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Research Article

The impact of disruptive classroom environments on science students' achievement: A TIMSS 2023 study

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This study examines how disruptive classroom environments are associated with Grade 8 students' science achievement across TIMSS 2023 participating countries, with a particular focus on classroom management and learning environment conditions in science education. Disruptions analyzed include student inattentiveness, excessive noise, delayed settling time, student interruptions, rule violations, and peer distractions. The study utilized four major analyses: Cluster analysis, One-way and Two-way ANOVA, and Multiple linear regression analysis. The results from cluster analysis showed countries belonging in high levels of disruption report frequent rule violations, peer distractions, longer settling time, frequent student interruptions, and excessive classroom noise, while countries belonging in low levels of disruption report more orderly classrooms. One-way and two-way ANOVA results showed that while disruption type alone did not significantly affect achievement, overall disruption level had a strong effect, with students in low-disruption settings performing better, particularly in Earth Science. Multiple linear regression identified peer distractions as the strongest negative predictor of achievement across all domains. Other disruption variables showed mixed effects, with some positively associated but not statistically significant. The findings suggest that the overall level of classroom disruption is more strongly associated with science achievement than any single disruption type. The study highlights the need for effective classroom management strategies and policy measures to reduce disruptive environments and improve student engagement and science performance internationally.

Keywords: Classroom management; Classroom learning environment; Cluster analysis; Disruptive classroom environments; Science achievement; Science education; TIMSS 2023

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1. Introduction

Disruptive classroom environments, characterized by noise, interruptions, and distractions, weaken students' focus, engagement, and overall learning (Gheller et al., 2024; Kraft & Monti-Nussbaum, 2021). While prior studies show that these disruptions, including digital multi-tasking and off-task behaviors weaken verbal working memory, increase listening effort, reduce attention and instructional time, and lower academic outcomes (Astolfi et al., 2019; Godwin et al., 2016; Schmidt, 2020; Seitz et al., 2024; Spicciarelli et al., 2025), little is known about their specific effects on science learning across countries. Moreover, they also treat science as a single domain rather than distinguishing among different domains of science (Kaya et al.,

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2024). This quantitative study aimed to explore how disruptive classroom environments influence the science achievement of Grade 8 students in TIMSS 2023, specifically focusing on five domains: Biology, Chemistry, Physics, Earth Science, and Integrated Science, to address existing gaps in understanding these relationships.

A study in Turkey using data from Trends in International Mathematics and Science Study found that student achievement depends not only on curriculum design or individual ability but also on school- and classroom-level factors, with classroom environment explaining about thirty-five percent of the variation in science and mathematics scores (Coşkun & Karadağ, 2023). International assessments such as TIMSS and Program for International Student Assessment [PISA] show that classroom climate strongly predicts achievement in Biology, Chemistry, Physics, Earth Science, and Integrated Science (Mullis et al., 2020; OECD, 2023). Students in classrooms with frequent noise, peer conflicts, or digital distractions tend to score lower in science because these disruptions reduce teaching time and make sustained focus difficult (Godwin et al., 2016; Schmidt, 2020). They also interfere with step-by-step learning and inquiry-based activities and compromise working memory and comprehension, especially for younger students or those with learning difficulties (Burns et al., 2021; Klatte et al., 2013). The SEA-PLM 2019 also found that poor classroom environments caused by behavioral issues, lack of resources, and inadequate teacher preparation reduce achievement in literacy, mathematics, and science across Southeast Asia (Lay & Ng, 2021). These findings show that disruptive classrooms are a widespread barrier to science learning worldwide.

Yet, not all disruptions are purely harmful. Evidence suggests the effects may be more complex. Collaborative peer dialogue can strengthen critical thinking and problem-solving (Gillies, 2023), while moderate background noise can, in some cases, stimulate cognitive effort and engagement (Seitz et al., 2024). This distinction between “productive noise” and “disruptive noise” highlights the importance of considering the type, frequency, and structure of classroom disruptions when examining their impact (Kaya & Erduran, 2024).

In the Philippines, a recent mixed-methods study conducted at a public high school in Imus City, Cavite, reported that excessive noise, peer interruptions, and classroom management issues reduced student engagement and weakened science achievement (Reyes, 2024). The Department of Education [DepEd] has acknowledged nationwide shortages of classrooms and frequent disruptions that compromise instructional quality (Gruta et al., 2025). PISA 2022 data further reveal that Filipino students face high levels of bullying and safety concerns, with eight percent feeling unsafe at school and over forty percent experiencing frequent bullying (Abrigo et al., 2024). These conditions create unstable learning environments that hinder academic achievement, including science learning.

Cebu schools reflect these national realities in a more acute form. The province faces a shortage of more than three thousand classrooms, forcing some classes to accommodate fifty or more students, above DepEd’s recommended forty-five per class (Villa & Palaubsanon, 2025). Beyond overcrowding, noise pollution has also been identified as a major barrier. One study found that elementary students in Argao, Cebu, were regularly exposed to the level of noise above thirty-five decibels [dB] which is recommended by the World Health Organization [WHO], impairing their ability to focus and process information (Camarillo et al., 2021). Other local research emphasizes the importance of uninterrupted instruction, showing that frequent disruptions reduce comprehension of scientific concepts, weaken laboratory learning, and hinder overall science achievement (Bibon, 2022).

Altogether, evidence from international assessments, Philippine studies, and Cebu-based research shows that disruptions reduce science learning by taking away time, attention, and focus needed for mastering complex ideas (Burns et al., 2021). At the same time, some studies point to possible benefits of well-structured peer interaction and moderate noise, suggesting that the impact of classroom disruptions is not always straightforward (Gillies, 2023).

This study is significant because it examines how various classroom disruptions influence science achievement across different domains and countries, providing insights that can help teachers improve classroom management and guide policymakers in promoting effective and equitable science education. Using data from TIMSS 2023, this study specifically seeks to answer the following questions:

RQ 1) What are the characteristics of disruptive classroom environments in science domains: Biology, Chemistry, Physics, Earth Science, and Integrated Science?

RQ 2) How do these disruptions affect student engagement and achievement in science?

RQ 3) Are there differences in the impact of disruptive variables across the five science domains?

RQ 4) Which types of classroom disruptions have the largest effect on science achievement across countries?

2. Literature Review

2.1. Disruptive Classroom Environments

Classroom disruptions, including frequent interruptions, lack of structure, and digital distractions, can negatively affect learning. Kraft and Monti-Nussbaum (2021) emphasized that even minor interruptions can accumulate, resulting in the loss of valuable instructional time and lower student performance. Similarly, Tancredi (2023) reported that off-task behaviors, such as talking during lessons, can interfere with the learning process, particularly in middle school settings. Gheller et al. (2024) further highlighted that both classroom noise and external noise, such as traffic, can impair students' ability to retain and comprehend information. However, not all disruptions are harmful. Yang (2023) found that when teachers implement effective classroom management, certain student behaviors can actually enhance engagement and learning outcomes. The evidence suggests that while classroom disruptions generally hinder learning, careful and structured management can mitigate their negative effects.

Systematic reviews and implementation studies show that some programs effectively reduce disruptions, while comparative studies of wider behavior frameworks sometimes find no differences in immediate test-scores. Marshall et al. (2024) conducted a systematic review of 65 studies across 27 interventions and found out that six interventions rated high/moderate evidence, with the Good Behavior Game frequently effective at reducing disruptive behaviors. However, through a causal-comparative archival analysis, Letterlough (2018) found no statistically significant difference in standardized test scores between PBIS and non-PBIS groups, despite PBIS aims to reduce disciplinary removals. This suggests that while interventions can reliably reduce misbehavior, they do not always produce measurable score gains in short-term comparisons.

For this study, the aforementioned literatures suggest concrete pathways to examine: measurement of lost instructional minutes during lessons, observation of disruptions during hands-on activities, and assessment of whether behavior-reduction interventions change both classroom behavior and outcomes (Marshall et al., 2024).

2.2. Student Science Achievement

Classroom disruptions have also been associated with lower achievement in science. According to Lewis (2020), a teacher reported that disruptions hinder classes to obtain instructional opportunities and that the value of instruction is dependent on classroom environment, showing that disruptions can really be harmful especially to subjects that require step-by-step demonstrations, guided inquiry, or lab work. Similarly, Tancredi (2023) noted that disruptive behaviors negatively affect subjects that require sustained attention like science.

Literature presents various conclusions about which factors most strongly influence science achievement. According to Li et al. (2021), elements of classroom learning environment such as direct instruction, adaptation of instruction, and disciplinary climate were positively related to PISA science scores, while inquiry-based practices and perceived feedback, on the other hand, showed negative relationships. This contradicts the conventional view about inquiry-based learning. Teig et al. (2018) explained this by pointing out a curvilinear relationship where moderate use tends to support achievement but excessive or poorly guided inquiry can reduce learning gains. In addition, other multilevel secondary analyses like TIMSS data actually found out that students' self-concept in science and their sense of connectedness in the classroom are strong predictors of science achievement. On the other hand, perceived teaching quality did not show a significant result, suggesting that students' beliefs and peer relationships can sometimes have greater effect than teaching practices (Zhang et al., 2021). Other studies have also identified specific disruptions associated with lower outcomes. Irambona and Syomwene (2023) noted that classrooms that are noisy and overcrowded are often linked to lower academic achievement. These studies therefore show that disruptions in classrooms impact science learning in multiple ways. These components of disruptions can lower students' science self-concept and engagement while also reducing the orderly environment and clarity of instruction, which are important predictors of science achievement (Li et al., 2021).

However, there are strategies that can be used to reduce these effects. In the study of Yang (2023), it has been discovered that allowing students to perform group activities and collaborative learning can improve engagement as well as achievement in science, even in classrooms where disruptions are noticeable. It can also be moderated by factors related to the teachers such as their efficacy and motivation, indicating that disruptive environments can be addressed through combinations of improved discipline, instructional clarity, adequate resources and strong teacher support (Bal-Tastan et al., 2018). These findings suggest that even though disruptions often lead to lower science achievement, students' focus and learning outcomes can still be maintained through structured and interactive teaching strategies (Zai et al., 2020).

2.3. Student Inattentiveness

Student inattentiveness remains a problem in classrooms as it affects students' focus, understanding, and ability to retain lessons (Bradbury, 2023). It is defined by lack of focus or engagement during class, which can stem from various uncontrollable and controllable factors like environmental distractions, personal issues, or teaching methods that fail to capture the students' interest (Sharmin, 2023). Most studies show that this issue is evident globally. The National Center for Education Statistics (2024) reported that about one-fourth of public schools during the 2023–2024 school year faced educational challenges due to students' lack of focus. International studies have also found that poor attention is linked to lower achievement in science and other subjects (Mullis et al., 2020; OECD, 2023). These findings emphasize the importance of attentiveness and highlight the need for teachers to develop strategies that prevent students from being distracted by non-educational tasks (Godwin et al., 2016; Schmidt, 2020).

Even though inattentiveness is a very serious issue, one way that the teachers can do is to create activities that are engaging and interactive. Research shows that hands-on activities, group works and inquiry based learning may help students stay focused and participate more actively (Saad, 2020). Yang (2023) found that when students actively participate in the discussion instead of just listening, they tend to understand it more easily. Similarly, Korpershoek et al. (2016) and Gillies (2023) noted that when students cooperate with one another and learn in groups, they are less likely to get distracted and are more likely to participate. Other studies also suggest that using real-world problems and situations that spark curiosity makes students more attentive and mentally active throughout the discussion (Burns et al., 2021; Gheller et al., 2024; Seitz et al., 2024). Altogether, these findings show that inattentiveness can be reduced when teachers use creative strategies that encourage active participation in discussions (Gillies, 2023; Yang, 2023).

2.4. Excessive Classroom Noise

Classroom noise is another variable that affects science achievement. Noises such as constant talking, unnecessary movements, or even external disturbances like children playing near classrooms or traffic noise can negatively affect students' ability to listen carefully and remember lessons (Mealings & Buchholz, 2024). Studies show that noisy environments make the brain work harder, which weakens memory and makes comprehension more difficult (Godwin et al., 2016; Klatte et al., 2013; Schmidt, 2020). Gheller et al. (2024) also emphasized that both the inside and the outside noise can disrupt thinking. This is particularly evident during cognitively demanding science lessons that require sustained concentration. Large international assessments like TIMSS and PISA reported that students in classrooms that are more noisy often score lower in science, showing that this problem does affect learners around the world (Burns et al., 2021; Mullis et al., 2020; OECD, 2023). For other subject like reading comprehension and math, Montiel et al. (2019) found out that the participants have higher test scores in quieter classrooms.

However, not all noise is detrimental for learning (Gheller et al., 2024). Leinster et al., (2025) distinguish between unproductive noise and productive noise, where the former distracts students and the latter supports group learning and discussion. Gillies (2023) found that moderate noise during group tasks can encourage teamwork, problem-solving and creativity. Likewise Seitz et al. (2024) showed that guided group discussions help students share ideas and think more deeply about science concepts. These findings show that classrooms do not need to be completely silent. Instead, teachers should manage noise in ways that promote and enhance learning. This shows that effective classroom management and careful lesson planning can transform distractions into opportunities where students can participate and engage actively (Gheller et al., 2024; Seitz et al., 2024).

2.5. Delayed Settling Time

Delayed settling time is another important classroom issue that affects the students' ability to concentrate and begin learning efficiently (Masci, 2008). It is the period at the start of a lesson when students take their time settling down like to organize materials and adjust their focus to the task they have (Saloviita, 2013). Long settling times can lead to a loss of class minutes and make it harder for teachers to establish a smooth learning flow (Ingram & Elliott, 2016). Research suggests that these transitions, though often overlooked have a strong influence on classroom productivity and student achievement (Emmer & Sabornie, 2015; Simonsen et al., 2020). When the students take too long to get ready or continue talking after the lesson begins, teachers spend more time managing behavior and spends lesser time teaching new concepts instead.

Over time, this can reduce the total amount of meaningful learning especially in science classes that require demonstrations like lab work or inquiry-based activities (Balli, 2023; Korpershoek et al., 2016).

However, the delayed settling time can be reduced through clear routines and effective classroom management strategies. Studies show that teachers who use consistent cues like structured transitions and positive reinforcement experience smoother lesson starts and greater student focus (Gage et al., 2018; Pas et al., 2019). Predictable routines help students know what is expected which allows them to shift from social interaction to academic engagement more quickly (Selman & Dilworth-Bart, 2024). In science learning where time is needed for experiments and analysis, minimizing settling time ensures that instructional periods are used efficiently and that students remain mentally prepared for hands-on tasks. Improving classroom transitions not only maximizes teaching time but also supports a calmer and more productive learning environment (Emmer & Sabornie, 2015; Gage et al., 2018; Simonsen et al., 2020).

2.6. Student Interruptions

Student interruptions can be understood as forms of disruptive classroom behaviour that interfere with the normal flow of teaching and learning. Figueroa Valencia et al. (2020) describe disruptive behaviour as student conduct that disturbs classroom interaction and affects the regular development of in-class activities, including behaviours associated with disengagement, lack of attention, and disrespectful interaction. Such behaviours create challenges for teachers because they reduce instructional time, weaken classroom order, and make it more difficult to maintain a supportive and productive learning environment (Asare et al., 2024; Figueroa Valencia et al., 2020). Halitoglu and Uzunboylu (2025) further added that these interruptions affect student achievement, including diminished concentration, reduced engagement, and weakened interpersonal interactions, particularly after the COVID-19 pandemic. Strom et al. (2023) indicated that it can take up to fifteen minutes to regain focus after an interruption, leading to diminished cognitive performance.

Still, not all interruptions are harmful. Some interruptions, like student questions or peer clarifications, can serve as formative checks that deepen understanding (Gillies, 2023). This highlights that engagement in classroom dialogue, which may include interruptions is positively associated with their conception of collaboration (Tong & Ding, 2024). Another is the concept of micro-breaks, suggesting that brief interruptions can enhance concentration and engagement. Students who experienced micro-breaks scored higher in the quiz than those in traditional break conditions (Sharpe et al., 2025).

These show that interruptions can either disrupt learning or support it, depending on their purpose and how teachers handle them. This study will look into how student interruptions significantly influence science achievement in specific domains across countries.

2.7. Rule Violations

Classroom rule violations are behaviors by students that go against established rules and disrupt learning (Vidić, 2022). These can include talking out of turn, arriving late, misusing electronic devices, interrupting the teacher, showing disrespect or aggression, neglecting homework, or damaging school property (Sun & Shek, 2012). Teachers often see these actions as interruptions that affect the flow of lessons, and responses can range from verbal warnings to suspension or expulsion, depending on how serious the behavior is (Özdal & Çağanağa, 2017; Sun & Shek, 2012). Classroom rules mainly serve to keep the learning environment organized, safe, and focused. They help students understand which behaviors are expected, why these expectations matter, and what may happen when rules are not followed. When rules and routines are clearly established and consistently reinforced, they can reduce disruptions, support positive classroom behavior, and allow lessons to proceed more smoothly (Asare et al., 2024; Dulay, 2023).

Research suggests that when students break classroom rules, it can influence how well they perform in school, although the effect can differ depending on the situation. For instance, a study done in Gasabo District, Rwanda, showed that schools with clear and consistent rules, active teacher supervision, proper guidance programs, and support from parents often had students who performed better academically (Nduwayezu & Gacinya, 2025). Programs such as CHAMPS have also been shown to help lessen disruptive behaviors and improve students' performance, especially in subjects like reading. Still, these programs don't completely remove misbehaviors or guarantee improvement in every area of learning (Herman et al., 2022; Lundahl, 2025). In the same way, the Good Behavior Game [GBG], which focuses on teamwork and positive reinforcement, has proven to be effective in promoting good classroom behavior, particularly among students with special educational needs, by offering a more supportive approach instead of relying on punishment (Gulboy et al., 2025).

Applying classroom rules in a consistent and positive way is essential for minimizing distractions and ensuring a smooth-running class (Nye & Williams, 2022). When there are fewer interruptions, students can pay attention better, especially in science, where lessons often need full focus. This shows how rules are followed or broken can affect the kind of learning atmosphere students have, and it can either help or hinder their performance in class.

2.8. Peer Distractions

Peer distractions happen when students lose focus because of off-task behaviors such as chatting with classmates, using phones for things unrelated to schoolwork, or moving around the classroom during lessons (Deng et al., 2022). These actions often draw attention away from the teacher and disrupt the flow of learning, making it harder for everyone to stay focused. Studies have found that this kind of behavior can lower class participation and concentration, which may lead to poorer learning outcomes over time (Godwin et al., 2016; Moon & Ke, 2020). Even small actions, such as fidgeting, might help some students control their attention, but they can also draw others' attention away and make the class feel less focused overall (Pelo et al., 2023).

These can also make it harder for students to think clearly and stay focused, which may lead to lower academic performance. Using digital devices too often during class, for example, can interrupt attention, lessen participation, and negatively affect performance in different subjects (Martin et al., 2025). On the bright side, teachers who pay close attention to their students and use clear and consistent classroom strategies can help maintain a more focused and positive learning atmosphere. These methods lessen distractions, encourage better behavior, and lead to improved academic results (Lundahl, 2025). Similarly, a study in Gasabo District, Rwanda, showed that when teachers clearly communicate behavior expectations and supervise consistently, students are less likely to engage in off-task behaviors, creating a calmer classroom and better academic outcomes (Nduwayezu & Gacinya, 2025).

Peer distractions play a big part in making classrooms more disruptive, which makes it difficult for science students to stay focused and participate fully in their lessons. Because of this, it's important for teachers to provide consistent supervision and practice active classroom management to lessen off-task behaviors and maintain a focused, productive environment for learning especially in science.

In summary, disruptive classroom environments bring consistent impacts to student learning and performance especially in science. However, the findings differ on which specific types of disruption cause the most harm or may have potentially constructive effects, and only limited researches have focused on addressing their effects across the different science domains. Drawing on these previous findings, this study explored the TIMSS 2023 Grade 8 data to assess the different impacts of disruptive environments on science achievement.

3. Research Methodology

3.1. Research Design

This study used a quantitative exploratory data analysis research design to examine how classroom disruptions affect science achievement in different subjects across countries. A quantitative approach fits this study because it focuses on numerical data that can confirm or disprove ideas, making it easier to compare and generalize findings. An exploratory approach was also used since the study does not test a specific prediction but instead looks into possible effects of disruptions on achievement. Exploratory data analysis [EDA] is helpful because it allows researchers to carefully check the data without fixed expectations, making it possible to find patterns, unusual results, and relationships in large datasets (Courtney, 2021).

3.2. Data Source

This study used the TIMSS 2023 International Database, which contains student achievement scores and background information from students, teachers, and principals. The focus is on Question 27 of the Student Questionnaire, where students reported how often disruptions happen in their science classes (such as noise, breaking rules, or not paying attention). Responses were recorded on a four-point scale: *Every or almost every lesson, About half the lessons, Some lessons, and Never.* These data are useful because they allow for internationally comparable insights into science learning and school conditions (IEA, 2023; Mullis et al., 2020).

3.3. Sample

The study used data from 29 countries (3 benchmarking) participating in TIMSS 2023. TIMSS collects data using a two-stage stratified cluster sampling design to ensure that student samples are nationally representative. To explain TIMSS' process of collecting the data, in the first stage, schools are selected with probability proportional to size [PPS]. In the second stage, intact Grade 8 classes are chosen within the selected schools, and all students in those classes participate. Only anonymized, secondary data from these students were used in this study, so no direct interaction with participants occurs. This sampling method allows valid comparisons across countries and supports the analysis of classroom disruptions and science achievement (Mullis et al., 2020).

3.4. Variables and Measures

The independent variables are the disruptive classroom environments, namely: (1) student inattentiveness, (2) excessive noise, (3) delayed settling time, (4) student interruptions, (5) rule violations, and (6) peer distractions. Each variable was derived as a weighted mean score, calculated from the response percentages reported in Question 27 of the TIMSS 2023 Student Questionnaire.

Table 1 presents the definitions of the variables used to measure disruptive classroom environments.

Table 1
Definition of the Variables Used in Measuring Disruptive Classroom Environments

Variables	*Code*	*Measurement*
Students don't listen to what the teacher says	Student Inattentiveness	Every lesson = 4 About half the lessons = 3 Some lessons = 2 Never = 1
There is too much noise for students to work well	Excessive Noise	Every lesson = 4 About half the lessons = 3 Some lessons = 2 Never = 1
My teacher has to wait a long time for students to be quiet	Delayed Settling Time	Every lesson = 4 About half the lessons = 3 Some lessons = 2 Never = 1
Students interrupt the teacher	Student Interruptions	Every lesson = 4 About half the lessons = 3 Some lessons = 2 Never = 1
Students do not follow the classroom rules	Rule Violations	Every lesson = 4 About half the lessons = 3 Some lessons = 2 Never = 1
Other students' behavior makes it hard for them to concentrate	Peer Distractions	Every lesson = 4 About half the lessons = 3 Some lessons = 2 Never = 1
Science Achievement - Biology - Chemistry - Physics - Earth Science - Integrated Science	Biology Chemistry Physics Earth Science Integrated Science	Mean achievement scores

Student inattentiveness is when students fail to pay attention during lessons, often miss explanations, instructions and resulting in weaker conceptual understanding (Finn et al., 2021). Excessive classroom noise is defined by Mealings and Buchholz (2024) as loud talking, movement, or external disturbances that compete with the teacher's voice and reduce students' ability to listen and concentrate. Delayed settling time is defined as when students take longer to become organized and attentive after transitions or at the start of lessons (Leek et al., 2026). Student interruptions can be understood as off-task or poorly timed comments, questions, or behaviors that disrupt the continuity of lessons and shift attention away from instructional goals. In this sense, they are closely related to classroom management, since clear behavioral expectations, rules, and routines help reduce disruptions and support a more focused learning environment (Asare et al., 2024; Dulay, 2023; Guzelergene et al., 2025). As for rule violations, Aelterman et al. (2019) defined it as anything that involve misconduct, defiance, or disregard for classroom rules and regulations that disrupt the learning environment. And lastly, peer distractions are off-task talking, joking, and/or even device use that shifts attention away from lessons.

The dependent variable is science achievement represented by TIMSS 2023 scores in Biology, Chemistry, Physics, Earth Science, and Integrated Science. In addition, country was treated as a grouping variable to compare differences across education systems.

3.5. Data Analysis

The data were analyzed in four steps. First, countries were grouped using cluster analysis based on their computed weighted mean scores for each type of disruption variable. To ensure a robust classification, a hierarchical approach (Ward's Method) was employed to minimize within-cluster variance. The three-cluster solution was validated using the Elbow method (Syakur et al., 2018), confirming three distinct levels of disruption across the 29 countries: Low, Medium, and High. While this method assumes the presence of meaningful natural groupings among countries, it is sensitive to scaling procedures and distance metrics, which is considered part of the study's limitations.

Second, a one-way analysis of variance [ANOVA] was conducted for each type of disruption variable and each science domain to test whether students' achievement scores differ among Low, Medium, and High disruption groups. When ANOVA results were significant, a post-hoc test (Tukey's HSD) was used to identify which groups differ. If the ANOVA is not significant, the differences were described using descriptive statistics.

Third, a two-way ANOVA was conducted to examine the effects of Disruption Type (student inattentiveness, excessive noise, delayed settling time, student interruptions, rule violations, peer distractions) and Disruption Level (Low, Medium, High) on science achievement. This determined whether the effect of a disruption type varies depending on the country's disruption level (interaction effect: Disruption Type × Disruption Level). Effect sizes (η^2) were reported for this ANOVA to indicate the strength of the effects. If found significant, post-hoc test was also used to identify which groups differ. These tests assume normality, homogeneity of variances, and independence of observations. Although they are robust under moderate violations, departures from these assumptions may affect the precision of statistical estimates and significance testing.

Finally, multiple linear regression analysis was performed to identify which disruptive classroom environment variables most strongly predict science students' achievement across the five domains. Each disruption variable was entered simultaneously as independent variables, while each science achievement served as dependent variable. The analysis examined the regression coefficients, significance levels (p), and explained variance (R^2) to determine the strength and direction of each predictor. This analysis extended the ANOVA findings by offering a more detailed view of how classroom disruptions influence science achievement in a continuous and predictive way. All statistical analyses were conducted using R software, with the level of significance set at .05. This regression analysis assumes linear relationships among variables, absence of severe multicollinearity, homoscedasticity, and normally distributed residuals, and any violation of these assumptions can influence the accuracy of the results. Because the analysis was conducted using aggregated country-level TIMSS 2023 data, the findings should be interpreted as macro-level statistical associations rather than direct individual-level relationships.

4. Results

In the preliminary data exploration, a cluster analysis was performed to group the countries into three distinct clusters according to their levels of classroom disruption (Low, Medium, and High)

Table 2 presents the cluster analysis of countries based on six types of disruptive classroom environments.

Table 2
Cluster Analysis of Countries by Disruptive Classroom Environments

Variable	*Cluster 1*	*Cluster 2*	*Cluster 3*	*Grand Centroid*
Student Inattentiveness	2.60	2.34	2.09	2.34
Excessive Noise	2.50	2.21	1.87	2.20
Delayed Settling	2.50	2.20	1.83	2.18
Student Interruptions	2.47	2.21	1.87	2.19
Rule Violations	2.45	2.15	1.84	2.15
Peer Distractions	2.47	2.13	1.72	2.11

Table 2 shows that classroom disruption levels were highest among countries in Cluster 1 and lowest in Cluster 3. Student inattentiveness recorded the highest overall mean, followed by excessive noise and peer distractions, showing that these are the most common issues in science classrooms. Countries in Cluster 1 observed to have more frequent cases of inattentiveness, noise, and interruptions, while those in Cluster 3 have fewer disruptions and more orderly classroom settings. These differences suggest that classroom behavior and environment vary across countries, which may also affect how students focus and perform in science learning.

Formal statistical tests were performed (through one-way analysis of variance) to determine whether the three disruption levels differ significantly in student achievement across five science domains, with disruption level as the independent variable and the five science achievements as the dependent variables.

Table 3 summarizes the differences in mean achievement scores across the three disruption levels for each science domain.

Table 3
One-Way Analysis of Variance of Science Achievement Across Disruption Levels

Achievement	*F-value*	*Interpretation*	*Largest Mean Difference*
Biology	2.81	Not Significant	Low vs. High = 51.13
Chemistry	2.92	Not Significant	Low vs. High = 51.39
Physics	2.88	Not Significant	Low vs. High = 51.07
Earth Science	3.50	Significant	Low vs. High = 59.20
Integrated Science	3.02	Not Significant	Low vs. High = 51.88

Table 3 shows that differences in science achievement across Low, Moderate, and High disruption levels were not statistically significant in Biology, Chemistry, Physics, and Integrated Science. Only Earth Science showed a significant difference ($F = 3.50$, $p < .05$), with the largest mean difference observed between Low and High disruption levels (59.20 points). This suggests that classroom disruptions generally do not lead to significant differences in science achievement across most domains, except in Earth Science, where higher disruption appears to be associated with lower achievement.

A two-way analysis of variance was also conducted to determine the combined effects of disruption type and disruption level on students' science achievement.

Table 4 presents the main effects of disruption type and disruption level, as well as their interaction, on student performance across all five science domains.

Table 4
Two-Way Analysis of Variance on the Effects of Disruption Type and Level on Science Achievement

Source	*F-value*	*p - value*	*η^2 (partial)*
Disruption Type	0.000	<.001	0.000
Disruption Level	177.602	.001	0.29
Disruption Type × Disruption Level	1.664	.085	0.02

Table 4 shows that disruption type alone did not have a significant effect on overall science achievement. This suggests that no single type of classroom disruption caused major differences in achievement. In contrast, disruption level had a highly significant effect, showing that students in low-disruption settings performed better compared to those in medium or high disruption levels. The interaction between disruption type and disruption level was only marginally significant, suggesting a weak relationship between the type and level of classroom disruptions. Post-hoc results also confirmed that achievement scores significantly differed among disruption levels —specifically between low and medium, and between low and high levels— while the differences between medium and high were smaller but still significant. This further supports that the degree/level of disruption had a stronger impact on science achievement, rather than the specific type of disruption variable.

Further statistical analysis (multiple linear regression) was done to identify which variable of disruptive classroom environment most strongly predict students' science achievement across the five domains.

4.1. Biology

Table 5 presents the results on the association between disruptive classroom environments and students' achievement in Biology.

Table 5
Regression Analysis with Biology Achievement as Dependent Variable

The regression equation is:
Achievement = 690.34 + 44.94 (Excessive Noise) + 188.68 (Delayed Settling Time) – 102.29 (Interruptions) + 88.61 (Rule Violations) – 310.19 (Peer Distractions) – 10.42 (Inattentiveness)

Predictor	*Coef*	*SE Coef*	*t*	*p*
Constant	690.34	96.11	7.18	.001
Excessive Noise	44.94	180.63	0.25	.806
Delayed Settling Time	188.68	143.84	1.31	.203
Interruptions	−102.29	134.30	−0.76	.454
Rule Violations	88.61	173.93	0.51	.616
Peer Distractions	**−310.19**	**109.79**	**−2.83**	**.010**
Inattentiveness	−10.42	118.34	−0.09	.931

S = 35.44 R^2 = 66.9% Adjusted R^2 = 57.8%

The six (6) disruption variables when taken together explained about 66.9% of the variance in the Biology achievement of the countries analyzed. Results revealed that three (3) out of the six (6) disruption variables were positively related to Biology achievement while Interruptions, Peer distractions, and Inattentiveness had a negative relationship to Biology achievement. However, among all predictors, only Peer distractions had a significant effect (p = .010), while the rest were not. This suggests that Peer distractions is the strongest negative predictor, and its negative coefficient (−310.19) means that as peer distractions increase, students' Biology achievement tends to decrease.

4.2. Chemistry

Table 6 presents the results examining the relationship between disruptive classroom environments and students' achievement in Chemistry.

Table 6
Regression Analysis with Chemistry Achievement as Dependent Variable

The regression equation is:
Achievement = 721.68 + 27.12 (Excessive Noise) + 246.80 (Delayed Settling Time) – 217.10 (Interruptions) + 220.99 (Rule Violations) – 337.76 (Peer Distractions) – 49.00 (Inattentiveness)

Predictor	*Coef*	*SE Coef*	*t*	*p*
Constant	721.68	97.96	7.37	.001
Excessive Noise	27.12	184.11	0.15	.884
Delayed Settling Time	246.80	146.61	1.68	.106
Interruptions	−217.10	136.89	−1.59	.127
Rule Violations	220.99	177.28	1.24	.226
Peer Distractions	**−337.76**	**111.91**	**−3.02**	**.006**
Inattentiveness	−49.00	120.62	−0.41	.688

S = 36.13 R^2 = 66.2% Adjusted R^2 = 57.0%

The six (6) disruption variables when taken jointly explained about 66.2% of the variance in the Chemistry achievement of the countries analyzed. Results revealed that three (3) out of the six (6) disruption variables were positively related to Chemistry achievement while Interruptions, Peer distractions, and Inattentiveness had a negative relationship to Chemistry achievement. However, among all predictors, only Peer distractions had a significant effect (p = .006), while the rest were not. This suggests that Peer distractions is the strongest negative predictor, and its negative coefficient (−337.76) means that as peer distractions increase, students' Chemistry achievement tends to decrease.

4.3. Physics

Table 7 presents the results on how disruptive classroom environments are associated with students' achievement in Physics.

Table 7
Regression Analysis with Physics Achievement as Dependent Variable

The regression equation is:
Achievement = 725.64 – 73.29 (Excessive Noise) + 235.65 (Delayed Settling Time) – 215.10 (Interruptions) + 257.79 (Rule Violations) – 304.63 (Peer Distractions) – 12.08 (Inattentiveness)

Predictor	*Coef*	*SE Coef*	*t*	*p*
Constant	725.64	90.78	7.99	.001
Excessive Noise	−73.29	170.61	−0.43	.672
Delayed Settling Time	235.65	135.86	1.73	.097
Interruptions	−215.10	126.85	−1.70	.104
Rule Violations	257.79	164.28	1.57	.131
Peer Distractions	**−304.63**	**103.70**	**−2.94**	**.008**
Inattentiveness	−12.08	111.77	-0.11	.915
S = 33.48	R^2 = 71.1%	Adjusted R^2 = 63.2%		

The six (6) disruption variables when taken together explained about 71.1% of the variance in the Physics achievement of the countries analyzed. Results revealed that two (2) out of the six (6) disruption variables were positively related to Physics achievement while Excessive Noise, Interruptions, Peer distractions, and Inattentiveness had a negative relationship to Physics achievement. However, among all predictors, only Peer distractions had a significant effect (p = .008), while the rest were not. This suggests that Peer distractions is the strongest negative predictor, and its negative coefficient (−304.63) means that as peer distractions increase, students' Physics achievement tends to decrease.

4.4. Earth Science

This subsection presents the results on the effects of disruptive classroom environments on students' Earth Science achievement.

Table 8
Regression Analysis with Earth Science Achievement as Dependent Variable

The regression equation is:
Achievement = 688.68 + 20.58 (Excessive Noise) + 115.06 (Delayed Settling Time) – 129.73 (Interruptions) + 175.17 (Rule Violations) – 332.70 (Peer Distractions) – 48.69 (Inattentiveness)

Predictor	*Coef*	*SE Coef*	*t*	*p*
Constant	688.68	99.17	6.94	.001
Excessive Noise	20.58	186.38	0.11	.913
Delayed Settling Time	115.06	148.42	0.78	.446
Interruptions	−129.73	138.58	−0.94	.359
Rule Violations	175.17	179.47	0.98	.340
Peer Distractions	**−332.70**	**113.29**	**−2.94**	**.008**
Inattentiveness	−48.69	122.11	−0.40	.694
S = 36.57	R^2 = 70.7%	Adjusted R^2 = 62.7%		

The six (6) disruption variables when taken together explained about 70.7% of the variance in the Earth Science achievement of the countries analyzed. Results revealed that three (3) out of the six (6) disruption variables were positively related to Earth Science achievement while Interruptions, Peer distractions, and Inattentiveness had a negative relationship to Earth Science achievement. However, among all predictors, only Peer distractions had a significant effect (p = .008), while the rest were not. This suggests that Peer distractions is the strongest negative predictor, and its negative coefficient (−332.70) means that as peer distractions increase, students' Earth Science achievement tends to decrease.

4.5. Integrated Science

This subsection presents the results on the relationship between disruptive classroom environments and students' achievement in Integrated Science.

Table 9
Regression Analysis with Integrated Science Achievement as Dependent Variable

The regression equation is:
Achievement = 700.82 + 8.19 (Excessive Noise) + 192.55 (Delayed Settling Time) – 155.13 (Interruptions) + 165.11 (Rule Violations) – 312.40 (Peer Distractions) – 1.89 (Inattentiveness)

Predictor	*Coef*	*SE Coef*	*t*	*p*
Constant	700.82	92.88	7.55	.001
Excessive Noise	8.19	174.55	0.05	.963
Delayed Settling Time	192.55	139.00	1.39	.180
Interruptions	−155.13	129.78	−1.20	.245
Rule Violations	165.11	168.08	0.98	.337
Peer Distractions	**−312.40**	**106.10**	**−2.95**	**.007**
Inattentiveness	−1.89	114.35	−0.02	.987
S = 34.25	R^2 = 69.1%	Adjusted R^2 = 60.6%		

The six (6) disruption variables when taken together explained about 69.1% of the variance in the Integrated Science achievement of the countries analyzed. Results revealed that three (3) out of the six (6) disruption variables were positively related to Integrated Science achievement while Interruptions, Peer distractions, and Inattentiveness had a negative relationship to Integrated Science achievement. However, among all predictors, only Peer distractions had a significant effect (p = .007), while the rest were not. This suggests that Peer distractions is the strongest negative predictor, and its negative coefficient (−312.40) means that as peer distractions increase, students' Integrated Science achievement tends to decrease.

5. Discussion

This study examined the impact of disruptive classroom environments on science achievement across five domains: Biology, Chemistry, Physics, Earth Science, and Integrated Science, using the TIMSS 2023 data. Across all analyses, peer distractions emerged as the only disruption variable that consistently and significantly predicted science achievement across domains, while other forms of disruption showed weak or non-significant effects. These findings highlight the importance of classroom social dynamics in shaping students' science learning outcomes across countries.

Peer distractions showed the most significant negative impact on the science achievement of the students across countries in all five domains, particularly in Chemistry achievement. This unique significance of peer distractions across all domains suggests a common cognitive obstacle for students across countries. In domains like Physics and Chemistry, which require high levels of working memory for multi-step problem solving, these social distractions likely create a "split-attention" effect that is more detrimental than in more descriptive science domains (Schmidt, 2020; Skulmowski, 2023). This implies that the social dynamics inside the classroom such as side conversations, use of phones during lectures, moving around during discussions, or general off-task behaviors greatly interfere with students' focus and cognitive engagement (Godwin et al., 2016; Moon & Ke, 2020). When students are frequently distracted by peers, their ability to engage with academic content, such as processing scientific concepts and participating in class discussions is compromised (Li et al., 2019). Learning science effectively requires sustained attention, cooperation, and individual concentration (Entress & Wagner, 2014; Gallen et al., 2023; Moss & Moss-Racusin, 2021) which can be disrupted by peer interference.

The negative link between peer distractions and students' science achievement shows the broader inequalities in classroom environments (Betache et al., 2025). In countries with education systems that perform poorly or lack resources, teachers usually handle larger classes and have limited support for managing student behaviors (Mullis et al., 2020). This situation makes it harder for teachers to control how students behave with each other during class. These results establish the importance of having a structured classroom and positive peer interactions in science learning.

Even though peer distractions in this study were identified as a significant negative predictor, it is important to distinguish between "off-task" distractions and "productive" peer interactions. According to Filippou et al. (2022), and Buchs and Butera (2004), peer interactions that involve socio-cognitive conflict can actually enhance scientific reasoning by forcing students to reconcile differing perspectives. In addition, "exploratory talk" among peers, though potentially perceived as a classroom disruption, can facilitate collaborative inquiry and deeper conceptual understanding (Patterson, 2018; T'Sas & Daems, 2024; T'Sas & De Mæyer, 2025). The negative impact found in this study may likely stems from distractions that are entirely unrelated to the curriculum, rather than collaborative social learning.

Rule violations exhibited a weak and statistically insignificant relationship with science achievement across all domains. This suggests that occasional or minor violations may not directly undermine learning outcomes, particularly when teachers maintain effective classroom management practices. Previous studies have shown that strong teacher–student relationships and consistent behavioral expectations can buffer the negative effects of minor misconduct, allowing students to remain academically engaged despite isolated rule-breaking behaviors (Kennedy & Haydon, 2021). These findings indicate that rule violations alone may not predict achievement unless they become frequent, severe, or poorly managed.

Other disruption variables such as student inattentiveness, excessive noise, delayed settling time, and student interruptions also showed weak or non-significant predictive effects. Although these variables did not emerge as statistically significant predictors, their influence on the classroom environment should not be overlooked. Brief inattentiveness or momentary noise may be counteracted by effective instructional routines and teacher strategies that help students quickly re-engage with learning tasks (Ajiboye et al., 2020). In some contexts, moderate levels of noise associated with collaborative activities, discussions, or hands-on experiments may even support engagement and conceptual understanding, particularly in science classrooms that emphasize inquiry-based learning (Gillies, 2023; Leinster et al., 2025). Similarly, short interruptions in the form of student questions or clarifications may function as formative checks that deepen understanding rather than disrupt learning (Gillies, 2023).

The findings further indicate that the overall level of classroom disruption, rather than the specific type of disruption, plays a more substantial role in shaping science achievement. Results from the two-way ANOVA showed that disruption level had a highly significant effect on achievement, while disruption type alone did not. This suggests that cumulative exposure to multiple disruptions may erode instructional quality and learning opportunities over time, consistent with research emphasizing the importance of orderly and supportive classroom climates (Burns et al., 2021; Mullis et al., 2020). Even when individual disruptions appear minor, their combined presence may reduce instructional time, weaken engagement, and limit opportunities for meaningful science learning. The findings of this study underscore the critical role of classroom management in promoting science achievement. While peer distractions were identified as the most influential predictor, all disruption variables collectively reflect the importance of maintaining focused, well-structured learning environments.

In mitigating these effects, schools should prioritize relational classroom management over punitive measures. Relational strategies include building relationships and setting clear expectations. This approach enhances student engagement, reduces problem behaviors, and fosters a positive learning environment (Skiba et al., 2016). Since rule violations were not a significant predictor of science achievement, strict policing of minor conduct may be less effective than strategies that promote Peer-Assisted Learning (Li et al., 2025). With this, teachers can convert potential disruptions into academic engagement and support more equitable and effective science learning across diverse educational contexts.

6. Limitations of the Study

This study provides international comparison using TIMSS 2023 data. However, several limitations should be noted. First, the data on classroom disruptions are self-reported by students, which may be subject to individual perception or cultural bias regarding what constitutes as "excessive noise" or "disruption." Second, the exploratory nature of the cluster analysis means that the grouping of countries into "Low, Medium, and High" levels is relative to the sampled 29 countries and may shift if a different set of nations were analyzed. Third, as a cross-sectional study, these findings identify correlations and predictive relationships but cannot definitively establish causality between disruptions and achievement. Fourth, the analysis does not account for school-level variables such as teacher experience or specific pedagogical styles, which may interact with classroom environments in ways not captured by the student questionnaire. Finally, although this study examined disruptive classroom environments across five science domains, the limited availability of domain-specific literature examining how disruptive classroom environments uniquely affect Biology, Chemistry, Physics, Earth Science, and Integrated Science constrained deeper subject-specific interpretation of the findings. This emphasizes an important gap in science education research and suggests the need for future studies that examine disruption effects within individual science disciplines.

7. Conclusion and Recommendations

Disruptive classroom environments including student inattentiveness, excessive noise, student interruptions, rule violations, and peer distractions, showed a measurable impact on science students' achievement in various domains, which in turn reflects on the overall quality of science education internationally. Some disruptions such as peer distractions or student inattentiveness tend to have stronger negative effects and may require more structured interventions, including clear classroom management strategies, routines, or teacher-student engagement practices. Other types of disruptions, like minor rule violations, excessive classroom noise or occasional interruptions, can often be addressed through simpler measures, such as seating arrangements, peer monitoring, or brief behavioral reminders. Addressing both major and minor disruptions effectively can help improve learning outcomes and support better science achievement across the classroom, often without demanding substantial financial resources.

Future research could employ longitudinal designs and multi-level modeling to further explore how teacher-student relationship quality moderates the impact of peer distractions over time. Also, future researchers could focus on studying interventions for minimizing peer distractions and the other variables. Additionally, comparing these impacts across different educational stages, such as elementary versus high school, could provide a more developmental perspective on classroom management.

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Data Availability Statement: The data utilized are publicly available online through the TIMSS 2023 International Database and may be accessed through the International Association for the Evaluation of Educational Achievement, subject to their access policies.

Ethical Approval and Consent: This study only utilized the TIMSS 2023 dataset, which is publicly available and de-identified. Although TIMSS collected data from intact Grade 8 classes in selected schools, there was no collection of any new data from the students. Issues of confidentiality and informed consent have already been addressed by the International Association for the Evaluation of Educational Achievement (IEA) during the data collection process. Institutional clearance was certified by the Cebu Normal University Ethics Review Committee (CNU-ERC certification: 2388 / 2025-10 Sarita et al.)

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