational structure needed to guide strategy use effectively (Fujita et al., 2024; Zimmerman, 2002).

High-performing TIMSS students in our study reported a greater reliance on learning behaviours associated with both rehearsal and elaboration. For example, responses to metacognitive self-rating items (e.g., “I ask myself questions to ensure I grasp the material I have been studying”) suggest that these students actively engaged in strategies that support self-monitoring and comprehension. These behaviours reflect the integration of cognitive and motivational aspects of self-regulation, which have been shown to enhance learning persistence and performance, particularly in science (Aydin et al., 2019; Zheng & Li, 2016). Although our study did not specifically isolate different strategy types, the reported use of elaborative prompts implies a layered strategy repertoire—where surface strategies like rehearsal function as stepping stones toward more sophisticated learning approaches.

Additionally, the difference in rehearsal strategy use between high-performing ninth-grade and fifth-grade students may reflect developmental trends in metacognitive awareness and prior knowledge accumulation. As observed in prior research, students with more extensive content knowledge are

better equipped to deploy rehearsal selectively and in coordination with higher-order strategies (Akyol et al., 2010). This developmental perspective supports the idea that strategy sophistication evolves through iterative self-regulatory practice, reinforced by academic experience and feedback loops (Panadero, 2017; Billore et al., 2023). Hence, our findings emphasise the importance of promoting not only self-regulatory goals and motivational beliefs but also flexible strategy use tailored to students' cognitive development and subject-matter familiarity.

Previous research had not ventured into exploring the relationship between students' self-regulation and science achievement in TIMSS, with cognitive items being categorised as either knowledge (low-level) or reasoning and application (high-level) clustering variables. Our study, however, harnessed MANOVA to scrutinise this connection, unearthing significant disparities between students with loftier goals, control of beliefs, and the utilisation of learning strategies through rehearsal, who performed more commendably in both low and high cognitive items of TIMSS. Curiously, the finding that test anxiety did not significantly differ between low-and high-performing students in this study merits closer examination. One likely explanation lies in the low-stakes nature of the TIMSS assessment, both in the context of this study and in its official international administration. TIMSS results do not influence students' grades, academic progression, or school placement, which likely minimizes the perceived consequences of the test. As a result, students may approach TIMSS with less pressure and fewer anxiety-driven performance constraints compared to high-stakes national exams. This diminished pressure may allow other psychological variables—such as goal orientation, control of learning beliefs, and rehearsal strategies—to exert a stronger influence on performance (Aydin et al., 2019; Zheng & Li, 2016). Additionally, the use of the TOSS digital platform may have further reduced anxiety by offering a more familiar and less formal test-taking experience, consistent with research suggesting that technology-based assessments can foster autonomy and emotional comfort (Billore et al., 2023).

These findings align with prior Omani research highlighting the significance of cognitive and metacognitive regulation in science assessment contexts. As shown by Al-Balushi et al. (2022a, 2022b), lower-performing students demonstrate higher levels of mind wandering and weaker metacognitive skills—factors that directly impact TIMSS science test performance. These patterns mirror our findings, which emphasize the role of goal-setting, control of learning beliefs, and rehearsal strategies in differentiating TIMSS performance levels. Collectively, the evidence points to a systemic need within Omani science education to move beyond content delivery and toward explicit instruction in self-regulation and metacognitive control as means to reduce achievement gaps.

Conclusion and Implications

This study offers valuable insights into the performance of 5th- and 9th-grade students in Oman participating in the TIMSS assessment. This research represents the first of its kind within Oman to probe the interrelationships among students' goal orientations, beliefs control, rehearsal-based learning strategies, anxiety levels, and their TIMSS performance. The study harnessed a sample of 776 students who undertook the Trends in Oman Science Study (TOSS). Our initial research question, aimed at discerning the extent of variations in self-regulation between low and high TIMSS achievers in 5th and 9th grades, was addressed through a rigorous MANOVA analysis. The findings underscored marked distinctions between high and low TIMSS performers. Precisely, high-performing students in both grade levels exhibited discernible disparities from their low-performing counterparts in terms of their capacity to establish loftier goals, exercise control over their learning beliefs, and employ learning strategies characterised by rehearsal.

Prior investigations have neglected to investigate the manner in which self-regulation within the realm of science education aligns with TIMSS performance while concurrently considering cognitive items as clustering variables. These cognitive items are categorised into knowledge (representing lower-level cognition) and reasoning and application (indicating higher-level cognitive skills). Our extensive

MANOVA scrutiny divulged substantial variations between students characterised by elevated goals, robust control over beliefs, and a penchant for learning strategies involving rehearsal. These differences manifested in both lower and higher cognitive items encompassed in the TIMSS assessment. Curiously, the study unearthed no significant indications of heightened anxiety levels among students spanning both grade levels. This finding intimate that the TIMSS assessment may exert a comparatively reduced degree of stress upon students when juxtaposed with conventional science courses or other disciplines. This propensity could be attributed to the fact that successful performance in the TIMSS test does not constitute a prerequisite for students to advance to the succeeding grade.

The implications arising from this study are multifaceted, with direct relevance to instructional design, teacher professional development, and educational policy. First, the findings underscore the importance of cultivating students' self-regulation skills—particularly goal adaptation, control of learning beliefs, and strategic rehearsal—as these elements are significantly associated with higher TIMSS science performance. This highlights the need for a pedagogical shift from teacher-centred to learner-centred approaches, where students are explicitly taught to set goals, monitor their understanding, and reflect on their progress. To facilitate this transformation, science teachers should be equipped with structured classroom strategies that foster metacognitive engagement. For example, embedding regular self-assessment prompts, goal-setting activities at the start of science units, and reflection journals can help students internalise self-regulation as part of their learning routine. Additionally, technology-enhanced instruction allows learners to adjust the pace of their learning based on their individual needs, thereby promoting self-regulated learning (Chohan et al., 2024; Reinoso-Tapia et al., 2024).

Professional development programs should also prioritize building teachers' capacity to scaffold these self-regulatory behaviours. Training modules could include modelling think-alouds for strategy use, integrating formative feedback loops, and designing tasks that promote autonomy and cognitive challenge. Such efforts would support a system-wide progression in self-regulatory capacity from early grades through secondary school, aligning with the study's call for continuity in fostering learner agency from Grade 1 to Grade 12.

This study's findings related to motivational constructs offer a foundational basis for boosting TIMSS performance at scale. Future research should expand these insights into cross-national investigations, aiming to develop motivational profiles that account for both systemic variables and localised policy environments. In the interim, curriculum designers and school leaders in Oman and comparable contexts can begin by auditing current science instruction for its alignment with motivational principles—such as relevance, autonomy support, and emotional engagement—and iteratively adapt teaching practices to reflect evidence-based motivational and self-regulation frameworks.

Beyond instructional shifts and teacher training in self-regulation, this study also highlights the importance of assessment design in fostering student engagement and reducing performance-related stress. Given that TIMSS is a low-stakes assessment with no direct consequences on students' grades or academic progression, its format provides a valuable model for promoting performance in emotionally supportive conditions. Teachers can leverage this insight by embedding similar low-stakes, TIMSS-style assessment tasks into routine classroom practice, encouraging students to engage with cognitively demanding science items without the pressure associated with high-stakes testing. This environment creates space for students to rehearse goal-setting, self-monitoring, and reflection strategies—skills that contribute to sustained academic growth. Teacher professional development should therefore include explicit training on implementing formative assessments that activate self-regulatory behaviours, such as structured rehearsal exercises, self-questioning routines, and timely feedback cycles. These practical interventions can help students internalise effective learning strategies and transfer them across contexts, ultimately supporting both immediate academic performance and long-term learner autonomy.

Future research endeavours should focus on scrutinising teaching practices within Omani schools to elevate students' levels of agency in the context of science curriculum learning. In addition,

the motivational facets of students' TIMSS performance assume paramount importance in heightening their performance. Thus, it is advisable to embark on a cross-country analysis aimed at constructing a more comprehensive motivational profile, which takes into account variations in the educational system and environmental policies.

One notable limitation of this study concerns the sample composition, particularly the gender imbalance in the Grade 5 cohort. While the overall sample size (n = 776) is robust, the Grade 5 participants were exclusively female due to the single-sex schooling structure at that level in Oman. This gender homogeneity presents a potential confounding variable when interpreting differences between the Grade 5 and Grade 9 cohorts and limits the generalisability of findings to all Omani students. Future studies should aim to include more balanced gender representation or conduct stratified analyses to better capture the variability attributable to gender, thereby enhancing the ecological validity of the findings.

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