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Enhancing Student Engagement in Meiosis Learning through an Anime-Based Biology Module: A Theoretical Framework

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ABSTRACT: Learning meiosis presents significant challenges for secondary school students due to its abstract nature, microscopic processes and complex sequential stages. Conventional teacher-centered instructional approaches and reliance on static learning materials often limit students' active involvement, resulting in low levels of engagement in Biology classrooms. Student engagement, encompassing cognitive, emotional and social dimensions, is widely recognized as a critical prerequisite for meaningful learning in science education. In response to these challenges, this article aims to develop a theoretical framework that explains how an anime-based Biology module can be used as an instructional strategy to enhance student engagement in learning meiosis. This study adopts a conceptual research design based on the systematic analysis and synthesis of established learning theories and instructional models relevant to constructivist learning and student engagement. The proposed framework integrates Vygotsky's Social Constructivist Theory with Needham's Five-Phase Constructivist Model to operationally explain how anime-based instruction can be implemented through structured instructional phases, namely orientation, elicitation of ideas, restructuring of ideas, application and reflection. Within the framework, anime is conceptualized as a form of visual and narrative scaffolding that supports social interaction, dialogue, and collaborative learning during classroom instruction. The major conceptual findings suggest that the integration of an anime-based Biology module with constructivist instructional principles provides a coherent explanation of how student engagement can be enhanced in meiosis learning. Cognitive engagement is supported through active reasoning and concept reconstruction, emotional engagement is fostered through narrative elements and visual appeal, and social engagement is promoted through peer interaction and guided classroom discourse. These engagement dimensions are theorized to emerge from the interaction between instructional design, visual–narrative scaffolding and socially mediated learning processes. The proposed theoretical framework contributes to the literature by offering a theory-driven explanation of how anime-based instructional approaches can be systematically designed and implemented in Biology education, and it provides practical guidance for educators seeking to develop more interactive and student-centered learning experiences for abstract scientific topics. Future research is recommended to empirically examine the applicability and effectiveness of the framework across diverse educational contexts.

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1. INTRODUCTION

1.1 Challenges in Learning Meiosis in Secondary School Biology

Meiosis is one of the most challenging topics in secondary school Biology, as it involves microscopic processes, complex sequential stages and abstract chromosomal movements. Understanding this topic requires students to construct mental representations of processes that cannot be directly observed (Lewis & Wood-Robinson, 2000). However, Biology teaching and learning practices in schools remain largely teacher-centered and rely heavily on static instructional materials such as textbooks and slides. Such approaches provide limited support for active meaning-making and often result in passive learning, particularly when dealing with abstract topics such as meiosis (Enebechi, 2023).

1.2 Student Engagement as a Foundation for Meaningful Learning in Science

Student engagement is a critical component of meaningful learning in science education. Fredricks, Blumenfeld and Paris (2004) conceptualize student engagement as a multidimensional construct encompassing cognitive, emotional, and social dimensions. In Biology learning, cognitive engagement is reflected in students' efforts to understand and connect concepts, while emotional and social engagement are manifested through interest, motivation and interaction during classroom activities. Previous research indicates that student engagement and motivation are strongly influenced by instructional context, task design, and classroom interaction, particularly in science learning environments (Törmänen et al., 2025; Lin et al., 2020). This situation highlights the need for more student-centered instructional strategies that actively support students' engagement in the learning process.

1.3 Anime as a Visual and Narrative Medium for Supporting Student Engagement

The increasing influence of visual culture and digital media in students' daily lives calls for pedagogical approaches that are more contextualized and aligned with their experiences. Anime, as a visual narrative medium that integrates animation, characters and storytelling, has the potential to function as an effective pedagogical tool for capturing students' attention and enhancing their engagement. Dynamic visual elements and character-driven narratives allow abstract concepts such as meiosis to be presented in more concrete and accessible forms, consistent with multimedia learning principles (Mayer, 2009; Clark & Mayer, 2016). Within Biology instruction, anime can facilitate social interaction, classroom discussion, and shared meaning-making, thereby supporting students' cognitive, emotional, and social engagement (Flemming et al., 2018; Faria et al., 2024).

Despite the growing discussion on the potential of visual and narrative media in science education, the use of anime in secondary school Biology remains limited and is often implemented without a clear learning theory framework. Much of the existing discourse focuses on the attractiveness of such media rather than explaining how it can be systematically integrated into classroom instruction to support student engagement (Rostek, 2020). Consequently, there is a need to develop a theoretical framework that explains the relationship between the use of anime-based instructional modules, classroom implementation and student engagement in Biology learning.

Taken together, existing studies indicate that while visual and narrative media have the potential to enhance student engagement in science learning, prior research has largely examined such media in isolation, with limited attention to their systematic integration within theory-driven instructional frameworks. In particular, there remains a gap in Biology education literature regarding how anime-based instructional approaches can be operationalised through structured pedagogical phases to support cognitive, emotional, and social engagement in learning abstract topics such as meiosis.

Accordingly, this article aims to develop a theoretical framework that explains the use of an Anime-Based Biology Module as a strategy to enhance student engagement in learning the topic of meiosis. The framework integrates Vygotsky's Social Constructivist Theory and Needham's Five-Phase Constructivist Model to operationally explain how an anime-based module can be implemented in secondary school Biology instruction to support students' cognitive, emotional and social engagement.

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1.4 Theoretical Framework of the Study

This study proposes a theoretical framework to explain how an Anime-Based Biology Module can be used as an instructional strategy to enhance student engagement in learning meiosis. The framework is grounded in Vygotsky's Social Constructivist Theory and operationalized through Needham's Five-Phase Constructivist Model, providing a coherent explanation of how student engagement is supported through social interaction, guided scaffolding and structured instructional phases (Vygotsky, 1978; Needham, 1987).

From a social constructivist perspective, learning is understood as a socially mediated process that occurs through interaction, dialogue, and support within the zone of proximal development (ZPD). In the context of this framework, anime functions as a form of visual and narrative scaffolding that provides shared representations of abstract biological processes, such as chromosomal behavior during meiosis. These shared visual–narrative representations serve as common reference points that facilitate classroom discussion, peer interaction, and teacher-guided explanation, thereby supporting students' meaning-making processes (Mayer, 2009; Flemming et al., 2018).

To operationalize this social constructivist approach in classroom practice, the Anime-Based Biology Module is structured according to Needham's Five-Phase Constructivist Model, namely orientation, elicitation of ideas, restructuring of ideas, application of ideas and reflection. During the orientation phase, anime scenes are used to introduce the topic and capture students' attention. In the elicitation of ideas phase, students express their prior understanding through guided questions and small-group discussions informed by the anime narrative. The restructuring of ideas phase involves teacher-facilitated explanations and visual clarification using anime-based representations to refine students' conceptual understanding of meiosis. Subsequently, in the application phase, students engage in collaborative learning activities, such as problem-solving or concept-based tasks, to apply newly constructed knowledge. Finally, the reflection phase provides opportunities for students to consolidate learning through discussion, feedback, and narrative-based reflection.

Within this framework, student engagement is conceptualized as a multidimensional construct encompassing cognitive, emotional and social engagement (Fredricks et al., 2004; Hidi & Renninger, 2006). Cognitive engagement is supported through active reasoning and concept reconstruction across instructional phases, emotional engagement is fostered through narrative elements and visual appeal of anime, and social engagement is promoted through structured interaction and collaborative learning activities. Overall, the proposed framework clarifies the relationship between the instructional design of the anime-based module, its classroom implementation, and the enhancement of student engagement in learning meiosis.

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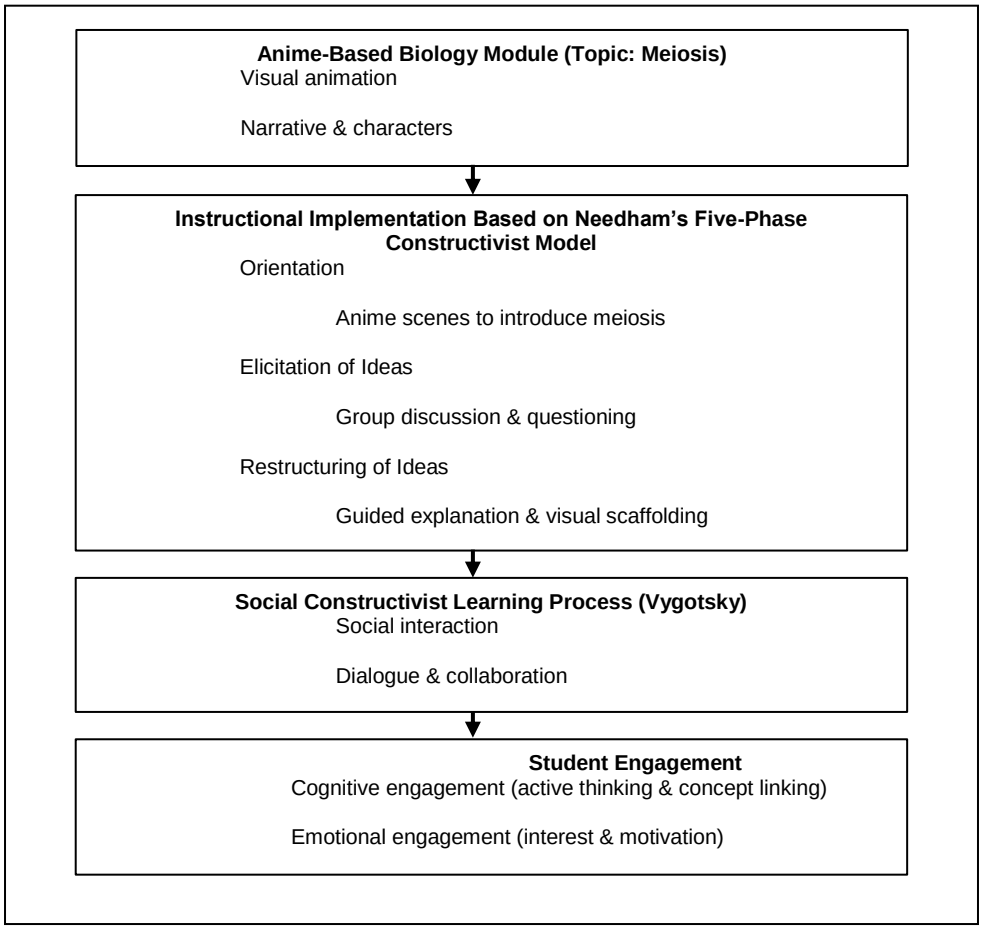

Figure 1. Theoretical framework illustrating the integration of an anime-based biology module, Needham's Five-Phase Constructivist Model and Vygotsky's Social Constructivist Theory in supporting student engagement in learning meiosis.

Figure 1 illustrates the proposed theoretical framework of the study, highlighting the relationship between the anime-based biology module, instructional implementation guided by Needham's Five-Phase Constructivist Model, and student engagement. The framework demonstrates how anime functions as visual and narrative scaffolding that supports social interaction, dialogue, and collaborative learning processes, consistent with Vygotsky's Social Constructivist Theory. Through structured instructional phases, the module is designed to enhance students' cognitive, emotional and social engagement in learning meiosis.

2. METHODS AND MATERIALS

2.1 Research Design

This study adopts a conceptual research design aimed at developing a theoretical framework that explains the use of an Anime-Based Biology Module as a strategy to enhance student engagement in learning meiosis. The study does not involve empirical data collection, participants or experimental procedures. Instead, it focuses on the systematic analysis and synthesis of established learning theories and instructional models relevant to student engagement and constructivist learning in science education.

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Conceptual research is appropriate for this study as the primary objective is to construct a theoretically grounded framework that clarifies the relationships between instructional design, classroom implementation and student engagement. Such an approach allows for the integration of multiple theoretical perspectives to generate new conceptual insights that can guide future empirical research and instructional practice.

2.2 Sources of Literature

The theoretical framework was developed based on an extensive review of scholarly literature related to student engagement, constructivist learning theories, and visual-narrative instructional approaches in science education. Sources included peer-reviewed journal articles, academic books, and authoritative theoretical works indexed in established databases such as Scopus and Web of Science. Priority was given to foundational theories and widely cited empirical and conceptual studies relevant to Biology education and student engagement.

Key theoretical sources informing the framework include Vygotsky's Social Constructivist Theory, Needham's Five-Phase Constructivist Model, and the multidimensional model of student engagement proposed by Fredricks, Blumenfeld, and Paris. These sources provided the conceptual basis for explaining learning as a socially mediated and instructional-structured process.

2.3 Framework Development Procedure

The development of the theoretical framework followed a three-stage conceptual synthesis process. First, relevant theories and models were identified and analyzed to determine their relevance to student engagement and the learning of abstract scientific concepts such as meiosis. Particular attention was given to theories that emphasize social interaction, scaffolding, and structured instructional phases.

Second, the selected theories were synthesized to establish conceptual linkages between instructional design and learning processes. Vygotsky's Social Constructivist Theory was used to explain how learning occurs through interaction, dialogue, and scaffolding within the *zone of proximal development*, while Needham's Five-Phase Constructivist Model was employed to operationalize these principles into a structured instructional sequence applicable to classroom practice.

Third, anime was positioned within the framework as a form of visual and narrative scaffolding that supports each instructional phase. Elements such as animation, characters, dialogue and storyline were conceptually mapped onto the five instructional phases to illustrate how the Anime-Based Biology Module can facilitate cognitive, emotional, and social engagement during Biology instruction.

2.4 Conceptualization of Student Engagement

In this study, student engagement is conceptualized as a multidimensional construct comprising cognitive, emotional and social engagement, consistent with the framework proposed by Fredricks, Blumenfeld and Paris (2004). Cognitive engagement refers to students' active involvement in reasoning, problem-solving and concept construction. Emotional engagement relates to students' interest, motivation and affective responses to learning activities. Social engagement involves interaction, collaboration and participation in classroom discourse.

These dimensions are not treated as measurable variables in this conceptual study but are used as analytical lenses to explain how engagement emerges through the interaction between instructional design and classroom implementation within the proposed theoretical framework.

2.5 Scope and Limitations of the Methodological Approach

As a conceptual study, this research does not aim to evaluate the effectiveness of the Anime-Based Biology Module through empirical testing. Instead, its contribution lies in providing a theoretically grounded explanation of how anime-based instruction can be systematically designed and implemented to support student engagement in learning meiosis. The proposed framework is intended to serve as a foundation for future empirical studies that may examine its applicability and effectiveness in real classroom settings.

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3. RESULTS AND DISCUSSION

This section presents and discusses the conceptual findings derived from the theoretical synthesis underpinning the proposed framework. As this study is conceptual in nature, the results do not involve empirical data; rather, they reflect the theoretical outcomes of integrating an anime-based instructional module with constructivist learning principles to support student engagement in learning meiosis.

3.1 Conceptual Outcomes of the Theoretical Framework

The primary outcome of this study is a theoretically grounded framework that explains how an Anime-Based Biology Module can enhance student engagement through structured instructional implementation and socially mediated learning processes. As illustrated in Figure 1, anime is positioned as visual and narrative scaffolding that supports instruction guided by Needham's Five-Phase Constructivist Model and learning processes explained by Vygotsky's Social Constructivist Theory.

The synthesis suggests that anime addresses core challenges in learning abstract biological processes by providing shared visual representations and narrative contexts. Prior research indicates that visualization and animation facilitate understanding of complex biological phenomena and help learners form coherent mental models (Lewis & Wood-Robinson, 2000; Mayer, 2009). In this framework, anime extends beyond static visual aids by embedding biological concepts within character-driven narratives that promote discussion and collaborative meaning-making.

3.2 Cognitive Engagement through Structured Instruction

From a cognitive perspective, the framework indicates that student engagement is strengthened when learners actively participate in reasoning, concept linking and problem-solving. Needham's Five-Phase Constructivist Model provides a systematic instructional structure that supports these processes. The elicitation and restructuring phases encourage students to articulate prior ideas, confront misconceptions and refine their understanding through guided explanation and visual support.

This aligns with constructivist learning principles, which posit that meaningful learning occurs through active knowledge construction rather than passive reception (Piaget, 1972; Needham, 1987). Additionally, visual narratives embedded in anime support cognitive processing by enabling learners to visualize abstract processes, consistent with multimedia learning principles (Mayer, 2009). Collectively, the framework demonstrates how anime-based instruction can promote sustained cognitive engagement in learning meiosis.

3.3 Emotional Engagement through Visual Narratives

The framework also highlights the role of anime in fostering emotional engagement, a key dimension of student engagement in science learning (Fredricks et al., 2004). Narrative elements, characters and visual aesthetics are theorized to capture students' attention and maintain interest, particularly when engaging with challenging content.

Research on interest development and narrative-based learning suggests that emotionally engaging materials can enhance learners' motivation and willingness to engage with scientific topics (Hidi & Renninger, 2006; Flemming et al., 2018). Within the proposed framework, emotional engagement is primarily supported during the orientation and reflection phases, where anime scenes introduce learning contexts and encourage reflective discussion. This suggests that anime-based instruction can create a more motivating learning environment for abstract topics such as meiosis.

3.4 Social Engagement through Interaction and Scaffolding

Consistent with Vygotsky's Social Constructivist Theory, the framework emphasizes social engagement as a central outcome of anime-based instruction. Anime provides a shared visual and narrative reference that facilitates classroom dialogue, peer interaction and collaborative learning. Through group discussions and guided tasks, students engage in collective meaning-making within their *zone of proximal development*, supported by teachers and peers (Vygotsky, 1978).

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This conceptual finding is supported by studies highlighting the importance of interaction and collaboration in enhancing engagement and learning in science education (Fredricks et al., 2004; Lin et al., 2020). By embedding anime within a constructivist instructional sequence, the framework illustrates how social engagement can be systematically integrated into Biology instruction.

3.5 Implications of the Conceptual Findings

Overall, the conceptual findings indicate that integrating an Anime-Based Biology Module with constructivist instructional principles offers a coherent theoretical explanation of how student engagement can be enhanced in learning meiosis. Engagement is conceptualised as emerging from the interaction between instructional design, visual–narrative scaffolding, and socially mediated learning processes. This framework contributes to the literature by providing a theory-driven explanation of how anime can be systematically implemented in Biology instruction, rather than being used solely as an attractive supplementary resource.

4. CONCLUSIONS

This article has proposed a theoretical framework that explains the use of an Anime-Based Biology Module as a strategy to enhance student engagement in learning meiosis. Grounded in Vygotsky's Social Constructivist Theory and operationalised through Needham's Five-Phase Constructivist Model, the framework clarifies how visual–narrative scaffolding, structured instructional phases and social interaction collectively support students' cognitive, emotional and social engagement. By positioning anime as an instructional medium rather than a supplementary visual aid, this study provides a coherent theoretical explanation of how abstract biological concepts can be taught in a more interactive and student-centred manner. As a conceptual study, this article does not present empirical evidence on learning outcomes. However, its primary contribution lies in offering a theory-driven framework that can guide instructional design and inform future research. The proposed framework may serve as a reference for educators in designing anime-based Biology instruction and as a foundation for empirical studies examining its effectiveness in enhancing student engagement and learning outcomes in science education. Future research is encouraged to empirically test the framework in classroom settings to evaluate its impact across different learner contexts and educational levels.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHORS CONTRIBUTION

Author 1 (Asmahan binti Azmi): Conceptualization, Methodology, Literature review, Writing - Original Draft Preparation, Visualization, Formal analysis. Author 2 (Prof. Dr. Salmiza Saleh): Supervision, Conceptual validation, Writing - Review & Editing.

AVAILABILITY OF DATA AND MATERIALS

Data available within the article.

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DECLARATION OF GENERATIVE AI

During the preparation of this work, the author(s) used ChatGPT (OpenAI) to enhance the clarity and readability of the manuscript and Google Scholar to support literature searching. After using these tools, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

ETHIC STATEMENTS

This study did not involve human participants, animals or the collection of personal data. Therefore, ethical approval was not required.

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