Contextualized Adaptive Differentiated Instruction (CADi) in Fostering Learning Autonomy and Critical-Thinking Skills Among Grade 9 Learners

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Abstract

This study examined the comparative effects of two instructional models under Contextualized Adaptive Differentiated Instruction (CADi)—the Adaptive Station Rotation Model (ASRM) and the Four-Phase Gradual Release of Responsibility (GRR) Model—on the learning autonomy and critical-thinking skills of Grade 9 science learners. Grounded in Constructivism, Self-Determination Theory, and Differentiated Instruction, the study addressed persistent concerns regarding learner dependence on teacher-directed instruction and limited higher-order thinking in science education. A quasi-experimental non-equivalent groups posttest-only design was employed. Two intact Grade 9 classes from Cuyab Integrated National High School during Academic Year 2025–2026 were selected through cluster sampling and assigned to either the ASRM or GRR instructional condition. Both groups received instruction on impulse, momentum, and collision-related phenomena over approximately four weeks using contextualized and differentiated learning experiences. Learning autonomy was measured through an adapted Learning Autonomy Questionnaire based on the framework of Nguyen and Habók, while critical-thinking skills were assessed using a contextually adapted instrument derived from the Physics Lab Inventory of Critical Thinking. Descriptive and inferential statistics were utilized to analyze posttest results. The study aimed to generate empirical evidence on the implementation of CADi in public secondary science classrooms and determine whether differences exist in learning autonomy and critical-thinking skills between the two instructional models. Findings may contribute to the design of adaptive, learner-centered, and contextually responsive science instruction.

Keywords: *Contextualized Adaptive Differentiated Instruction (CADi); Adaptive Station Rotation Model; Four-Phase Gradual Release of Responsibility; learning autonomy; critical-thinking skills; science education*

1 Introduction

Contemporary science education increasingly emphasizes the development of learners who are capable of directing their own learning and engaging in reasoned evaluation of information rather than merely reproducing scientific knowledge. As science instruction continues to move toward inquiry-oriented and learner-centered approaches, greater at-tention has been given to educational outcomes that support lifelong learning and scien-tific literacy. Among these outcomes, learning autonomy and critical-thinking skills have emerged as essential competencies that enable learners to actively participate in knowledge construction, regulate their learning processes, and apply scientific under-standing to authentic contexts.

Learning autonomy refers to learners' ability to take responsibility for planning, monitoring, and evaluating their own learning experiences, while critical-thinking skills involve the capacity to analyze information, evaluate evidence, draw reasoned conclusions, and justify decisions through logical inquiry. Together, these competencies contribute to meaningful engagement in science learning because they support independent inquiry, reflective thinking, and informed decision-making. Empirical literature further suggests that autonomy and critical thinking are associated with improved learner engagement, self-regulation, and deeper conceptual understanding across educational contexts (Nguyen & Habók, 2021; Facione, 1990/2016; Walsh et al., 2019).

Despite ongoing efforts to promote learner-centered science education, the development of these competencies remains a continuing concern. Educational evidence suggests that many learners continue to depend heavily on teacher guidance and demonstrate limited engagement in higher-order cognitive processes. International educational assessments have reported persistent difficulties among Filipino learners in applying scientific knowledge beyond procedural tasks and transferring learning to unfamiliar contexts (OECD, 2023). Similar concerns have been linked to instructional environments that continue to emphasize teacher direction while providing limited opportunities for learners to regulate their learning, evaluate evidence, and construct independent understanding of scientific concepts (Bautista & Aranas, 2023; Balagtas et al., 2019).

These concerns remain evident despite recent educational reforms advocating contextualized, inquiry-based, and learner-centered instruction. Although instructional policies emphasize the importance of adaptive and inclusive pedagogies, implementing these approaches consistently in public secondary classrooms remains challenging. Factors such as classroom heterogeneity, limited instructional time, curriculum coverage requirements, and implementation demands often encourage continued reliance on teacher-centered practices (Garcia et al., 2025; Demalata & Espacio, 2025; Wabingga & Tomakin, 2025). Consequently, learners may demonstrate procedural success while remaining dependent on instructional support and showing limited development of independent reasoning and critical evaluation.

One instructional direction proposed to address these challenges is the integration of contextualization, differentiation, and adaptivity within science instruction. Differentiated instruction recognizes differences in learner readiness, interests, and learning profiles and provides multiple pathways for students to engage with learning objectives (Tomlinson et al., 2003). Contextualized instruction strengthens learning by connecting concepts to meaningful and authentic experiences, while adaptive instruction allows teachers to respond dynamically to learner performance and emerging instructional needs. Research indicates that these approaches are associated with improvements in learner engagement, participation, and cognitive outcomes when implemented systematically rather than as isolated instructional modifications (Mirawati et al., 2022; Smale-Jacobse et al., 2019; Marks et al., 2021; Suryati & Ratih, 2023). However, empirical evidence remains limited regarding integrated instructional frameworks that combine these principles into operational classroom models capable of simultaneously developing learning autonomy and critical-thinking skills.

Responding to this need, the present study adopts Contextualized Adaptive Differentiated Instruction (CADi) as an integrated instructional framework designed to combine contextualization, adaptivity, and differentiation within science instruction. CADi is informed by constructivist perspectives, which view learning as an active process of knowledge construction through interaction and reflection, and by Self-Determination Theory, which explains how autonomy-supportive environments contribute to learner engagement and independent learning behaviors (Chand, 2023; Deci & Ryan, 2000; Ryan & Deci, 2000). Through these theoretical foundations, CADi is intended to create instructional environments that gradually transfer cognitive responsibility from teacher to learner while maintaining appropriate support and challenge.

The present study operationalizes CADi through two instructional models: the Adaptive Station Rotation Model (ASRM) and the Four-Phase Gradual Release of Responsibility (GRR) Model. ASRM organizes instruction through differentiated learning stations that adjust task complexity, grouping, and instructional support according to learner performance, allowing students to participate in guided, collaborative, and independent learning experiences (Nagy, 2018; Wong et al., 2022; Yılmaz & Açıkgül Fırat, 2024). In contrast, the Four-Phase GRR Model structures learning through sequential phases of focused instruction, guided practice, collaborative engagement, and independent application to progressively transfer responsibility to learners (Fisher & Frey, 2008; Skillings, 2021; Casinillo & Casinillo, 2024). Although both instructional models are grounded in the same theoretical and pedagogical assumptions, they differ in how instructional support is organized and how learner independence is developed throughout instruction.

Existing literature supports differentiated instruction, adaptive learning, and gradual release practices independently; however, limited empirical evidence directly compares alternative implementations of an integrated contextualized adaptive framework within Philippine secondary science education. Furthermore, studies simultaneously examining learning autonomy and critical-thinking skills as instructional outcomes remain limited. Addressing this gap, the present study investigates the comparative effects of two Contextualized Adaptive Differentiated Instruction (CADi)-based instructional models on the learning autonomy and critical-thinking skills of Grade 9 science learners.

Specifically, this study addressed the following research questions:

1. What is the level of learning autonomy among students after exposure to the Adap-tive Station Rotation Model in terms of: (a) beliefs about teacher's role; (b) meta-cognitive knowledge; (c) metacognitive skills; (d) desire to engage; (e) motivation; and (f) freedom?

2. What is the level of learning autonomy among students after exposure to the Four-Phase Gradual Release of Responsibility Model in terms of: (a) beliefs about teach-er's role; (b) metacognitive knowledge; (c) metacognitive skills; (d) desire to engage; (e) motivation; and (f) freedom?

3. What is the level of critical-thinking skills among students after exposure to the Adaptive Station Rotation Model in terms of: (a) analysis; (b) evaluation; and (c) in-ference?

4. What is the level of critical-thinking skills among students after exposure to the Four-Phase Gradual Release of Responsibility Model in terms of: (a) analysis; (b) evaluation; and (c) inference?

5. Is there a significant difference in learning autonomy between students exposed to the Adaptive Station Rotation Model and those exposed to the Four-Phase Gradual Release of Responsibility Model?

6. Is there a significant difference in critical-thinking skills between students exposed to the Adaptive Station Rotation Model and those exposed to the Four-Phase Grad-ual Release of Responsibility Model?

2 Methods

2.1 Research design

This study employed a quasi-experimental non-equivalent groups posttest-only design to examine the effects of Contextualized Adaptive Differentiated Instruction (CADi), opera-tionalized through the Adaptive Station Rotation Model (ASRM) and the Four-Phase Gradual Release of Responsibility (GRR) Model, on the learning autonomy and critical-thinking skills of Grade 9 science learners. This design was selected because random as-signment of individual participants was impractical within the natural classroom envi-ronment and intact class groupings had to be maintained (Campbell & Stanley, 1963; Shadish et al., 2002). Quasi-experimental approaches permit examination of instruction-al effects while preserving authentic educational conditions.

Two intact Grade 9 classes from the same public secondary school served as comparison groups. One class received instruction through ASRM, while the second class received instruction through GRR. Following the intervention period, both groups completed posttests measuring learning autonomy and critical-thinking skills. Differences in posttest performance were interpreted as outcomes associated with exposure to the instructional conditions.

Because participants were assigned at the class level rather than individually, controls were introduced to strengthen internal validity. Both groups belonged to the same grade level, followed the same curriculum, were taught by the same teacher during the same instructional period, and received equivalent instructional materials, learning environment conditions, instructional time, and assessment procedures. Although this design cannot establish initial equivalence between groups, these controls reduced threats associated with selection and instructional variability and allowed systematic comparison of the two CADi instructional models in an authentic classroom context.

2.2 Participants and sampling

The participants were Grade 9 learners enrolled in the regular science program of Cuyab Integrated National High School during Academic Year 2025–2026. The sampling frame consisted of six intact Grade 9 sections with a total population of 217 students.

Cluster sampling was used because participants were naturally grouped into classroom sections. Two intact classes were selected using a lottery procedure facilitated by the school science coordinator to promote transparency and minimize selection bias. Following selection, the two classes were randomly assigned at the group level to either the ASRM or GRR instructional condition.

The average class size of the selected sections was approximately 37 students, resulting in an estimated total sample of approximately 74 participants. An a priori power analysis using G*Power indicated that a minimum sample size of 64 students (32 per group) was required to detect a medium effect size ($d = 0.50$) using a two-tailed independent-samples t-test at $\alpha = .05$ with statistical power of .80.

Participation was voluntary. Parental consent and student assent were obtained prior to implementation. Inclusion criteria consisted of enrollment in one of the selected Grade 9 classes, complete participation during the intervention period, and completion of all posttest instruments. Students with prolonged absence, transfer during implementation, or incomplete posttest responses were excluded from analysis.

2.3 Research instruments

Two outcome measures were used in the study: the Learning Autonomy Questionnaire (LAQ) and the Critical-Thinking Assessment (CTA).

The LAQ was adapted from the instrument developed by Nguyen and Habók (2021). The questionnaire measured six dimensions of learning autonomy: beliefs about teacher’s role, desire to engage, motivation, metacognitive knowledge, metacognitive skills, and freedom. The instrument was contextually modified for Grade 9 science instruction while preserving the original multidimensional structure. Responses were collected using a 4-point Likert scale ranging from strongly disagree (1) to strongly agree (4).

Critical-thinking skills were measured using the CTA adapted from the Physics Lab Inventory of Critical Thinking (PLIC) developed by Walsh and colleagues. The assessment retained the original scenario-based and closed-response structure while aligning content with Grade 9 science competencies on impulse, momentum, and collision-related phenomena. Items measured analysis, evaluation, and inference. A table of specifications was prepared to align competencies, content coverage, and higher-order thinking dimensions.

Prior to implementation, both instruments underwent expert validation by three specialists in science education and assessment to establish clarity, relevance, and alignment with intended outcomes. Pilot testing was subsequently conducted with a comparable Grade 9 population to evaluate reliability, item clarity, difficulty, discrimination, and overall instrument performance before final administration.

2.4 Data gathering procedure

Data collection occurred in three phases: preparatory activities, intervention implementa-tion, and posttest administration.

Prior to implementation, approval was secured from school authorities and coordination was conducted with the science coordinator regarding scheduling and participant selection. Ethical safeguards included informed parental consent, student assent, voluntary participation, and confidentiality of responses.

During preparation, the researcher adapted the LAQ and CTA and developed lesson plans aligned with the CADi framework. Instruments and instructional materials underwent expert validation and pilot testing before implementation. In addition, the teacher responsible for delivering instruction completed a two- to three-day training workshop focused on CADi principles, ASRM procedures, GRR implementation, formative assessment practices, and instructional fidelity.

The intervention was implemented over four weeks. Both groups studied the same Grade 9 science competencies on impulse, momentum, and collision using equivalent instructional duration, learning objectives, and contextualized learning tasks.

Students assigned to the ASRM condition engaged in differentiated learning stations involving teacher-guided, collaborative, and independent learning experiences with adjustments informed by formative assessment data. Students assigned to the GRR condition received instruction through sequential phases consisting of focused instruction, guided practice, cooperative learning, and independent application.

Implementation fidelity was monitored through daily lesson logs and fidelity checklists completed by the teacher. Approximately 20% of lessons were additionally observed by an external observer using a structured observation checklist. Instruction was considered acceptable when at least 80% of planned instructional components were implemented.

Following completion of the intervention, both groups completed the LAQ and CTA under standardized administration procedures. Responses were screened for completeness, coded, and entered into a secured database for analysis.

2.5 Statistical treatment of data

Descriptive and inferential statistical procedures were employed.

For Research Questions 1–4, descriptive statistics including mean and standard deviation were used to determine students' levels of learning autonomy and critical-thinking skills under each instructional condition.

For Research Questions 5–6, a two-tailed independent-samples t-test was used to determine whether significant differences existed between students exposed to the ASRM and those exposed to the GRR model in terms of learning autonomy and critical-thinking skills.

All statistical decisions were interpreted using an alpha level of .05.

3 Results and Discussion

3.1 Learning Autonomy After Exposure to the Adaptive Station Rotation Model

Table 1. Beliefs About Teacher's Role After Exposure to Adaptive Station Rotation

Statements	Mean	SD	Verbal Interpretation
My science teacher should set my learning goals for me.	2.16	0.53	Disagree
My science teacher should explain everything to us during science lessons.	1.47	0.51	Strongly Disagree
My science teacher should decide the objectives of our science lessons.	1.91	0.43	Disagree
My science teacher should decide all the activities we do in science class.	1.95	0.31	Disagree
My science teacher should choose all the materials we use in science learning.	2.00	0.49	Disagree
My science teacher should be responsible for evaluating my learning in science.	2.05	0.62	Disagree
Overall	1.92	0.26	Disagree

***Legends**: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low*

Table 1 presents students' beliefs about the teacher's role after exposure to the Adaptive Station Rotation Model (ASRM). The overall mean score (M = 1.92, SD = 0.26), interpreted as Disagree, indicates that learners generally did not view the teacher as the sole source of direction in science learning. The lowest rating was observed in the expectation that teachers should explain all lesson content (M = 1.47, SD = 0.51; Strongly Disagree), while relatively higher ratings remained for teacher responsibilities in selecting instructional materials and evaluating learning.

These findings suggest that learners developed greater participation and reduced dependence on direct teacher instruction. Exposure to ASRM may have supported active engagement through differentiated learning stations that promoted discussion, guided exploration, problem solving, independent task completion, formative feedback, and instructional scaffolds. This pattern aligns with Self-Determination Theory (Ryan & Deci, 2000a;

2000b) and prior studies showing that differentiated and responsive learning environments strengthen learner engagement, responsibility, and autonomy (Black & Deci, 2000; Sapan & Mede, 2022).

Table 2. Metacognitive Knowledge After Exposure to Adaptive Station Rotation

Statements	Mean	SD	Verbal Interpretation
I know my strengths and weaknesses in learning science.	3.14	0.56	Agree
I understand how I learn science best.	3.07	0.51	Agree
I know which strategies help me understand science concepts.	3.02	0.56	Agree
I know which science topics are difficult for me.	3.21	0.56	Agree
I know what I need to improve to learn science better.	3.19	0.55	Agree
Overall	3.13	0.38	Agree

***Legends**: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low*

Table 2 presents students' level of metacognitive knowledge following exposure to the Adaptive Station Rotation Model (ASRM). The overall mean score (M = 3.13, SD = 0.38), interpreted as Agree, indicates that learners generally developed awareness of how they learn and understand science concepts. Students showed the highest awareness in identifying difficult science topics (M = 3.21, SD = 0.56), while lower ratings were observed in recognizing the most effective learning strategies for understanding concepts (M = 3.02, SD = 0.56).

These findings suggest that ASRM may have strengthened learners' awareness of learning challenges and conceptual understanding, although their ability to independently select and optimize learning strategies remained less developed. The differentiated and learner-centered structure of ASRM—including teacher-guided, collaborative, independent, and technology-supported activities, formative feedback, and reflective questioning—may have supported this development by encouraging reflection and engagement across varied learning conditions. This pattern aligns with constructivist perspectives that view metacognitive awareness as developing through active participation and reflection (Bruner, 1966; Piaget, 1970; Vygotsky, 1978) and supports previous findings linking differentiated instruction to improved learner engagement, responsiveness, and autonomy (Smale-Jacobse et al., 2019; Marks et al., 2021; Sapan & Mede, 2022; Khan et al., 2024).

Table 3. Metacognitive Skills After Exposure to Adaptive Station Rotation

Statements	**Mean**	**SD**	**Verbal Interpretation**
I set goals for my science learning.	2.95	0.65	Agree
I plan how I will complete science tasks or investigations.	3.09	0.48	Agree
I check whether I understand science concepts during lessons.	3.12	0.45	Agree
I change my learning strategies if I do not understand a science topic.	3.07	0.55	Agree
I reflect on my progress in learning science.	3.02	0.60	Agree
I use feedback from my science teacher to improve my science work.	3.12	0.59	Agree
Overall	3.06	0.30	Agree

Legends: *3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low*

Table 3 presents students' level of metacognitive skills following exposure to the Adaptive Station Rotation Model (ASRM). The overall mean reflected an Agree level of response, indicating that students generally demonstrated planning, monitoring, and evaluation behaviors during science learning. Statements 3 and 6 obtained the highest mean scores (M = 3.12), showing that learners frequently monitored their understanding and used teacher feedback to improve performance, whereas Statement 1 obtained the lowest mean score (M = 2.95), indicating lower consistency in explicit goal-setting.

The findings suggest that learners demonstrated stronger monitoring and evaluative processes than proactive planning behaviors. Students appeared more capable of reviewing work, identifying errors, and adjusting understanding based on feedback than independently setting learning goals. ASRM may have supported this pattern through differentiated learning stations that required continuous reflection, strategy adjustment, and response adaptation across teacher-guided, collaborative, independent, and technology-supported activities. This pattern aligns with constructivist perspectives that view metacognitive regulation as developing through active engagement and reflection (Bruner, 1966; Piaget, 1970; Vygotsky, 1978) and supports previous studies linking differentiated, learner-centered environments with stronger self-regulation and learner responsibility (Khan et al., 2024; Ruelens, 2019; Pham, 2022; Nguyen & Nguyen, 2020; Pratiwi & Waluyo, 2023).

Table 4. Desire to Engage After Exposure to Adaptive Station Rotation

Statements	Mean	SD	Verbal Interpretation
I try to understand science lessons even when they are challenging.	3.33	0.47	Strongly Agree
I actively participate in science activities and discussions.	3.12	0.54	Agree
I am willing to do additional science tasks when given the opportunity.	3.02	0.51	Agree
I continue working on science tasks even when they are difficult.	3.30	0.47	Strongly Agree
I put effort into learning science beyond what is required.	3.28	0.59	Strongly Agree
Overall	3.21	0.30	Agree

Legends: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low

Table 4 presents students' level of desire to engage following exposure to the Adaptive Station Rotation Model (ASRM). The overall mean score (M = 3.21), interpreted as Agree, indicates that students generally demonstrated willingness and initiative to participate in science learning activities. The highest mean was observed in students' willingness to complete science lessons despite difficulty (M = 3.33), while the lowest mean (M = 3.02) reflected comparatively lower willingness to engage in additional science-related activities beyond classroom requirements.

These findings suggest that students sustained participation and effort within structured instructional settings but showed less initiative to extend learning independently beyond required tasks. The differentiated and participatory structure of ASRM may have supported engagement by providing teacher-guided, collaborative, independent, and technology-supported activities that promoted persistence through contextualized tasks, peer interaction, guide questions, and formative feedback. This pattern aligns with Self-Determination Theory, which emphasizes autonomy, competence, and meaningful participation as foundations of sustained engagement (Ryan & Deci, 2000), and supports previous findings that differentiated and autonomy-supportive environments enhance learner participation and continued engagement (Black & Deci, 2000; Tomlinson et al., 2003; Smale-Jacobse et al., 2019; Rizalda, 2023; Sapan & Mede, 2022).

Table 5. Motivation After Exposure to Adaptive Station Rotation

Statements	Mean	SD	Verbal Interpretation
I am motivated to learn science because it helps me understand real-life situations.	3.42	0.59	Strongly Agree
I am motivated to learn science because it is useful in everyday life.	3.35	0.57	Strongly Agree
I want to learn science so that I can help solve problems in my community.	3.26	0.58	Strongly Agree
Learning science is important because it develops my thinking skills.	3.44	0.50	Strongly Agree
I am interested in the science topics discussed in class.	3.40	0.50	Strongly Agree
Overall	3.37	0.35	Strongly Agree

Legends: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low

Table 5 presents students' level of motivation following exposure to the Adaptive Station Rotation Model (ASRM). The overall mean score (M = 3.37), interpreted as Strongly Agree, indicates high motivation and sustained interest in science learning throughout the intervention. The highest mean was observed in students' motivation when science activities developed their thinking skills (M = 3.44), while similarly high ratings were found when science concepts were connected to real-world contexts and meaningful classroom interaction. The lowest mean (M = 3.26), although still within the Strongly Agree range, was associated with applying scientific principles to broader community and societal problems.

These findings suggest that motivation was strongest when students perceived science as meaningful, cognitively engaging, and relevant to their immediate learning experiences. Motivation appeared less pronounced when learning extended toward broader societal application, indicating stronger engagement with personally and instructionally relevant contexts. The learner-centered and differentiated structure of ASRM—including contextualized tasks, inquiry-based activities, collaboration, formative feedback, and technology-supported learning—may have reinforced perceptions of competence and sustained participation. This pattern aligns with Self-Determination Theory, which emphasizes autonomy, competence, and meaningful participation as drivers of intrinsic motivation (Deci & Ryan, 2000; Ryan & Deci, 2000a; Ryan & Deci, 2000b), and is supported by studies linking differentiated instruction with increased engagement, interest, and persistence (Black & Deci, 2000; Tomlinson et al., 2003; Sapan & Mede, 2022; Rizalda, 2023).

Table 6. Freedom After Exposure to Adaptive Station Rotation

Statements	Mean	SD	Verbal Interpretation
I have opportunities to explain my ideas during science class.	3.00	0.69	Agree
I am allowed to explore different solutions during science activities.	2.91	0.57	Agree
I ask questions when I do not understand a science topic.	3.05	0.72	Agree
I relate science lessons to real-life situations on my own.	2.88	0.73	Agree

I make choices about how I complete some of my science tasks.	3.07	0.63	Agree
Overall	2.98	0.43	Agree

Legends: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low

Table 6 presents students' level of perceived freedom following exposure to the Adaptive Station Rotation Model (ASRM). The overall mean score (M = 2.98), interpreted as Agree, indicates that students generally perceived opportunities to exercise choice and maintain some control over their science learning experiences. The highest mean was observed in students' perception of having a comfortable environment for asking questions when they did not understand science concepts (M = 3.05), while the lowest mean (M = 2.88) reflected comparatively lower ability to relate science lessons to everyday life.

These findings suggest that ASRM supported learner participation and perceived autonomy through opportunities for questioning, idea expression, exploration, and decision-making during instruction. Exposure to teacher-guided, collaborative, independent, and technology-supported stations may have encouraged students to manage task approaches, seek clarification, and engage actively while remaining aligned with common learning goals. However, the lower rating for connecting lessons to everyday life suggests that contextual application beyond classroom activities may require further emphasis. This interpretation aligns with Self-Determination Theory, which proposes that autonomy-supportive and structured learning environments strengthen engagement, ownership, and persistence (Deci & Ryan, 2000; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan et al., 2009), and is supported by studies linking differentiated instruction with increased learner voice, participation, and engagement (Black & Deci, 2000; Tomlinson et al., 2003; Khan et al., 2024; Rizalda, 2023).

3.2 Level of Learning Autonomy of Students After Exposure to the Four-Phase Gradual Release of Responsibility Model

Table 7. Beliefs About Teacher's Role After Exposure to Gradual Release of Responsibility

Statements	Mean	SD	Verbal Interpretation
My science teacher should set my learning goals for me.	2.00	0.72	Disagree
My science teacher should explain everything to us during science lessons.	1.42	0.55	Strongly Disagree
My science teacher should decide the objectives of our science lessons.	1.75	0.44	Disagree
My science teacher should decide all the activities we do in science class.	1.72	0.51	Strongly Disagree
My science teacher should choose all the materials we use in science learning.	1.86	0.72	Disagree
My science teacher should be responsible for evaluating my learning in science.	1.61	0.60	Strongly Disagree
Overall	1.73	0.42	Strongly Disagree

Legends: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low

Table 7 presents students' level of learning autonomy in terms of beliefs about the teacher's role following exposure to the Four-Phase Gradual Release of Responsibility (GRR) Model. The findings indicate that learners generally did not perceive the teacher as the sole authority in learning but instead viewed the teacher as a facilitator who gradually transferred responsibility throughout instruction. Statement 5 obtained the highest mean (M = 1.86; Disagree), reflecting continued recognition of the teacher's role in evaluating learning, whereas Statements 2 (M = 1.42; Strongly Disagree) and 6 (M = 1.61; Strongly Disagree) indicate reduced expectations for direct teacher explanation and full teacher responsibility for assessment.

These findings suggest that the Four-Phase GRR model supported reduced dependence on teacher-directed instruction while maintaining structured guidance. Through progression across focused instruction, guided learning, collaborative engagement, and independent application, students may have developed greater confidence in completing tasks and constructing understanding independently. Rather than removing teacher involvement, the model appears to reposition support toward facilitation and scaffolding while increasing learner ownership. This interpretation aligns with constructivist perspectives and the GRR framework, which emphasize the gradual transfer of cognitive responsibility through guided and reflective learning experiences (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Fisher & Frey, 2008), and supports previous findings linking learner-centered environments with increased engagement and autonomy (Ryan et al., 2009; Black & Deci, 2000; Khan et al., 2024).

Table 8. Metacognitive Knowledge After Exposure to Gradual Release of Responsibility

Statements	Mean	SD	Verbal Interpretation
I know my strengths and weaknesses in learning science.	2.89	0.62	Agree
I understand how I learn science best.	3.14	0.54	Agree
I know which strategies help me understand science concepts.	2.94	0.58	Agree
I know which science topics are difficult for me.	3.08	0.50	Agree
I know what I need to improve to learn science better.	3.31	0.53	Strongly Agree
Overall	3.07	0.41	Agree

Legends: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low

Table 8 presents students' level of metacognitive knowledge following exposure to the Four-Phase Gradual Release of Responsibility (GRR) Model. The overall mean score (M = 3.07), interpreted as Agree, indicates that students generally demonstrated awareness of their learning processes and understanding of science concepts throughout the intervention. The highest mean was observed in students' recognition of areas requiring improvement in science learning (M = 3.31; Strongly Agree), while the lowest mean was obtained in identifying their own strengths and weaknesses (M = 2.89; Agree), suggesting that deeper self-evaluation remained less developed.

These findings suggest that the gradual transfer of responsibility within the GRR model supported learners' awareness of how they learn and where improvement was needed. Through progression from teacher modeling to guided, collaborative, and independent learning experiences, students were encouraged to monitor understanding, recognize learning difficulties, and reflect on factors influencing performance. This pattern aligns with constructivist perspectives and the GRR framework, which emphasize reflective engagement and scaffolded experiences in developing metacognitive awareness and learner responsibility (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Fisher & Frey, 2008). The findings also support autonomy-oriented perspectives and previous studies linking responsive instructional environments with increased learner reflection and ownership of learning (Ryan et al., 2009; Nguyen & Habók, 2021; Marks et al., 2021).

Table 9. Metacognitive Skills After Exposure to Gradual Release of Responsibility

Statements	Mean	SD	Verbal Interpretation
I set goals for my science learning.	2.89	0.67	Agree
I plan how I will complete science tasks or investigations.	3.06	0.67	Agree
I check whether I understand science concepts during lessons.	3.06	0.63	Agree
I change my learning strategies if I do not understand a science topic.	2.89	0.62	Agree
I reflect on my progress in learning science.	3.03	0.51	Agree
I use feedback from my science teacher to improve my science work.	2.94	0.53	Agree
Overall	2.98	0.42	Agree

Legends: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low

Table 9 presents students' level of metacognitive skills following exposure to the Four-Phase Gradual Release of Responsibility (GRR) Model. The overall mean score (M = 2.98), interpreted as Agree, indicates that learners generally demonstrated the ability to plan, monitor, and evaluate their learning during science instruction. Statements 2 and 3 obtained the highest mean scores (M = 3.06), suggesting that students frequently planned task completion and monitored their understanding, whereas Statements 1 and 4 obtained the lowest mean scores (M = 2.89), indicating that independent goal-setting and strategy modification remained comparatively less developed.

These findings suggest that the scaffolded progression of the GRR model supported metacognitive regulation by encouraging learners to engage in planning, monitoring, reflection, and response adjustment across increasingly independent learning conditions. Through focused instruction, guided practice, collaborative engagement, and independent application, students gradually assumed greater responsibility for managing learning while continuing to receive structured support through teacher modeling, process questioning, formative feedback, and revision opportunities. This pattern aligns with constructivist perspectives and the GRR framework, which explain that reflective and scaffolded learning experiences strengthen planning, monitoring, and evaluation skills (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Fisher & Frey, 2008). Similar findings have been reported by Ruelens (2019), Pham (2022), and Nguyen and Nguyen (2020), linking these behaviors with developing self-regulation and learner autonomy.

Table 10. Desire to Engage After Exposure to Gradual Release of Responsibility

Statements	Mean	SD	Verbal Interpretation
I try to understand science lessons even when they are challenging.	3.39	0.55	Strongly Agree
I actively participate in science activities and discussions.	3.22	0.49	Agree
I am willing to do additional science tasks when given the opportunity.	3.17	0.56	Agree
I continue working on science tasks even when they are difficult.	3.17	0.56	Agree
I put effort into learning science beyond what is required.	3.08	0.69	Agree
Overall	3.21	0.41	Agree

Legends: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low

Table 10 presents students' level of desire to engage following exposure to the Four-Phase Gradual Release of Responsibility (GRR) Model. The overall mean score (M = 3.21), interpreted as Agree, indicates that learners generally demonstrated willingness to participate actively and sustain effort during science learning activities. The highest mean was observed in students' willingness to complete science tasks despite difficulty (M = 3.39; Strongly Agree), reflecting strong persistence, whereas the lowest mean (M = 3.17; Agree) indicated comparatively lower willingness to pursue science-related activities beyond formal classroom requirements.

These findings suggest that the scaffolded and progressively learner-directed structure of GRR supported students' engagement by gradually increasing responsibility across instructional phases. Through focused instruction, guided practice, collaborative engagement, and independent application, learners were encouraged to participate actively while developing greater ownership of learning outcomes, supported by teacher modeling, process questioning, formative feedback, and revision opportunities. However, the lower tendency to extend participation beyond classroom expectations suggests that additional opportunities for independent exploration may be needed to strengthen sustained engagement outside structured settings. This pattern aligns with Self-Determination Theory and the GRR framework, which explain that engagement increases when learners experience autonomy, competence, meaningful participation, and scaffolded responsibility (Deci & Ryan, 2000; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Fisher & Frey, 2008), and supports previous findings linking learner-centered environments with stronger participation and persistence (Black & Deci, 2000; Rizalda, 2023).

Table 11. Motivation After Exposure to Gradual Release of Responsibility

Statements	Mean	SD	Verbal Interpretation
I am motivated to learn science because it helps me understand real-life situations.	3.33	0.59	Strongly Agree
I am motivated to learn science because it is useful in everyday life.	3.19	0.62	Agree
I want to learn science so that I can help solve problems in my community.	3.11	0.58	Agree
Learning science is important because it develops my thinking skills.	3.33	0.48	Strongly Agree
I am interested in the science topics discussed in class.	3.31	0.58	Strongly Agree
Overall	3.26	0.44	Strongly Agree

Legends: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low

Table 11 presents students' level of motivation following exposure to the Four-Phase Gradual Release of Responsibility (GRR) Model. The overall mean score (M = 3.26), interpreted as Strongly Agree, indicates high motivation and sustained interest toward science learning throughout the intervention. Statements 1 and 4 obtained the highest mean scores (M = 3.33; Strongly Agree), showing that students were most motivated when science instruction emphasized real-world relevance and development of thinking skills. In contrast, Statements 2 and 3 obtained lower mean scores (M = 3.11; Agree), suggesting comparatively lower motivation toward broader and long-term applications of science beyond immediate learning experiences.

These findings suggest that students responded more strongly to contextualized, meaningful, and cognitively engaging learning experiences than to abstract future-oriented applications. The scaffolded structure of GRR may have supported motivation by progressively increasing participation and cognitive responsibility through focused instruction, guided participation, collaborative engagement, and independent application. Opportunities for teacher modeling, inquiry, problem solving, formative feedback, and independent task completion may have reinforced students' perceptions of competence and relevance while sustaining engagement. This interpretation aligns with Self-Determination Theory and previous research indicating that autonomy-supportive, scaffolded, and learner-centered environments strengthen motivation, participation, and positive attitudes toward science learning (Deci & Ryan, 2000; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Black & Deci, 2000; Fisher & Frey, 2008; Rizalda, 2023; Sapan & Mede, 2022).

Table 12. Freedom After Exposure to Gradual Release of Responsibility

Statements	Mean	SD	Verbal Interpretation
I have opportunities to explain my ideas during science class.	2.94	0.58	Agree
I am allowed to explore different solutions during science activities.	2.97	0.61	Agree
I ask questions when I do not understand a science topic.	3.14	0.68	Agree
I relate science lessons to real-life situations on my own.	3.22	0.54	Agree
I make choices about how I complete some of my science tasks.	3.14	0.64	Agree
Overall	3.08	0.43	Agree

Legends: 3.26 – 4.00 : Strongly agree/Very High, 2.51 – 3.25 : Agree/High, 1.75 – 2.50 : Disagree/Low, 1.00 – 1.74 : Strongly disagree/Very Low

Table 12 presents students' level of perceived freedom following exposure to the Four-Phase Gradual Release of Responsibility (GRR) Model. The overall mean score (M = 3.09), interpreted as Agree, indicates that learners generally perceived opportunities to make choices and exercise control over aspects of their science learning experiences. The highest mean was observed in students' ability to connect science lessons to real-world situations independently (M = 3.22), while the lowest mean (M = 2.94; Agree) was associated with opportunities to explain ideas aloud during class, suggesting comparatively fewer opportunities for verbal expression.

These findings suggest that the scaffolded and learner-centered structure of GRR supported perceived freedom by gradually transferring responsibility from teacher guidance toward independent learning. Through guided, collaborative, and independent phases, students were encouraged to question, explore alternatives, justify reasoning, and apply scientific understanding while remaining supported through clear instructional goals. The comparatively lower rating for verbal explanation indicates that additional opportunities for discussion may further strengthen confidence in communicating scientific understanding. This interpretation aligns with Self-Determination Theory and prior research suggesting that autonomy develops through structured support, increasing independence, and meaningful participation rather than the removal of instructional guidance (Deci & Ryan, 2000; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan et al., 2009; Fisher & Frey, 2008; Black & Deci, 2000; Khan et al., 2024).

3.3 Level of Critical-Thinking Skills of Students After Exposure to the Adaptive Station Rotation Model

Table 13. Analysis in Critical Thinking After Exposure to Adaptive Station Rotation

Score Range	f	%	Verbal Interpretation
13 – 15	--	--	Very High

10 – 12	37	86.05	High
7 – 9	4	9.30	Moderate
4 – 6	1	2.33	Low
0 – 3	1	2.33	Very Low
Total	43	100	

Table 13 presents students' level of analysis in critical-thinking skills following exposure to the Adaptive Station Rotation Model (ASRM). Results showed that most learners demonstrated a High level of analytical performance, with 37 out of 43 students (86.05%) classified in this category, indicating strong ability to interpret evidence, identify patterns, and analyze relationships among scientific concepts in contextualized tasks. Students in the Moderate level (9.30%) showed partial analytical performance and may have required additional support in interpreting evidence and connecting concepts, while those in the Low and Very Low levels demonstrated more limited analytical ability. No student reached the Very High level, suggesting that mastery-level, consistently independent evidence-based reasoning may require longer exposure to inquiry-oriented learning experiences.

These findings suggest that the differentiated and inquiry-based structure of ASRM supported analytical thinking by providing repeated opportunities for contextualized problem solving, interpretation of scientific evidence, and evaluation of alternative explanations across varied learning conditions. Through teacher-guided, collaborative, and independent stations, students engaged in identifying variables, comparing explanations, interpreting evidence, and justifying conclusions while assuming increasing responsibility for learning. This pattern aligns with constructivist perspectives that view analytical thinking as developing through inquiry, reflection, and evidence evaluation (Bruner, 1966; Piaget, 1970; Vygotsky, 1978), and supports previous findings linking differentiated and inquiry-oriented instruction with stronger critical thinking and cognitive engagement in science learning (Walsh et al., 2019; Tomlinson et al., 2003; Rizalda, 2023).

Table 14. Evaluation in Critical Thinking After Exposure to Adaptive Station Rotation

Score Range	f	%	Verbal Interpretation
13 – 15	1	2.33	Very High
10 – 12	31	72.09	High
7 – 9	8	18.60	Moderate
4 – 6	3	6.98	Low
0 – 3	--	--	Very Low
Total	43	100	

Table 14 presents students' level of evaluation in critical-thinking skills following exposure to the Adaptive Station Rotation Model (ASRM). Results showed that most learners demonstrated High evaluative performance, with 31 of 43 students (72.09%) classified under the High category and one learner (2.33%) reaching the Very High level. Meanwhile, eight learners (18.60%) were categorized as Moderate and three learners (6.98%) as Low, with no students classified under the Very Low category. These findings indicate that most students were able to assess scientific evidence, compare explanations, and justify conclusions within contextualized science tasks.

The findings suggest that ASRM supported the development of evaluative reasoning by providing repeated opportunities to verify information, compare alternative explanations, and defend conclusions across teacher-

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guided, collaborative, independent, and technology-supported learning stations. Students at higher performance levels demonstrated stronger ability to evaluate evidence and justify scientific claims, whereas those in lower categories relied more on surface-level indicators and required additional instructional support. Opportunities for discussion, feedback, and revision may have reinforced evidence-based judgment and strengthened learners' confidence in evaluating scientific claims. This pattern aligns with constructivist perspectives and previous research emphasizing inquiry, reflection, and evidence evaluation as foundations of scientific critical thinking (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Walsh et al., 2019; Tomlinson et al., 2003; Rizalda, 2023).

Table 15. Making-Inference in Critical Thinking After Exposure to Adaptive Station Rotation

Score Range	f	%	Verbal Interpretation
13 – 15	4	9.30	Very High
10 – 12	27	62.79	High
7 – 9	10	23.26	Moderate
4 – 6	1	2.33	Low
0 – 3	1	2.33	Very Low
Total	43	100	

Table 15 presents students' level of making inference in critical-thinking skills following exposure to the Adaptive Station Rotation Model (ASRM). Results showed that most learners demonstrated High inferential reasoning, with 27 out of 43 students (62.79%) classified under this category, while four learners (9.30%) achieved the Very High level. Ten learners (23.26%) were categorized as Moderate, and only one learner each fell under the Low and Very Low levels. These findings indicate that most students were able to draw logical conclusions from scientific evidence by interpreting information, identifying relationships, and generating evidence-based explanations within contextualized science tasks.

The findings suggest that the inquiry-oriented and differentiated structure of ASRM supported inferential reasoning by repeatedly engaging learners in interpreting evidence, recognizing patterns, and constructing conclusions across varied learning conditions. Through teacher-guided, collaborative, independent, and technology-supported stations, students were encouraged to connect evidence with real-world situations, compare interpretations, justify conclusions, and verify the logical strength of emerging explanations. Learners at higher performance levels demonstrated stronger independent reasoning and more consistent use of evidence, whereas those in lower categories required additional support in integrating information and developing scientifically grounded conclusions. This pattern aligns with constructivist perspectives and previous studies emphasizing inquiry, reflection, and contextual engagement as foundations for inferential reasoning and evidence-based thinking in science learning (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Walsh et al., 2019; Tomlinson et al., 2003; Rizalda, 2023).

3.4 Level of Critical-Thinking Skills of Students After Exposure to the Four-Phase Gradual Release of Responsibility Model

Table 16. Analysis in Critical Thinking After Exposure to Gradual Release of Responsibility

Score Range	f	%	Verbal Interpretation
13 – 15	29	80.56	Very High
10 – 12	4	11.11	High
7 – 9	3	8.33	Moderate

4 – 6	--	--	Low
0 – 3	--	--	Very Low
Total	36	100	

Table 16 presents students' level of analysis in critical-thinking skills following exposure to the Four-Phase Gradual Release of Responsibility (GRR) Model. Results showed that most learners demonstrated Very High analytical reasoning, with 29 out of 36 students (80.56%) classified in this category, while four learners (11.11%) achieved High performance and three learners (8.33%) were categorized as Moderate. No students were classified under the Low or Very Low levels, indicating that all participants demonstrated at least functional analytical reasoning during science learning. These findings suggest that learners generally exhibited strong ability to interpret evidence, identify patterns, recognize conceptual relationships, and analyze contextualized scientific tasks.

The findings suggest that the scaffolded and sequential structure of the GRR model supported analytical thinking by gradually transferring responsibility for interpreting evidence and constructing explanations. Through explicit modeling, process questioning, guided practice, collaborative engagement, and independent application, students repeatedly engaged in examining evidence, recognizing patterns, and justifying conclusions using scientific reasoning. Greater opportunities for independent interpretation across instructional phases may have strengthened reflective and intentional approaches to analytical problem solving. This interpretation aligns with constructivist perspectives and the GRR framework, which emphasize reflective engagement, structured support, and progressive independence in developing higher-order thinking (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Fisher & Frey, 2008), and supports previous findings linking scaffolded and learner-centered instruction with stronger analytical reasoning and critical thinking in science learning (Walsh et al., 2019; Rizalda, 2023).

Table 17. Evaluation in Critical Thinking After Exposure to Gradual Release of Responsibility

Score Range	F	%	Verbal Interpretation
13 – 15	26	72.22	Very High
10 – 12	6	16.67	High
7 – 9	4	11.11	Moderate
4 – 6	--	--	Low
0 – 3	--	--	Very Low
Total	36	100	

Table 17 presents students' level of evaluation in critical-thinking skills following exposure to the Four-Phase Gradual Release of Responsibility (GRR) Model. Results showed that most learners demonstrated Very High evaluative reasoning, with 26 out of 36 students (72.22%) classified in this category, while six learners (16.67%) achieved High performance and four learners (11.11%) were categorized as Moderate. No learners were classified under the Low or Very Low levels, indicating consistently favorable evaluative performance across the group. These findings suggest that students developed strong ability to assess scientific evidence, compare competing explanations, determine credibility, and justify conclusions using scientific reasoning.

The findings suggest that the structured and scaffolded design of the GRR model supported the development of evaluative reasoning by providing repeated opportunities to examine evidence, reconsider assumptions, and defend conclusions across increasingly independent learning phases. Through focused instruction, guided practice, collaborative engagement, and independent application, learners engaged in evidence-based decision-making supported by teacher modeling, process questioning, formative feedback, and gradual reduction of instructional support. Students at higher performance levels demonstrated more independent and consistent evaluation, whereas those in the Moderate category benefited from additional guidance in validating explanations. This interpretation aligns with constructivist perspectives and the GRR framework, which emphasize reflective inquiry, scaffolded cognitive support, and progressive independence in developing higher-order thinking (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Fisher & Frey, 2008), and supports previous findings linking learner-centered instruction with stronger evaluative reasoning and scientific decision-making (Walsh et al., 2019; Rizalda, 2023).

Table 18. Making-Inference in Critical Thinking After Exposure to Gradual Release of Responsibility

Score Range	F	%	Verbal Interpretation
13 – 15	24	66.67	Very High
10 – 12	9	25.00	High
7 – 9	3	8.33	Moderate
4 – 6	--	--	Low
0 – 3	--	--	Very Low
Total	36	100	

Table 18 presents students' level of making inference in critical-thinking skills following exposure to the Four-Phase Gradual Release of Responsibility (GRR) Model. Results showed that most learners demonstrated Very High inferential reasoning, with 24 out of 36 students (66.67%) classified in this category, while nine learners (25.00%) achieved High performance and three learners (8.33%) were categorized as Moderate. No learners were classified under the Low or Very Low levels, indicating that all participants demonstrated at least functional inferential ability. These findings suggest that students generally showed strong capacity to interpret evidence, identify relationships, and generate logical conclusions from contextualized scientific situations.

The findings suggest that the scaffolded and sequential structure of GRR supported inferential thinking by progressively transferring responsibility from teacher-supported reasoning to independent conclusion-making. Through focused instruction, guided activities, collaborative engagement, and independent application, learners repeatedly interpreted evidence, recognized patterns, justified conclusions, and determined implications using decreasing levels of instructional support. Opportunities for modeling, questioning, feedback, and collaborative discussion may have strengthened students' ability to construct evidence-based explanations and reason more independently. This interpretation aligns with constructivist perspectives and the GRR framework, which emphasize reflective inquiry, interpretation, and gradual transfer of cognitive responsibility in developing higher-order thinking (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Fisher & Frey, 2008), and supports previous findings linking scaffolded and learner-centered instruction with stronger inferential reasoning and scientific explanation (Walsh et al., 2019; Rizalda, 2023).

3.5 Difference in the Posttest Learning Autonomy of Students Exposed to the Adaptive Station Rotation Model and the Four-Phase Gradual Release of

Table 19. Test of Difference in Learning Autonomy between Adaptive Station Rotation Model and Four-Phase Gradual Release of Responsibility Model

Learning Autonomy	ASRM		GRR		t-value	p-value
	Mean	SD	Mean	SD		
Beliefs about Teacher's Role	1.92	0.26	1.73	0.42	2.504	0.014

Metacognitive Knowledge	3.13	0.38	3.07	0.41	0.600	0.550
Metacognitive Skills	3.06	0.30	2.98	0.42	1.055	0.295
Desire to engage	3.21	0.30	3.21	0.41	0.047	0.963
Motivation	3.37	0.35	3.26	0.44	1.315	0.193
Freedom	2.98	0.43	3.08	0.43	-1.049	0.298

Table 19 presents the test of difference in learning autonomy between students exposed to the Adaptive Station Rotation Model (ASRM) and the Four-Phase Gradual Release of Responsibility (GRR) Model. Results showed that among the six dimensions of learning autonomy, only beliefs about the teacher's role demonstrated a statistically significant difference ($t = 2.504$, $p = 0.014$), whereas metacognitive knowledge, metacognitive skills, desire to engage, motivation, and perceived freedom showed no significant differences ($p > 0.05$). Learners exposed to GRR ($M = 1.73$) demonstrated lower dependence on teacher-directed learning than those exposed to ASRM ($M = 1.92$), indicating greater perceived transfer of responsibility from teacher to learner.

These findings suggest that the sequential structure of GRR may have strengthened learner autonomy specifically by progressively reducing teacher support through focused instruction, guided practice, collaborative learning, and independent performance. In contrast, ASRM promoted participation through differentiated stations but maintained visible teacher support and feedback across activities, which may have reinforced perceptions of teacher involvement. Despite this difference, the absence of significant variation across the remaining dimensions suggests that both approaches created similarly autonomy-supportive environments through shared features such as contextualized tasks, collaboration, formative feedback, process questioning, and opportunities for independent learning. This pattern supports constructivist perspectives and Self-Determination Theory, which emphasize active participation, structured support, and increasing learner ownership as foundations of autonomy development (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Deci & Ryan, 2000; Ryan & Deci, 2000a; Ryan & Deci, 2000b; Ryan et al., 2009), and aligns with previous findings linking learner-centered instruction with greater responsibility and engagement (Black & Deci, 2000; Khan et al., 2024).

3.6 Difference in the Posttest Critical-Thinking Skills of Students Exposed to the Adaptive Station Rotation Model and the Four-Phase Gradual Release of Responsibility Model

Table 20. Test of Difference in Critical Thinking Skills Between Adaptive Station Rotation and Four-Phase Gradual Release of Responsibility

Critical-Thinking Skills	ASRM		GRR		t-value	p-value
	Mean	SD	Mean	SD		
Analysis	10.37	1.66	13.75	2.08	-8.033	< .001
Evaluation	10.12	1.80	13.28	2.31	-6.826	< .001
Making-Inference	10.30	1.98	12.83	1.95	-5.695	< .001

Table 20 presents the test of difference in critical-thinking skills between students exposed to the Adaptive Station Rotation Model (ASRM) and the Four-Phase Gradual Release of Responsibility (GRR) Model. Results revealed statistically significant differences across all dimensions of critical-thinking skills: analysis ($t = -8.033$, $p < .001$), evaluation ($t = -6.826$, $p < .001$), and making inference ($t = -5.695$, $p < .001$). Across all dimensions, learners exposed to GRR obtained higher mean scores than those exposed to ASRM, with higher performance in analysis ($M = 13.75$), evaluation ($M = 13.28$), and making inference ($M = 12.83$) compared with ASRM scores of 10.37, 10.12, and 10.30, respectively.

These findings suggest that GRR more strongly supported students' ability to analyze scientific information, evaluate evidence and explanations, and generate logical conclusions from contextualized science tasks. The scaffolded and sequential structure of GRR may have strengthened reasoning processes through repeated opportunities for teacher modeling, guided questioning, feedback, and progressively independent application, allowing students to consolidate evidence-based thinking before performing autonomously. In contrast, although ASRM promoted inquiry, differentiated engagement, and flexible participation across learning stations, its rotational design may have distributed attention across multiple learning experiences rather than sequentially reinforcing reasoning development. This interpretation aligns with constructivist perspectives and the GRR framework, which emphasize guided inquiry, structured cognitive support, and gradual transfer of responsibility in developing higher-order thinking (Bruner, 1966; Piaget, 1970; Vygotsky, 1978; Fisher & Frey, 2008), and supports previous findings linking scaffolded science instruction with stronger critical-thinking performance (Walsh et al., 2019; Rizalda, 2023).

4 Conclusion and implication

This study examined the effects of Contextualized Adaptive Differentiated Instruction (CADi), operationalized through the Adaptive Station Rotation Model (ASRM) and the Four-Phase Gradual Release of Responsibility (GRR) Model, on Grade 9 learners' learning autonomy and critical-thinking skills in science.

Findings showed that both instructional models supported favorable learning autonomy outcomes across beliefs about teacher's role, metacognitive knowledge, metacognitive skills, desire to engage, motivation, and freedom. Comparative results further indicated that learning autonomy outcomes were generally comparable between groups, with the exception of beliefs about teacher's role, where learners exposed to GRR demonstrated lower dependence on teacher-directed instruction. These findings suggest that both rotational and scaffolded instructional structures can support learner participation, self-regulation, engagement, and increasing responsibility for learning when implemented within contextualized and differentiated learning environments.

In terms of critical-thinking skills, both instructional models supported learners' ability to analyze information, evaluate evidence, and generate reasoned conclusions; however, learners exposed to GRR consistently demonstrated stronger observed performance across all dimensions. The results suggest that scaffolded and sequential instructional support may provide stronger conditions for developing scientific reasoning than rotational instructional organization under the conditions of this study.

Overall, the findings highlight that contextualized, differentiated, and learner-centered science instruction can support both autonomy and higher-order thinking, but instructional structure may influence which outcomes are strengthened more strongly. Instructional approaches similar to ASRM may be useful when emphasizing learner engagement and autonomy-related outcomes, whereas scaffolded approaches similar to GRR may be more suitable when the instructional objective prioritizes analysis, evaluation, and inferential reasoning. Future studies may further examine these outcomes across different contexts, learner populations, durations, and research designs to strengthen understanding of how instructional organization shapes learner development.

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