

Tracing the impact of teacher engagement on student creativity in biology classrooms: A multi-level diary study at the senior high school level

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ABSTRACT

This study explores how teacher engagement influences student creativity in biology classrooms. Although teacher engagement is known to enhance student outcomes, its short-term and classroom-level effects on creativity remain unclear. This study examines the relationship between teacher engagement and student creativity in high school biology learning through a multilevel diary study. A total of 112 eleventh-grade students from seven public senior high schools in Pekanbaru, Indonesia, participated over four weeks, with repeated measures after each session. Teacher engagement was assessed using a modified Utrecht Work Engagement Scale and student creativity through open-ended essay tests. Hierarchical linear modelling captures both within-class and between-class variations. Results indicate that session-level engagement did not significantly predict creativity, while aggregated classroom-level engagement had a positive effect. These findings suggest that sustained teacher engagement fosters creative learning environments, implying the need for professional development programmes that promote consistent teacher engagement.

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Introduction

Teacher engagement in the learning process is a fundamental element that influences educational success. Teachers who are emotionally, cognitively and physically engaged not only facilitate learning but also create a classroom environment that supports students' holistic development (Chia-Wei & Li-Chun, 2024; Talvio & Lonka, 2019). In practice, teacher engagement is reflected in the ability to build strong interpersonal relationships, provide full attention to students' needs, and demonstrate enthusiasm in teaching. When teachers exhibit high levels of engagement, students tend to feel valued and are more motivated to learn (Brandmiller et al., 2024; Wang et al.,

2022). In biology classrooms, engaged teachers are those who demonstrate enthusiasm in explaining complex topics, connect biological concepts with environmental or local issues, and stimulate inquiry-based discussions that encourage students to ask questions. Such engagement not only enhances comprehension but also nurtures curiosity and creative problem-solving, which are central to scientific learning (Chikaluma et al., 2022; Krajcik & Czerniak, 2018). Conversely, when teachers show low engagement, biology learning tends to become passive and teacher-centered, reducing students' intrinsic motivation to learn (Krajcik & Czerniak, 2018; Precious & Feyisetan, 2020).

The impact of teacher engagement on students is substantial, particularly in enhancing motivation, self-confidence, and learning outcomes (Ayllón et al., 2019; Guoxia & Yang, 2024). Teachers who show enthusiasm and strong commitment can encourage active student participation in the learning process. Teacher engagement also fosters students' sense of responsibility for their learning, as they feel supported and cared for (Dewaele & Li, 2021; Yan et al., 2023). In the context of biology education, engaged teachers often integrate experiments, visualisations, and contextual examples that make abstract biological processes more tangible (Davidsson & Granklint-Enochson, 2021). These practices provide cognitive and emotional stimulation that fosters student creativity, a key competency in science learning. This not only affects academic achievement but also contributes to the development of more positive student character traits, including greater confidence in exploring new ideas, thereby fostering higher levels of creativity (Al Jaber et al., 2024; Tao et al., 2022).

Creativity is considered an essential skill that must be cultivated to address the challenges of a dynamic and complex world. It enables students to think critically, generate innovative solutions, and adapt to rapid changes (Saad et al., 2024; Ye & Xu, 2023). Teacher engagement plays a crucial role in fostering student creativity, as engaged teachers tend to be more innovative in delivering material, allowing space for independent thinking, and encouraging students to explore new ideas (Brandmiller et al., 2024; Dewaele & Li, 2021). With strong engagement, teachers serve not only as facilitators of learning but also as motivators who inspire students to think creatively (Liu et al., 2021; Saad et al., 2024). Teachers' engagement was positively correlated with creative process engagement by Yuan et al. (2019).

Teacher engagement cannot be separated from the teaching experience they possess. Teaching tenure often contributes to the development of pedagogical skills and more effective classroom management abilities (Tormey, 2021; Woodcock et al., 2022). Teachers with longer teaching experience tend to have a deeper understanding of student needs and more effective strategies to engage them in the learning process. Such experience also enhances teachers' confidence in managing classroom challenges, thereby supporting their overall engagement. Consequently, teaching experience not only shapes teacher engagement but also influences student learning outcomes, including the development of creativity (Anderson et al., 2022; Derakhshan et al., 2023). Teachers with longer teaching experience tend to demonstrate higher instructional quality and contribute more significantly to student learning outcomes (Davidsson & Granklint-Enochson, 2021). In the context of creativity, these experienced teachers are better able to design flexible learning environments, provide meaningful guidance, and give students the freedom to explore and express original ideas in problem-solving activities (Mnguni & Moyo, 2021).

Previous studies on teacher engagement and student creativity have generally employed cross-sectional research designs, which capture only a snapshot at a single point in time (Castillo-Vergara et al., 2018; Hofkens & Pianta, 2022). Such designs tend to overlook the recurring dynamics that take place throughout the learning process and overlook the fluctuating nature of classroom interactions (Castillo-Vergara et al., 2018; Hofkens & Pianta, 2022). In biology learning, where each topic presents different levels of complexity and student response, engagement and creativity can vary significantly from one session to another. Yet, this temporal variability has rarely been examined systematically. Furthermore, limited research has investigated how teaching experience moderates the relationship between engagement and creativity across consecutive biology lessons (Rao et al., 2025; Xie & Jiang, 2022). This represents a significant research gap in understanding how dynamic patterns of teacher engagement contribute to creative learning. Teaching and learning are inherently dynamic

interactions in which teacher engagement and student responses can vary from one session to another (Burić & Frenzel, 2023).

Moreover, there is still a limited exploration of the relationship between teacher engagement, teaching experience, and student creativity within repeated instructional contexts, representing a significant research gap. Most previous studies have focused on the relationship between two variables in isolation, without considering how teaching experience might moderate or strengthen the link between teacher engagement and student creativity (Rao et al., 2025; Xie & Jiang, 2022). The lack of attention to these dynamic interactions across consecutive learning sessions. For example, over four successive class meetings, leave an underexplored area in the existing literature.

To address this gap, the diary study approach offers significant advantages. Diary studies allow for the collection of data periodically and repeatedly over a certain time frame, providing a more detailed and dynamic picture of changes in teacher engagement and student creativity from one session to the next (Garn et al., 2019). By employing a diary study, researchers can track patterns of change and factors influencing teacher engagement, as well as its impact on student creativity, with greater depth (Karwowski et al., 2017; Smith et al., 2022).

The combination of diary studies and HLM provides a more powerful analytical approach compared to other methods. Diary studies offer data to capture changes over time, while HLM allows modeling relationships between variables while accounting for the hierarchical structure of the data. Based on the background presented, the purpose of this study is to explore the relationships between teacher engagement, student creativity, and teacher teaching experience using a more in-depth approach. To capture the complexity of these relationships, a diary study approach was employed throughout to analyze data with a hierarchical structure, where students represent the individual level and teachers represent the group level.

Hypothesis Development

Teacher engagement in the learning process plays a crucial role in creating an environment that supports the development of student creativity. Self-Determination Theory explains that deep teacher engagement in teaching can satisfy students' psychological needs, such as the need to feel competent and connected to others (Deci & Ryan, 2012). Teachers who are emotionally and cognitively engaged can provide encouragement for exploration and creative problem-solving. Shank et al. (2024) found that teacher engagement influences student motivation, which in turn promotes greater creativity. Furthermore, other studies have found that teacher engagement positively affects student learning outcomes, including their creativity (Anderson et al., 2022). Therefore, teacher engagement is expected to have a positive effect on student creativity. Based on the empirical evidence discussed above, we hypothesise that as: H1 teacher engagement has a positive effect on student creativity.

Teachers' teaching experience greatly influence their ability to design and manage learning that supports student creativity. The theory of teacher expertise suggested that teachers with more experience have a better understanding of student needs, effective teaching strategies, and ways to encourage creative thinking (Cai et al., 2023; Nash et al., 2024). Research by Voss et al. (2022) and Wubbels et al. (2016) show that longer teaching experience correlates with improved teaching quality and student learning outcomes. In the context of creativity, experienced teachers can more effectively create space for students to develop new ideas and solve problems creatively. Teaching experience enhances teachers' pedagogical skills, which indirectly supports the development of student creativity (Alsitova et al., 2024; Skrbinjek et al., 2024). Based on these findings, teaching experience is expected to have a positive effect on student creativity. Thus, we propose the following hypothesis H2: Teaching experience has a positive effect on student creativity.

In addition to teacher engagement at the individual level, the overall level of teacher engagement in the classroom, or the average teacher engagement, can also influence student learning outcomes. Classroom climate theory states that the classroom atmosphere, driven by teacher

engagement, affects students' attitudes and motivation to participate in learning (Rosen et al., 2025). Teachers who are consistently engaged in the learning process create an environment that supports creative exploration and collaboration among students (Su et al., 2022). A positive classroom climate is associated with better student engagement, higher levels of social-emotional learning, and improved academic performance. The quality of teacher-student relationships significantly impacts students' affective and cognitive outcomes (Li et al., 2022). Therefore, the average level of teacher engagement in the classroom is expected to have a positive effect on student creativity. Drawing on this evidence, we propose the following hypothesis H2: The average teacher engagement in the classroom has a positive effect on student creativity.

Methods

Research Design

This study employed a multilevel diary study design, which combines the strengths of repeated within-person measurement and hierarchical analysis. A diary study approach was chosen because it enables the exploration of short-term variations in teacher engagement and student creativity across consecutive biology learning sessions, capturing the real-time dynamics of classroom interactions. The multilevel framework was deemed appropriate because the data had a nested structure, with students (Level 1) nested within teachers (Level 2). Therefore, Hierarchical Linear Modeling (HLM) was used to account for dependencies among observations and to examine how teacher-level factors (e.g., engagement and experience) influence student-level outcomes.

The use of HLM is essential for analyzing data with a hierarchical structure, such as data from multiple teachers (level 2) instructing several students (level 1) (Chen et al., 2022; Khine, 2022). HLM enables simultaneous analysis of relationships between variables across different levels, capturing the complexity of learning dynamics involving both teachers and students. With HLM, researchers can separate variability originating from individuals (students) and groups (teachers) and analyse how teaching experience influences teacher engagement and, ultimately, student creativity (Bash et al., 2021).

Data Collection and Sampling

The population targeted in this study comprised all eleventh-grade students enrolled in public senior high schools in Pekanbaru City, Riau Province, Indonesia, who were taking biology as part of their curriculum. Participants consisted of 112 students selected using an experience sampling methodology.

Participant selection was conducted using an experience sampling methodology, which the selected students and teachers had prior experience interacting in the classroom during the learning process. This approach allowed for a more accurate observation of the natural and contextual dynamics of teacher engagement and student creative responses. Consent was obtained from all participants prior to the study, and their confidentiality was maintained throughout the data collection process. Regarding the sample size, the determination was guided by previous literature to ensure adequate statistical power. Gabriel et al. (2019), in a comprehensive review of 90 diary studies conducted in educational contexts, suggested that at least 83 participants are required for a three-day diary design to yield reliable multilevel estimates. Following the completion of all four measurement sessions, 112 students provided complete data, resulting in 448 valid observations included in the analysis.

Data were collected four times over four consecutive weeks, each time immediately after a biology learning session. At each measurement point, students were asked to complete two main instruments, namely, (1) a teacher engagement questionnaire and (2) an essay test to measure student

creativity. Theoretically, the maximum number of data entries was 560; however, only 112 students completed all four measurement sessions, resulting in 448 valid data entries for analysis.

Measurement Instruments

This study employed two main types of instruments administered at four measurement points: a teacher engagement questionnaire and a student creativity test. Teacher engagement was measured using the Utrecht Work Engagement Scale (UWES), which was modified for the secondary education context. The UWES evaluates three main dimensions of engagement: vigor, dedication, and absorption (Minghui et al., 2018). This scale was designed to assess the extent to which students perceive their teachers' engagement during the learning process. The instrument consists of 9 items, each reflecting aspects of teacher engagement observed by students throughout the learning activities. Each item is rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

To ensure that the three-dimensional structure of the UWES remained consistent in this context, we conducted a confirmatory factor analysis (CFA). The CFA results indicated that the three-factor model of the UWES fit the empirical data well. Model fit indices such as CFI, TLI, RMSEA, and SRMR fell within recommended ranges, indicating high construct validity and reliability of the instrument. The results of the Confirmatory Factor Analysis (CFA) demonstrated satisfactory construct validity and reliability. The model exhibited a good fit with RMSEA = 0.024 (values <0.05 indicate a close fit) and both the CFI and TLI values exceeding 0.95. Furthermore, all three latent factors showed high and statistically significant factor loadings on their respective indicators, ranging from 0.60 to 0.81, suggesting that each item contributed substantially to representing the underlying construct dimensions.

Student creativity was measured using an open-ended essay test based on biology content, developed contextually to assess students' divergent thinking abilities after the learning sessions. The learning materials used in this study were drawn from the high school biology curriculum, focusing on the human body system and environmental issues. These topics were selected because they provide rich contexts for stimulating students' creativity. The creative thinking instrument was developed based on the creative thinking framework proposed by Torrance, as described by Runco et al (2010). This instrument was designed to explore the potential for original ideas, as well as the flexibility and depth of students' elaboration in responding to scientific problems. Each measurement session was conducted at the end of the biology lesson, where students were asked to complete the creativity test related to the biology material. Student responses were evaluated based on four main creativity indicators: fluency, elaboration, being critical, and flexibility. Each indicator was rated on a scale from 1 to 4, with scoring criteria detailed in a marking key. The assessment rubric was developed and validated by Hidayati et al. (2019), covering four key indicators of creativity: fluency, elaboration, being critical, and flexibility.

The validation of the research instruments was carried out by two experts from the biology education study program. Both experts possess extensive experience in educational research, specifically in the areas of biology learning and educational assessment. Their role was to review the content validity of the instruments, ensuring that each item accurately reflected the intended constructs of teacher engagement, student creativity, and self-efficacy.

In addition to the two main instruments, this study also utilized a general questionnaire administered to the biology teachers involved in the research. This questionnaire served to collect descriptive data on teacher profiles, including school name, age, gender, highest education level, and years of teaching experience, specifically in teaching biology at the senior high school level. This information was used to categorize the level of teaching experience, which was subsequently analyzed within the multilevel model.

Statistical Analysis

Data analysis in this study was conducted using Mplus version 7.0 with a Hierarchical Linear Modelling (HLM) approach, which is appropriate for the hierarchical structure of the data. The dataset consisted of 448 observations at Level 1 (session level). A two-level model was employed to accommodate the nested data dependency structure. Level 1 represented the creativity scores of each session for each student, while Level 2 captured the variation between teachers, including variables such as teacher engagement and teaching experience. To enhance the accuracy of result interpretation, person-mean centring was applied to the Level 1 predictors to isolate within-individual effects from between-student variation. Meanwhile, grand-mean centring was used for Level 2 predictors, such as teacher engagement and teaching experience, to appropriately compare the effects of predictors across teachers relative to the overall mean.

The analytical procedure began with validating the measurement model using confirmatory factor analysis (CFA) to ensure the constructs demonstrated satisfactory reliability and validity. Subsequently, a null model was estimated to calculate the intraclass correlation coefficient (ICC), which served to confirm the suitability of applying a multilevel analytical approach. Finally, a two-level hierarchical model was employed to examine the effects of teacher engagement, both at the session level and the aggregated classroom level, along with teaching experience, on students' creativity outcomes.

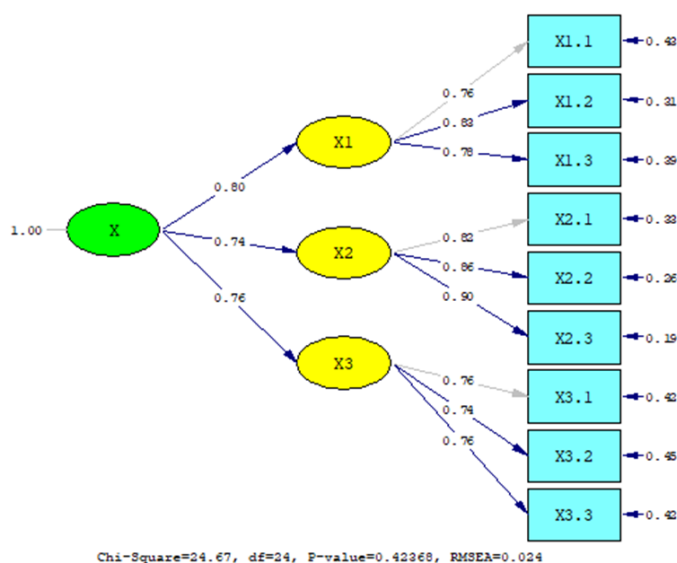
Results and Discussion

Confirmatory Factor Analysis of Teacher Engagement

We conducted a confirmatory factor analysis (CFA) to test the construct validity of the teacher engagement instrument adapted from the Utrecht Work Engagement Scale (UWES). The CFA model consisted of three latent factors: Vigor (X1), Dedication (X2), and Absorption (X3), each reflected by three observed indicators as illustrated in Figure 2.

Figure 2

Results of the confirmatory factor analysis of teacher engagement



The results of the CFA analysis show that the proposed model fits the data well, as indicated by the chi-square value of 24.67, $df = 24$, $p = 0.42$, which is not statistically significant, suggesting no meaningful difference between the hypothesised model and the empirical data. Other fit indices also support the model fit, with RMSEA = 0.024 (a value < 0.05 indicates a close fit), and CFI and TLI values above 0.95. All three factors show high and significant factor loadings on their respective indicators, ranging from 0.60 to 0.81, indicating that each item makes a substantial contribution in representing the latent constructs. For example, indicators X1.1 to X1.3 load on the Vigor dimension with loadings between 0.60 and 0.82, while X2.1–X2.3 and X3.1–X3.3 correspond to Dedication and Absorption, respectively, also showing strong and consistent loadings.

Furthermore, the correlations among the three factors were significant and strong, with correlations of 0.80 between X1 (Vigor) and X2 (Dedication), 0.74 between X1 (Vigor) and X3 (Absorption), and 0.76 between X2 (Dedication) and X3 (Absorption). These results indicate that the three dimensions of teacher engagement are closely related yet conceptually distinct, consistent with the underlying theory of work engagement that forms the basis of the UWES structure. This finding aligns with previous studies supporting the three-dimensional structure of the UWES in educational contexts. For instance, Dimitriadou et al. (2020) and Meng and Jin (2017) demonstrated that the Utrecht Work Engagement Scale Student version is a concise and valid instrument with satisfactory psychometric properties, making it suitable for measuring counsellor engagement in schools. Similarly, Um and Ji (2024) found confirmatory factor analysis results that supported the reliability and three-factor structure of the Utrecht Work Engagement Scale.

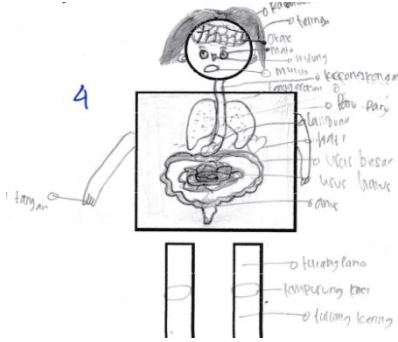
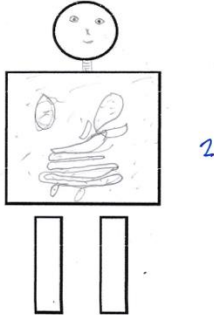
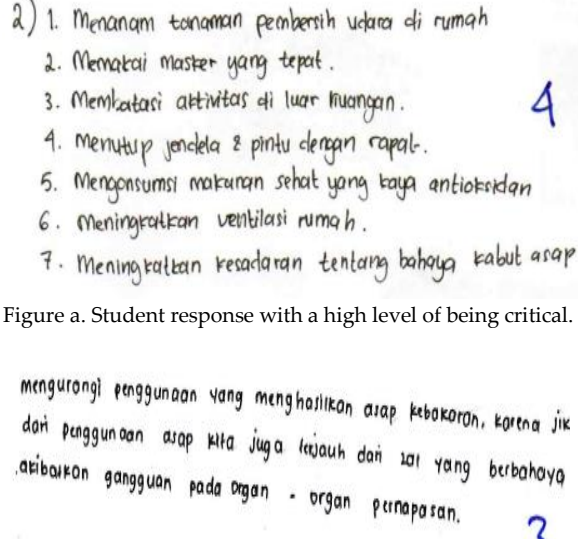
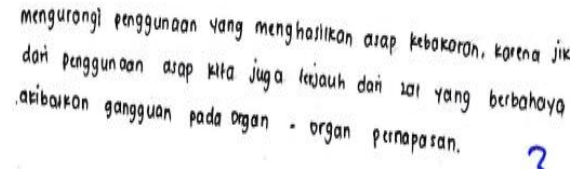
Hierarchical Linear Modelling of Teacher Engagement, Creativity, and Teaching Experience

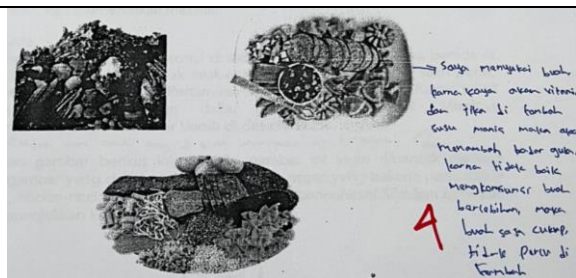
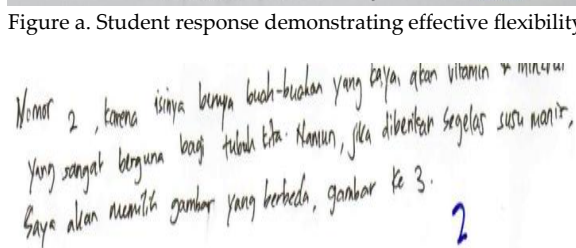
Before conducting the HLM analysis, accompanied by transcription and interpretation based on creativity indicators, as shown in Table 1.

Table 1

Sample excerpts of student responses on the creativity test

Creativity Indicators and Question	Student Answers	Answer Transcription
<p>Fluency</p> <p>You are participating in a social activity in a remote village. During your visit, you observe that many children and toddlers are suffering from stomach pain, abdominal cramps, and watery stools. What scientific questions would you like to investigate in response to this situation? Write down as many questions as possible.</p>	<p>① <u>Definisi Persepsi</u></p> <ol style="list-style-type: none"> 1. Apa upaya pencegahan agar anak-anak dan Bantu tidak Menjalani Cacar Peris? 2. Mengapa anak-anak dan Bantu anak mudah terkena Penyakit? 3. Seberapa apa yang harus di lakukan untuk mencegah agar selamat dan terhindar dari Penyakit! 4. Apa yang harus dilakukan agar air dapat aman bisa konsumsi? 5. Apakah ada bantuan dari Pemerintah untuk Memhadapi Persepsi itu? 6. Seberapa cara pengalihan air yang baik dan benar untuk dapat dikonsumsi! 7. Bagaimana cara yang harus dilakukan agar anak-anak dan Bantu dapat kembali Selesai? 8. Bagaimana halnya anak-anak dan Bantu yang hanya Lesung?? Mengapa Prangku tidak Jelas? 9. Bagaimana kebersihan lingkungan & sekitar desa itu? 10. Apakah masyarakat disana menjalankan Pola hidup sehat? 11. Apakah disana ada sosialisasi dari Pihak Kesehatan? <p>Figure a. Student response demonstrating extensive idea</p>	<p>In Figure a, a high level of fluency is demonstrated, as the student is able to generate many relevant questions (11 questions). For instance, the student asks about the condition of environmental cleanliness and whether there has been any awareness campaign. In contrast, in Figure b, the student fails to generate relevant questions, for example, asking about the definition of feces.</p>
	<p>① - Apa yang dimaksud tinja encer? , mengapa encer? dan berapa mengalami sakit Per tinja encer?</p> <p>Figure b. Student response demonstrating limited idea</p>	

Creativity Indicators and Question	Student Answers	Answer Transcription
<p>Elaboration</p> <p>Observe the following image. If this image were to be transformed into a diagram that illustrates the organ systems functioning within the human body, what specific details would you add? Feel free to be creative in developing your ideas.</p>		<p>In Figure a, the student is able to add many details to the drawing to illustrate the human body, such as parts of the digestive system, respiratory system, and skeletal system. In contrast, in Figure b, the student includes only a few details, which are also difficult to interpret.</p>
	<p>Figure a. Student response demonstrating effective elaboration</p>	
		
	<p>Figure b. Student response demonstrating minimal elaboration</p>	
<p>Being critical</p> <p>Riau has experienced forest fires that have resulted in a haze disaster. The smoke contains harmful substances for the respiratory organs, such as carbon monoxide, methane, ammonia, and sulfur dioxide. As a biology student, what efforts would you undertake to minimize the health risks of the haze, especially to the respiratory system? Write down as many strategies or actions as possible and explain your reasoning.</p>		<p>In Figure a, when asked to describe the haze phenomenon, the student demonstrates deep evaluation of information by proposing appropriate strategies to address the issue, such as planting air-purifying plants and limiting outdoor activities. In contrast, the response in Figure b is limited to a general suggestion, such as reducing the use of activities that produce smoke.</p>
	<p>Figure a. Student response with a high level of being critical.</p>	
		
	<p>Figure b. Student response with a low level of being critical.</p>	
<p>Flexibility</p> <p>Observe the pictures of fruits, vegetables, and bread. From the three images, choose the one you like the most and explain why you prefer it. If a glass of sweetened milk were added to the picture, would</p>		<p>Figure a shows a student's response demonstrating the ability to apply different approaches when facing different situations. For example, the student initially chooses vegetables as a meal option, but when milk is added, they switch to fruit</p>

Creativity Indicators and Question	Student Answers	Answer Transcription
<p>you still choose the same image or a different one? Provide your reason.</p>		<p>and provide a clear justification for the change. In contrast, Figure b also shows a change in choice, but without any explanation or reasoning.</p>
		

After evaluating the students' responses, the analysis proceeded with HLM to examine the effects of teacher engagement and teaching experience on student creativity at multiple levels. The model included predictors at the individual level (within level) and the teacher level (between level). The analysis results are presented in Table 2.

Table 2

Result of hierarchical linear modelling analysis

Variable	Estimate	S.E.	Est./S.E.	Two-Tail P-Value
Within Level				
Creativity (Y) ON teacher engagement (X)	0.017	0.020	0.858	0.391
Residual Variance Y	2.674	0.143	18.756	0.000
Between Level				
Creativity (Y) ON teacher experience (M)	0.013	0.005	0.610	0.542
Creativity (Y) ON teacher engagement (Y) (C)	0.239	0.049	4.835	0.000
Intercepts Y	5.722	1.190	4.087	0.000
Residual Variances Y	0.131	0.065	1.99	0.046

Table 2 shows that at the within level, teacher engagement perceived by students in each session does not have a significant effect on their creativity ($\beta = 0.017$, $p = 0.391$). This indicates that fluctuations in students' perception of teacher engagement from one session to another do not directly drive changes in student creativity scores at the same time level, so the first hypothesis cannot be strongly supported in the context of this study. This may be due to the fact that creativity does not arise immediately from short-term interactions but requires an accumulative process involving time, consistent learning experiences, and continuous support from the learning environment. Furthermore, since creativity involves divergent thinking processes, idea elaboration, and cognitive flexibility, it is

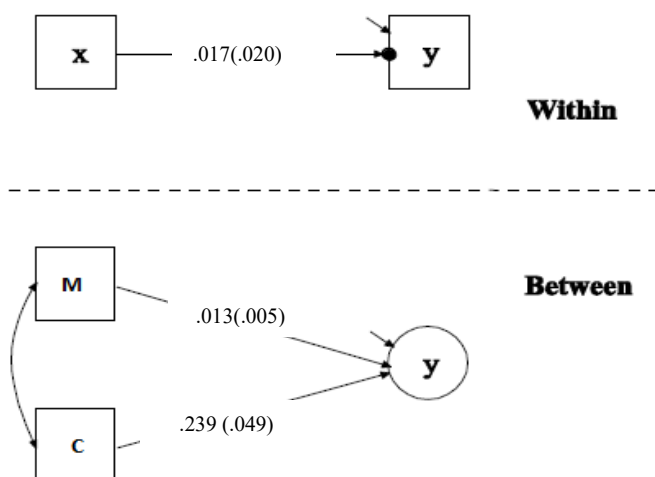
not easily stimulated by temporary learning experiences such as the perception of teacher engagement in a particular session. In the study by Raffaelli et al. (2024), creativity is characterised not by quick responses to external situations but by the ability to explore free associations, manage boredom, and shift loosely and flexibly between ideas. This suggests that creative students may be more influenced by reflective space, freedom of thought, and time for idea exploration rather than short-term contextual factors such as momentary perceptions of the teacher in a specific learning session.

At the between-teacher level, the HLM analysis results show that teaching experience ($\beta = 0.013, p = 0.542$) has a positive relationship with student creativity; however, this relationship has not reached statistical significance. This means that in this model, the variation in creativity among students cannot yet be meaningfully explained by these two variables. Empirical support for the second hypothesis is still insufficient. Nevertheless, these results do not discount the importance of teacher engagement and teaching experience, but rather indicate the possibility that their effects occur indirectly, through mediating mechanisms or interactions with other contextual variables such as students' intrinsic motivation (Goulet-Pelletier et al., 2023), classroom climate (Fan & Cai, 2022; Z. Wang et al., 2023), or even curriculum design. Creativity in learning, particularly in scientific disciplines such as biology, requires continuity in pedagogical and emotional support rather than situational engagement during a single session. Similarly, teaching experience did not independently predict creativity differences across classrooms, suggesting that experience alone may not be a sufficient driver unless accompanied by adaptive and reflective engagement strategies (Anderson et al., 2022).

Another consideration is that creativity was measured using a divergent thinking essay test requiring idea elaboration. This type of measurement heavily depends on students' internal abilities such as vocabulary, experience and reflection, which are not always directly influenced by teaching conditions or teacher experience. Therefore, even if teachers are experienced and highly engaged, students' idea productivity still depends on internal factors not covered in this model (Park et al., 2017; Peng et al., 2013).

Figure 3

Mplus analysis of model results



The description in this results and discussion section is also supplemented with an overview of the Mplus output as shown in Figure 3. The HLM analysis results indicate that the aggregate average teacher engagement has a positive and significant effect on student creativity ($\beta = 0.239, p < 0.001$); thus the third hypothesis is accepted and empirically supported within the model used. This finding provides an important contribution to understanding how consistent teacher engagement over a certain period can shape a learning climate conducive to the development of student creativity (Richardson & Mishra, 2018; Shermukhammadov, 2022). Conceptually, teacher engagement,

consisting of three main dimensions, namely vigor, dedication and absorption, reflects the affective and cognitive quality in the execution of teaching roles. Teachers who demonstrate a high level of engagement are not only physically present but also fully involved in learning activities. Such engagement can act as a catalyst that forms a safe emotional environment, supports active participation, and encourages free exploration, all of which are fundamental conditions for fostering creativity (Pedler et al., 2020). Positive interactions between teachers and students foster self-confidence, learning comfort, and students' courage to express new ideas. Teacher engagement—manifested through understanding, firmness and care toward students can create a supportive and comfortable learning environment (Che Ahmad et al., 2017).

Creativity in biology learning remains relatively low, which aligns with prior studies showing that science classrooms often emphasize factual knowledge rather than idea generation and problem-solving. This limitation can be attributed to the persistence of teacher-centered instruction, time constraints in completing curriculum targets, and limited opportunities for students to engage in inquiry-based or experimental activities that foster divergent thinking (Sugiyanto & Masykuri, 2018). In many cases, biology lessons focus more on memorization of concepts rather than on exploration, reflection, and creative application of scientific ideas (Xu et al., 2024). To address these challenges, concrete steps are needed, such as implementing problem-based and project-based learning approaches that encourage students to develop original solutions (Baran et al., 2021), incorporating open-ended and higher-order questioning strategies, and providing continuous professional development for teachers. These efforts can help create a more supportive classroom environment that values curiosity, experimentation, and the development of creativity in biology education.

This finding is further supported by empirical evidence from the study by Huang & Wang, (2023), which shows that the positive influence created through social relationships and a warm classroom atmosphere is largely driven by teacher engagement and is strongly correlated with students' motivation to participate in creative activities (Anderson et al., 2022; Starko, 2021). In this context, teacher engagement functions not only as academic support but also as a provider of emotional and social support that triggers students' readiness to think divergently.

Conclusion

This study aimed to examine how teacher engagement influences student creativity in high school biology classes through a multilevel diary approach. Findings indicate that while teacher engagement at the session and teaching experience levels did not significantly influence student creativity, aggregate teacher engagement across sessions had a significant positive impact. These results emphasize that sustained and consistent teacher engagement is more influential than fleeting enthusiasm in fostering a creative learning environment. This highlights that it is not just momentary engagement that is important, but rather the consistency of teacher engagement over time that fosters a learning climate conducive to exploration, active participation, and independent thinking. Teachers who are emotionally and cognitively present in the learning process are better able to create a classroom environment that supports the generation of creative ideas and thinking. This study contributes to biology education research by providing empirical evidence on how teachers' involvement shapes creativity in an authentic classroom context, offering new insights into the dynamic interactions between teachers and students. Practically, these findings suggest that teachers must maintain stable engagement throughout the learning process. Future research could expand on this study by incorporating mediating variables such as classroom climate or student self-regulation to deepen understanding of the mechanisms linking teacher engagement to student creativity development.

Limitations

While this study provides valuable insights into the relationships between teacher engagement, teaching experience, and student motivation, several limitations should be acknowledged. First, the cross-sectional design limits the ability to conclude causal relationships or to observe how these dynamics evolve over time. A longitudinal approach would be more effective in capturing changes in teacher engagement and its impact on student motivation across different teaching periods. Second, the absence of qualitative data limits the depth of understanding regarding the negative interaction effect found between teaching experience and teacher engagement. In-depth interviews or classroom observations could reveal contextual factors, such as teacher burnout or instructional rigidity, that may explain the decline effect of experience.

Recommendations

Based on the findings of this study, several suggestions can be proposed. First, since the results revealed that aggregate teacher engagement had a stronger influence on student creativity than momentary engagement during a single session, professional development programmes for teachers should emphasise the importance of maintaining consistent and reflective engagement throughout the learning process. Secondly, future research is encouraged to incorporate mediating variables such as classroom climate and student self-regulation to gain deeper insights into the mechanisms linking teacher engagement to student creativity. These variables may help explain how teacher engagement leads to creative behaviours and meaningful learning outcomes among students. Finally, the use of a longitudinal research design should be considered to allow researchers to capture the fluctuations and patterns of teacher engagement as well as its cumulative impact on student creativity.

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Declaration of Interest

No conflict of interest is declared by the authors.

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