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Learning Engagement in Reaction Kinetics: A Three-Dimensional Analysis in an Integrated Islamic Senior High School

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Abstract

Education plays a vital role in promoting students' academic success, particularly in subjects that involve abstract and complex concepts such as reaction rates in chemistry. These concepts integrate macroscopic, microscopic, and symbolic aspects, which often lead to misconceptions when not properly understood. Therefore, students' learning engagement encompassing behavioral, emotional, and cognitive dimensions is essential to foster meaningful understanding. This study aims to analyze the learning engagement of eleventh-grade students in the reaction rate topic at Integrated Islamic Senior High School Al-Mumtaz Pontianak during classroom learning activities. A descriptive qualitative approach was employed involving 18 students enrolled in the chemistry specialization for the 2024/2025 academic year. Data were collected through observation, interviews, and documentation. The findings reveal varied levels of engagement across the three dimensions. Behaviorally, students demonstrated active participation in academic tasks, although attendance consistency and adherence to classroom rules require improvement. Emotionally, students expressed enjoyment during the learning process, yet their specific interest in the reaction rate topic remains limited. Cognitively, students exhibited high motivation and initiative, particularly in collaborative learning contexts and through the use of diverse learning resources and strategies to enhance conceptual understanding. These findings emphasize the need to cultivate balanced engagement across behavioral, emotional, and cognitive domains to strengthen students' conceptual mastery in chemistry learning.

Keywords: chemistry education, learning engagement, reaction rate, student motivation

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1. Introduction

The rapid transformation of education and the increased integration of learning technology require instructional approaches that support effective, efficient learning aligned with current demands (Masgumelar & Mustafa, 2021; Syaputra & Hasanah, 2022; Fahrozy et al., 2022). In Indonesia, the implementation of the Merdeka Curriculum further emphasizes student autonomy in selecting subjects based on interest, talent, and learning needs, which places greater responsibility on schools to ensure learning experiences are engaging and meaningful (Adhyatma, 2023).

Student engagement is widely viewed as a key contributor to academic success because it reflects students' sustained involvement and investment in learning activities, supported by motivation, self-efficacy, peer interaction, and learning perseverance (Shao & Kang, 2022; Zhong et al., 2022). Engaged students tend to participate actively, respond constructively, enjoy the learning process, and strive for better achievement outcomes (Christanty & Cendana, 2021). Empirical evidence across subjects also shows a positive relationship between engagement and achievement (Bariyah, 2017; Sa'adah & Ariati, 2020), as well as broader academic performance and learner well-being (Rajabalee et al., 2020; Kathleen, 2015; Reina et al., 2014). Conversely, low engagement may appear as low interest and motivation, which can contribute to problematic behaviors such as skipping school (Damayanti & Setiawati, 2013). Therefore, engagement is not merely a desirable classroom atmosphere but a learning condition closely tied to students' persistence and achievement.

This issue becomes especially critical in chemistry, where students' interest and engagement can strongly influence success in conceptually demanding topics. Reaction rate, commonly taught in Grade XI, is frequently perceived as difficult because it requires understanding abstract concepts, remembering and applying relationships, performing calculations, and analyzing factors that affect rate—often through laboratory or inquiry activities (Efliana & Azhar, 2019). Importantly, reaction rate understanding depends on students' ability to coordinate chemistry's three levels of representation: macroscopic (observable phenomena), microscopic/submicroscopic (particulate explanations), and symbolic (formulas, equations, graphs, and quantitative relationships). Macroscopic representations can be directly observed in experiments, but microscopic representations are abstract and often need visualization support such as diagrams, animations, or simulations to depict particle interactions. Symbolic representations provide a language for reasoning and calculation, including chemical equations and mathematical expressions (Gilbert & Treagust, 2009).

However, instruction that emphasizes macroscopic and symbolic work without explicitly connecting to microscopic reasoning risks producing fragmented understanding and learning difficulties in reaction rate (Khaeruman et al., 2015). From a constructivist perspective, students build meaning based on prior knowledge and learning experiences, which implies that misconceptions can persist when learners cannot reconcile what they see in experiments with what happens at the particle level (Yamtinah et al., 2014). In this context, engagement in chemistry should be understood not only as participation, but also as students' willingness to invest effort in making sense of representations and linking them into coherent explanations.

Despite the recognized importance of engagement, two gaps remain prominent in chemistry education research and classroom practice. First, studies that identify engagement indicators are still limited in chemistry topics that demand coordination of multiple representation levels, such as reaction rate. Engagement is often measured generally, without closely examining how it manifests when students must shift between macroscopic observations, particulate explanations, and symbolic reasoning. Second, students continue to show persistent difficulty in connecting macroscopic observations to particulate (microscopic) explanations, which can weaken conceptual understanding and potentially reduce sustained engagement during learning activities. These gaps highlight the need to examine students' learning engagement specifically within reaction rate learning that requires representational integration.

Based on these considerations, this study focuses on describing students' learning engagement in reaction rate material at Integrated Islamic Senior High School Al-Mumtaz Pontianak during classroom teaching and learning activities, with the objective of determining the profile of students' learning engagement in the reaction rate topic in the classroom context.

2. Research Methods

2.1. Research Design

This study employed a descriptive qualitative design to explore how student learning engagement emerges during the teaching and learning process of reaction rate in chemistry. A qualitative approach was selected because engagement is expressed through observable classroom behaviors, interactions, and meaning-making processes that are best captured through detailed descriptions and participants' perspectives. The focus was not to test a causal relationship, but to construct a rich account of engagement patterns and their context among Grade XI students taking chemistry specialization in the 2024/2025 school year at Integrated Islamic Senior High School Al-Mumtaz Pontianak.

2.2. Participants and Sampling Justification

Participants consisted of 18 Grade XI students who chose the chemistry specialization subject. The sample was selected using purposeful sampling because these students were directly involved in reaction rate learning activities and could provide information-rich cases relevant to the study focus. The number of participants was considered adequate for qualitative inquiry because the aim was depth rather than statistical generalization; moreover, the class constituted a bounded group, allowing intensive observation across multiple meetings and cross-checking of engagement patterns across students. Teacher participants were also included as key informants to support interpretation of classroom practices and student responses.

2.3. Data Sources and Data Collection Procedures

To obtain reliable and structured information, this study used triangulated data sources: non-participant observation, semi-structured interviews, and documentation.

2.3.1. Classroom Observation (Non-Participant)

Observation was conducted through non-participatory (passive) observation, where the researcher attended the classroom to record events without intervening in learning activities (Sugiyono, 2019). Observation was used to capture engagement indicators as they occurred naturally (Patton, 2002), including participation, attention, questioning, persistence, peer collaboration, and representational linking behaviors relevant to reaction rate learning. Field notes were written during and immediately after lessons, emphasizing thick description (detailed accounts of setting, tasks, teacher prompts, student actions, and peer interactions) so that readers can understand engagement within the classroom context.

The observation sheet was used to observe students' activities during the research by using sheets that contained contextual-based aspects. Observation sheet as an evaluation tool commonly used to assess individual behavior or processes that occur in an activity that can be observed (Sudijono, 2007). The sheet used is an observation sheet, with a checklist form on the observation indicators shown in Table 1.

Table 1. Observation Indicators

No	Solution	Concentration
1	Behavioral Engagement	Students attendance Learning environment rules Student's behavioral during the class Academic tasks
2	Emotional Engagement	Students interest Student' feelings during learning
3	Cognitive Engagement	Students' strategies for learning

(Zanira & Cahyadi, 2021)

To improve consistency, the researcher used an observation guide that focused on: 1) Lesson phases (introduction, exploration, discussion, practice, closure); 2) Student responses (verbal contributions, nonverbal cues, collaboration); 3) Task demands involving macroscopic – microscopic – symbolic representations; 4) Moments of confusion, persistence, and representational shifts (e.g., moving from observing a demo to explaining particulate collisions).

2.3.2. Semi-structured Interviews

Interviews were conducted as semi-structured interviews using guiding questions while allowing probing questions to follow participants' answers (Stewart & Cash, 2012). Interviews involved the chemistry teacher(s) and selected students to clarify observed behaviours and to capture participants' perceptions of engagement, difficulties, and learning experiences during reaction rate lessons. Student interviews targeted concrete episodes from observations (e.g., "During the experiment when the reaction sped up, what were you thinking?") to support alignment between self-reports and observed classroom behaviour.

An interview guide is a guide used during the interview process to gather information from research participants. In addition, this guideline also serves to remind the researcher of the aspects that need to be discussed and the interview serves as a checklist to ensure that all aspects have been asked or discussed. The aspects to be explored in the interviews are as shown in Table 2.

Table 2. Interview Guideline Grid

No	Aspects	Informant	Grid
1	Behavioral Engagement	Teachers	Development of understanding related to the subject matter.
			Duties.
			Assessment.
			Discussion.
		Students	Understanding of the subject matter.
			Duties.
			Discussion.
			Class rules.
2	Emotional Engagement	Teachers	Interest/Enthusiasm
			Feelings
		Students	Interest/Enthusiasm
			Feelings
3	Cognitive Engagement	Teachers	Use of teaching strategies
			Additional literature
		Students	Use of teaching strategies
			Additional literature

(Van Dulmen et al., 2023)

2.3.3. Documentation

Documentation was used to collect complementary evidence such as lesson plans, student work samples, photos of class activities, and video recordings of learning sessions (Sukmadinata, 2010). These materials served two purposes: (a) to provide additional context about tasks and learning design, and (b) to enable repeated review of key moments where engagement was visible (e.g., student discussion while interpreting a graph or explaining particle collisions).

2.4. Data Analysis: Coding and Analytic Procedures

Data analysis followed an iterative coding process across observation notes, interview transcripts, and documentation.

2.4.1. Data Preparation

Data preparation involved several steps: (1) Observation notes were typed and organized by date and lesson phase; (2) Interviews were transcribed verbatim; (3) Documentation, including photos, videos, and student work, was cataloged and linked to the related lesson and observation notes.

2.4.2. First-Cycle Coding (Open / Descriptive Coding)

The researcher conducted line-by-line coding to identify initial engagement indicators (e.g., "asks clarification," "explains using particle model," "persists after error," "off-task talk"). Codes were deliberately kept close to participants' observable actions and verbatim expressions, ensuring that the coding process remained descriptive rather than inferential and avoiding premature interpretation during the early stages of analysis, while preserving analytic openness for subsequent category development.

2.4.3. Second-Cycle Coding (Pattern / Thematic Coding)

Codes were clustered into broader categories aligned with engagement dimensions (e.g., behavioral participation, cognitive investment, emotional responses) and chemistry-specific engagement features (e.g., representational translation, macro – micro connection attempts, symbolic reasoning linked to phenomena), enabling a more systematic interpretation of students' learning behaviors and disciplinary thinking.

2.4.4. Cross-Source Triangulation

Themes were systematically checked across multiple data sources; an engagement indicator was treated as strong when it appeared consistently in (a) classroom observations and (b) interview data and/or supporting documentation, thereby enhancing the credibility and robustness of the findings through triangulation.

2.4.5. Analytic Matrix

To improve transparency and credibility, findings were summarized in an analytic matrix mapping:

student(s) / lesson phase → engagement indicator(s) → evidence source(s) → interpretive note

This matrix helped ensure that each interpretation was grounded in data rather than impressions.

2.5. Ethical Considerations

Student identities were protected through pseudonyms or participant codes (e.g., S01–S18). Participation was voluntary, and data were used only for research purposes. Photos/videos were stored securely and used in reporting only in ways that protect participant privacy, ensure confidentiality, and prevent any form of personal identification or unintended disclosure of sensitive information.

3. Result and Discussion

This section reports and interprets students' engagement during reaction rate learning by organizing findings into behavioral, emotional, and cognitive engagement (Fredricks et al., 2004). Interpretation is further situated within the representational demands of chemistry learning — particularly the need to coordinate macroscopic, submicroscopic / particulate, and symbolic representations (Tümay, 2016). To explain why engagement strengthened in some activities but weakened in others, findings are also discussed using Self-Determination Theory (SDT), emphasizing how learning conditions may support or constrain students' needs for autonomy, competence, and relatedness (Deci & Ryan, 2013).

3.1. Behavioral Engagement

Behavioral engagement refers to students' visible participation and academic conduct, including attendance, rule-following, attention, task completion, and involvement in classroom activities (Juwita & Kusdiyati, 2015). Based on observation and interview data (Table 3), behavioral engagement in Grade XI reaction rate learning at Integrated Islamic Senior High School Al-Mumtaz Pontianak appears moderate: students generally participate in academic tasks and comply with instructional demands, yet several indicators reflect uneven discipline, fluctuating on-task behavior, limitations in sustained attention throughout the learning process, particularly during extended discussions and independent problem-solving activities.

Table 3. Behavioral Engagement Observation Results

Indicator	Observed Activities	Observation Results	Information
Student attendance	Students attend class on time.	Learning is carried out less on time because there is a change of lesson hours and moving classrooms and there are still some students who leave the school environment to buy practicum needs when learning is about to start so that learning is not on time according to the schedule.	Observed during the implementation of practical observations, learning1 and learning 2
	Students are late for class.	There were students who were late entering the classroom because some bought practicum needs outside the school environment and did not immediately enter the class at the turn of the class lesson hours.	Observed during the implementation of practical observations and learning 1
Learning environment rules	Students are orderly in following the lesson.	The learning environment is less orderly because there are some students who are busy chatting with friends, eating and drinking and playing games on the laptop when the teacher explains.	Observed during the implementation of practical observations, learning 1 and learning 2
	Students use cell phones in learning without direction from the teacher.	The use of cell phones is directed by the teacher for students to do practice questions on Quiz and for the purposes of documenting experiments during practicum and the use of cell phones can only be used 1 cell phone per group, but there is still 1 person who uses a laptop without direction to play games.	Observed during the implementation of learning observations 1 and 2
Student behavior	Students pay attention to the teacher's explanation during the lesson.	Some students are still not paying attention to the teacher's explanation because they are chatting with friends and there is even 1 person who often sleeps in class so they don't pay attention to the teacher's explanation.	Observed during the implementation of practical observations and learning 2
	Students remain concentrated in following the lesson even	Students are often disturbed when there are outside distractions, such	Observed during the implementation of practical observations

Indicator	Observed Activities	Observation Results	Information
	though there are outside interference.	as other students peeking and talking loudly from windows and doors, causing students to look at the door and talk to people outside.	and learning 1
Academic assignments	Students work on tasks given by the teacher.	Students work on the tasks given, most of the tasks are given to be done in groups in the form of questions on quizzes and *LKPD* (Students' Worksheet)	Observed during the implementation of practical observations, learning1 and learning 2
	Students take notes on important things explained by the teacher.	Students take notes on the teacher's explanation and the material displayed from the Powerpoint and some make additional notes at home.	Observed during the implementation of practical observations and learning 1
Participation in Learning	Students are actively involved in discussions during learning.	Students actively discuss in working in groups and share tasks and parts when working.	Observed during the implementation of practical observations and learning 1
	Students are active in responding to questions given by the teacher.	4-6 students often ask questions if something is unclear and respond to teacher questions during material review.	Observed during the implementation of practical observations, learning1 and learning 2.

In terms of attendance and punctuality, learning frequently begins later than scheduled due to classroom transitions and students leaving the school area to purchase practicum materials. These delays are consistent across practicum observation and learning sessions 1–2. The teacher confirms this pattern, stating that class often requires time to settle and the fastest start is typically "within 15 minutes." This indicates that behavioral engagement is constrained by classroom routines and readiness. From an SDT lens, such repeated delays may weaken students' sense of structured competence in managing learning time and reduce opportunities for immediate task immersion.

Regarding classroom rules and on-task behavior, the learning environment is occasionally less orderly. Observations document students chatting, eating/drinking, and one student playing games on a laptop while the teacher explains. Although the teacher directs cell phone use for learning purposes (e.g., Quiz activities, documentation of practicum) and limits usage to one phone per group, non-instructional device use still occurs. These patterns suggest that behavioral engagement is not uniformly distributed across the class and that a subset of students disengage behaviorally during teacher explanations. The presence of a student who frequently sleeps in class further indicates reduced attentional engagement at key instructional moments.

Behavioral engagement is also influenced by external distractions. During some lessons, noise and interruptions from other students outside the classroom cause learners to shift attention toward doors/windows and engage in side interactions. A student explicitly notes being disturbed "especially because of loud voices and the sound of people playing," indicating that concentration is vulnerable to environmental interruptions. Such conditions reduce sustained attention and can disrupt persistence during cognitively demanding phases, weakening students' ability to maintain focus, regulate behavior, and consistently engage with instructional explanations, problem-solving processes, and teacher-guided learning activities over time, particularly in open or less controlled classroom settings.

Despite these constraints, students demonstrate meaningful behavioral engagement through task completion and participation. Most assignments are completed in groups through quizzes and *LKPD* (Students' Worksheet) and are submitted on time when tasks are assigned for same-day completion. The teacher notes that in-class submissions tend to be punctual, while homework submission rates drop (reported as less than 50% in some cases). Student reports similarly indicate that tasks completed at school are timely, whereas practicum reports take longer. This pattern suggests that behavioral engagement strengthens when tasks are embedded within structured classroom time and peer accountability but weakens when completion depends on independent regulation outside class—consistent with SDT's distinction between supported and unsupported self-regulation.

Students also demonstrate engagement through note-taking. Many record key points from teacher explanations and PowerPoint slides, and some extend notes at home. The teacher reports that students voluntarily "wanted to record everything from the PowerPoint" even without explicit instruction, suggesting proactive academic behavior. Finally, participation is visible in group discussions and questioning: students divide roles and collaborate during group tasks, and approximately 4–6 students frequently ask questions and respond during review sessions. These behaviors represent strong behavioral indicators of engagement and also create conditions that support relatedness and competence through peer exchange.

Overall, behavioral engagement shows a dual pattern: participation in learning tasks and collaborative group interactions is consistently evident and reflects students' willingness to be involved in classroom activities. However, aspects such as punctuality, sustained attention during teacher explanations, and orderly classroom behavior remain areas that require more structured instructional strategies, clearer routines, and supportive learning environments to be effectively strengthened and maintained, particularly to promote consistency, self-regulation, and sustained engagement across different lesson phases and learning demands.

3.2. Emotional Engagement

Emotional engagement refers to students' affective responses to learning, including interest, enjoyment, boredom, anxiety, and feelings of connection with teachers, peers, and learning activities. The observation results (Table 4) indicate that emotional engagement is generally positive during reaction rate learning, particularly during practicum sessions and group-based quiz activities, where students demonstrate higher enthusiasm, active participation, and positive peer interaction. These learning contexts appear to foster a more supportive and motivating atmosphere, helping to reduce anxiety and increase students' enjoyment and sense of involvement in the learning process, while encouraging emotional comfort, mutual support, and sustained willingness to engage in classroom tasks.

Students appear eager to participate, as seen in their enthusiasm when completing tasks and responding to teacher questions. Interviews reinforce this observation, with students describing learning as "fun and exciting," especially practicum activities, which they find engaging and not monotonous. The teacher similarly estimates that around "90% of the children are enthusiastic" and notes that quiz activities support discussion and learning. These findings align with SDT, suggesting that group quizzes and practicum may satisfy relatedness, strengthen competence, and provide a degree of autonomy, thereby sustaining positive affect, motivation, and students' willingness to remain actively involved throughout the learning process, even when tasks become more challenging or conceptually demanding.

Table 4. Emotional Engagement Observation Results

Indicator	Observed Activities	Observation Results	Information
Student Interests	Students feel interested in learning in class.	Students seemed eager to participate in the learning process as seen from their enthusiasm when working on problems and enthusiastically answering questions from the teacher.	Observed during the implementation of practical observations, learning1 and learning 2
Student Feelings During Learning	Students feel interested in learning in class.	Students feel happy and enthusiastic about learning using quiz and learning in groups.	Observed during the implementation of practical observations, learning1 and learning 2.
	Students are confident when presenting in class.	In learning reaction rate material, students do not make presentations in class because the tasks on the *LKPD* are not presented but are collected directly to the teacher. In addition, the practicum experiment reports were made in the form of videos or infographics so they were not presented either.	Observed during the implementation of learning observations 1 and 2

However, emotional engagement does not imply the absence of difficulty. Although students express enjoyment, some report challenges—particularly in reaction order items that require careful interpretation of presented data. One student notes continued difficulty in the reaction order section, indicating that interest coexists with moments of uncertainty. The teacher's account that only about half the class reaches completion criteria on tests (with a small number scoring below 50 or 40) suggests that emotional enthusiasm may not always translate into uniformly strong performance across students. In representational terms (Tümay, 2016), emotional engagement may be strongest during macroscopic, concrete experiences (practicum) and weaker when tasks shift toward symbolic/data processing (reaction order analysis), especially for students with lower perceived competence.

The data also show that students do not engage in in-class presentations because *LKPD* tasks and practicum products are submitted directly (e.g., videos/infographics) rather than presented. While this does not reduce reported enthusiasm, the absence of presentation may limit opportunities for public articulation and feedback, which can strengthen competence and relatedness. Taken together, emotional engagement is predominantly positive, but it becomes more fragile when learning demands intensify in symbolic reasoning segments.

3.3. Cognitive Engagement

Cognitive engagement reflects students' mental investment in learning, including strategy use, persistence in understanding, effortful thinking, and the ability to connect and apply ideas (Salam et al., 2022). Based on Table 5, cognitive engagement in reaction rate learning appears uneven: students show strategic effort and participation, yet conceptual integration—especially in reaction order—remains a consistent challenge, indicating difficulties in linking mathematical representations with underlying chemical concepts and reasoning processes.

Table 5. Cognitive Engagement Observation Results

Indicator	Observed Activities	Observation Results	Information
Student Strategies for Learning	Students are motivated to follow the learning.	Students are motivated to participate in learning because they are always present in class if there are no other activities from school that require participation and appear ready to participate in learning.	Observed during the implementation of practical observations, learning 1 and learning 2
	Students have additional literature to learn more about what they have learned in class.	During class, students do not use any literature, they only use personal notes and focus on the Powerpoint material display provided by the teacher.	Observed during the implementation of practical observations, learning 1 and learning 2.
	Students give critical opinions related to the problems given by the teacher.	A total of 4 students who are always active in responding to teacher questions including answering sample problems given by the teacher and giving opinions about calculations, especially on reaction order material.	Observed during the implementation of learning observations 1 and 2
	Students use learning strategies according to their learning style and ability to understand material.	Students create reports on the results of practical experiments on reaction rate material in the form of videos, infographics or written descriptions according to their learning style, whether visual, audio-visual or kinesthetic.	Observed during the implementation of practical observations, learning 1 and learning 2
	Students' understanding of the material on reaction rates	Students still do not fully understand the material on reaction rates as a whole, especially in the sub-topic on reaction orders which involve formulas and calculations, so many still have difficulty in completing the tasks given by the teacher.	Observed during the implementation of practical observations, learning 1 and learning 2

Students demonstrate cognitive engagement through motivation to participate and through the use of learning strategies. Observations show readiness to attend and follow lessons when there are no competing school activities. Students also indicate that group learning supports understanding because knowledge can be shared; as one student explains, groups are enjoyable because "if we don't know, we can ask other friends and vice versa." The teacher confirms that reaction rate instruction emphasizes group-based Quiz practice alongside explanation and exercises, suggesting deliberate pedagogical structuring to maintain cognitive engagement through interaction and repeated practice.

In terms of learning resources, students largely rely on personal notes and teacher-provided PowerPoint during class. Some students report using external resources outside class—such as YouTube or Ruang Guru—particularly when preparing for tests or when concepts remain unclear. This indicates self-initiated strategy use beyond the classroom, although in-class reliance on PPT and notes may also suggest limited exposure to alternative explanations or multi-representational supports during lessons.

A subset of students (approximately four) consistently responds to teacher questions and offers opinions during calculation-oriented discussions, particularly in reaction order. These behaviors indicate deeper cognitive engagement for these students: they not only participate but also attempt reasoning through procedures and interpretations. In addition, students produce practicum reports in varied formats (videos, infographics, written descriptions), which reflects adaptive strategy use aligned with different learning preferences (visual, audio-visual, kinesthetic). Such products may support cognitive engagement when they require students to organize information and communicate findings.

Nonetheless, observations and interviews consistently indicate incomplete understanding of reaction rate material for many students, especially in the reaction order subtopic involving formulas, calculations, and interpretation of data tables. Students explicitly report difficulty with reaction order questions that present data and require careful analysis. Reports of partial understanding and forgetting ("understanding rating is 8… the rest 2 because they still like to forget") suggest that knowledge may be unstable and not fully consolidated.

Tümay, (2016) representational framework helps explain this pattern: reaction order tasks are often dominated by symbolic representations (rate laws, graphs, numerical tables), yet meaningful mastery requires coordination with macroscopic evidence (observed changes in rate) and particulate explanations (collision frequency/effective collisions). When students cannot connect these representation levels, cognitive effort may shift toward procedural completion rather than conceptual integration, leading to persistent difficulty and limited retention. From an SDT perspective, repeated struggle in symbolic tasks can reduce perceived competence, which may contribute to uneven participation and dependence on peers for completion. Thus, while cognitive engagement is present through group learning and strategy use, it remains constrained by representational integration demands—most clearly in reaction order reasoning.

3.4. Summary of Findings, Implications, and Limitations

3.4.1. Summary of Findings

Based on the analysis of eleventh-grade students' learning engagement in reaction rate lessons at Integrated Islamic Senior High School Al-Mumtaz Pontianak—viewed across behavioral, emotional, and cognitive dimensions the findings indicate an engagement profile characterized by both strengths and constraints.

For behavioral engagement, several indicators require attention, particularly punctuality and adherence to classroom norms. Learning sessions frequently began later than scheduled due to transitions and preparation routines, and off-task behaviors (e.g., chatting, eating/drinking, non-instructional device use) occasionally reduced attentional focus during explanations. At the same time, students generally completed class-based tasks (Quiz/*LKPD*) and demonstrated active participation through group discussion, note-taking, and questioning. This combination suggests that students' behavioral engagement is strongest when learning structures are clear and activity-based, yet vulnerable during less structured transitions and teacher-centered segments.

For emotional engagement, students expressed enjoyment and enthusiasm—especially during practicum and Quiz-based group work—indicating that the learning environment supports positive affect and interest. However, emotional engagement appeared less stable when activities shifted toward difficult, symbolically intensive subtopics (e.g., reaction order), where students reported uncertainty and challenge. This pattern implies that positive emotion is present but still needs to be strengthened by supports that reduce frustration during cognitively demanding tasks.

For cognitive engagement, students showed motivation and strategic effort, particularly through cooperative learning, using notes and teacher materials, and (for some students) seeking external resources outside class. Nonetheless, understanding remained uneven, with persistent difficulty in subtopics involving formulas, calculations, and data interpretation. These findings point to the need for explicit scaffolding that supports representational coordination and sustained sensemaking, not only task completion.

3.4.2. Practical Implications for Chemistry Learning

To strengthen engagement and address observed challenges—especially around representational demands in reaction rate learning—several implications follow: 1) Use digital simulations to support sub-microscopic visualization, reaction rate concepts often require bridging what students observe (macroscopic) with particulate mechanisms (sub-microscopic) and symbolic forms (graphs, rate laws). Digital simulations/animations can make particle-level processes visible (e.g., collision frequency, temperature effects, concentration changes), helping students form explanatory links rather than relying on memorization or procedural calculation. Simulation use is especially important before and during reaction order lessons, where students struggle to interpret data and connect it to mechanisms; 2) Adopt cooperative learning strategies aligned with cognitive engagement, because group work in this study consistently supported participation and positive emotion, cooperative learning can be intentionally designed to promote cognitive engagement, not only collaboration. Strategies such as structured roles (explainer, checker, connector, recorder), "think–pair–share," jigsaw for subtopics (factors affecting rate, collision theory, graphs), and peer instruction questions can encourage deeper processing and reduce reliance on a few high-participation students. Cooperative structures also support motivation by strengthening relatedness and competence through guided peer support; 3) Design assessments that target representational transitions, student difficulty in symbolic/data-heavy segments suggests that conventional assessment formats may overemphasize calculation without testing representational linking. Assessment design can be improved by incorporating items that explicitly require transitions, such as: Macro → Micro: explain a lab observation using particle-level reasoning; Micro → Symbolic: translate a collision explanation into a rate expression or graph interpretation; Symbolic → Macro: interpret rate data and predict observable changes in an experiment.

This study has several limitations that should be considered when interpreting the findings: 1) Observer bias, because observation is interpretive, the identification of engagement indicators may be influenced by the researcher's expectations, attentional focus, and subjective judgments. Although triangulation across interviews and documentation strengthens credibility, observational conclusions may still reflect observer bias, particularly when coding subtle behaviours (e.g., attention, interest, persistence); 2) Limited context and sample scope, data were collected from one school and one Grade XI group (18 students). This bounded context supports depth but limits transferability to other schools, grade levels, or instructional contexts; 3) Lack of longitudinal measures of engagement, engagement was captured within a limited period and does not show whether behavioural, emotional, and cognitive engagement patterns remain stable over time, change across units, or develop as students gain experience with representational tasks. Without longitudinal tracking, the study cannot explain engagement trajectories or sustained effects of instructional practices 4) No quantitative triangulation, the study relied on qualitative sources (observation, interviews, documentation) and did not include quantitative engagement instruments (e.g., validated engagement scales). As a result, the findings cannot be compared statistically across students or linked to numeric engagement profiles that might strengthen generalizability; 5) No direct measurement of chemistry learning outcomes, the study did not systematically measure students' learning outcomes (e.g., pre/post-tests, concept inventories, performance assessments) to examine how engagement relates to achievement in reaction rate concepts. Any references to classroom performance are therefore best treated as contextual impressions rather than outcome evidence.

Future research should adopt a mixed-methods design that combines classroom observations with a validated student engagement scale, alongside pre/post concept tests on reaction rate (including items targeting representational transitions), and follow-up interviews to explain patterns in the quantitative results. Such triangulation would allow researchers to examine not only how engagement is expressed in classroom interactions but also how it relates to measurable changes in students' conceptual understanding. In addition, longitudinal studies across multiple chemistry topics (e.g., equilibrium, thermochemistry, acid–base, and electrochemistry) are needed to track whether engagement profiles shift as representational demands change and to identify which instructional supports sustain engagement over time. This extended scope would strengthen transferability and clarify whether strategies such as simulations and cooperative learning produce durable improvements in engagement and learning.

4. Conclusion

This study demonstrates that student engagement in reaction kinetics learning is multidimensional and unevenly distributed across behavioral, emotional, and cognitive domains. Guided by Fredricks' three-dimensional engagement framework and interpreted through the lens of Johnstone's Triangle, the findings reveal that students exhibit strong behavioral involvement, particularly in completing academic tasks such as group discussions, laboratory activities, and practicum reporting. However, this engagement is accompanied by persistent challenges related to classroom discipline, including punctuality and adherence to learning norms. Emotionally, students respond positively to learning activities that emphasize macroscopic phenomena and social interaction, such as experiments and collaborative quizzes, indicating that interactive and varied instructional strategies successfully foster enjoyment and a supportive classroom climate.

In contrast, cognitive engagement emerges as the most problematic dimension. Although students demonstrate motivation, initiative, and effort—evidenced by their use of external learning resources and peer collaboration—their conceptual understanding of reaction order and related calculations remains limited. This difficulty can be attributed to the substantial cognitive load required to integrate microscopic explanations with symbolic representations, a challenge that lies at the core of Johnstone's Triangle. As a result, high levels of behavioral participation and emotional involvement do not consistently translate into deep conceptual mastery.

Overall, the findings suggest that while students possess a solid foundation of behavioral and emotional engagement, these strengths alone are insufficient to support meaningful learning in abstract chemical concepts. Therefore, pedagogical efforts should move beyond general engagement-enhancing strategies toward chemistry-specific instructional interventions. The integration of digital simulations to visualize microscopic processes and the systematic use of structured worked examples to scaffold symbolic reasoning are recommended to rebalance engagement across domains and support deeper cognitive processing. Such targeted interventions are essential to ensure that students' observable effort and positive learning attitudes culminate in genuine conceptual understanding of reaction kinetics.

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