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Analysis of Factors Causing Learning Difficulties in High School Students on the Excretion System Material

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Abstract

Background: Learning difficulties related to the human excretory system remain a persistent challenge in high school biology education, particularly concerning abstract subtopics such as urine formation, nephron structures, and physiological mechanisms including filtration, reabsorption, and secretion. This study aims to identify internal and external factors that hinder student understanding of these concepts. **Methods:** A descriptive approach was employed, involving the distribution of structured questionnaires to 73 high school students. The instruments were designed to assess both cognitive and instructional aspects influencing learning barriers. Data analysis focused on patterns of student responses concerning content difficulty, teaching methods, and availability of learning resources. **Results:** The study revealed that 85.7% of students encountered substantial difficulty in understanding urine formation within the nephron. Additionally, 77.1% reported that monotonous, teacher-centered instruction contributed to their challenges, while 65.7% cited a lack of practical laboratory experiences. Cognitive issues such as low abstract reasoning ability, poor visualization skills, limited memory retention, and low motivation were identified as core barriers. Instructional deficiencies, including minimal use of multimedia and interactive strategies, further exacerbated learning difficulties. **Conclusions:** The results highlight the importance of integrating visual aids, interactive media, and experiential learning in biology instruction to improve conceptual understanding. Addressing both cognitive and instructional barriers is essential for enhancing learning outcomes in complex biological systems.

Keywords: Abstract reasoning; Biology education; Excretory system; Instructional strategy; Learning barriers; Visualization.

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Introduction

Biology is a fundamental pillar within science education; however, students frequently encounter substantial challenges in comprehending its core concepts. These difficulties arise primarily due to the abstract nature of many biological processes, the inherent complexity of biological systems, and cognitive demands associated with visualization and abstract reasoning (Mnguni & Moyo, 2021). Furthermore, persistent alternative conceptions significantly impede effective learning, as highlighted by Reinoso et al., (2023), who found that pre-service teachers held enduring misconceptions concerning fundamental biological structures and functions. Additionally, traditional pedagogical methods often fail to adequately address diverse learner needs, further exacerbating students' difficulties in grasping intricate biological concepts (Lahlali et al., 2023). Moreover, cultural and educational backgrounds influence student comprehension of essential biological principles, indicating a multifaceted nature of the challenges encountered in biology education (Chan, 2021).

Specifically, the excretory system represents one of the most abstract and challenging topics in biology education due to its intricate physiological functions and numerous interrelated processes. Students typically struggle to conceptualize how organs like kidneys, ureters, bladder, and urethra coordinate to maintain homeostasis through waste removal and regulation of fluids and electrolytes (Lázaro et al., 2022). Detailed biochemical and physiological mechanisms, including filtration, reabsorption, and secretion, are inherently difficult to visualize, further complicating student comprehension (Ellianawati et al., 2021). Additionally, abstract concepts such as osmolarity and fluid regulation require significant cognitive abstraction and mathematical understanding, often exceeding students' cognitive capacity and necessitating more targeted educational strategies (Abba & Rashid, 2020; Baboolal & Singaram, 2023).

Understanding human physiology, including the excretory system, is critical in secondary education. It provides foundational knowledge necessary for informed personal health management and decision-making in adulthood, thereby enhancing public health literacy (Bradaric & Tresselt, 2022; Esmaelzadeh et al., 2020). Additionally, proficiency in physiology develops critical thinking skills essential for analyzing complex systems and their interactions within broader biological contexts (Andersen et al., 2022). This understanding has become increasingly significant, particularly following global health crises such as COVID-19, which highlights the relevance of physiology education in public health policy and preventive measures (Hinds & Johns, 2023).

Conceptual difficulties in biology have a direct impact on students' academic performance and interest in science. Studies indicate that these difficulties can diminish academic achievement and reduce student engagement, particularly when faced with complex concepts like genetics, physiology, or ecology (Flores-Camacho et al., 2021; Oladejo et al., 2023). To mitigate these challenges, effective instructional methods that incorporate visual aids and interactive multimedia resources are essential, as they enhance comprehension and foster sustained interest in the biological sciences (Mnguni & Moyo, 2021).

Previous studies have identified numerous conceptual and educational challenges associated with understanding the human body's organ systems. For example, Esmaelzadeh et al. (2020) and Goegan et al. (2022) documented significant learning barriers in physiology education, especially among nursing students and those with learning disabilities. Furthermore, students often struggle to connect theoretical knowledge about organ systems to practical applications, resulting in knowledge gaps that negatively impact academic performance and interest (Iriarte et al., 2022). Cognitive load theory (CLT) further explains that the complexity and interconnectedness of biological concepts can overwhelm students' working memory, particularly those with specific learning difficulties, necessitating instructional designs that effectively manage cognitive demands (Bishara, 2021; Okur & Aksoy, 2025).

Despite the existing research, significant gaps persist regarding specific subtopics within the excretory system, particularly in terms of student conceptual understanding and instructional strategies. While emotional and psychosomatic factors influencing physiological comprehension have been suggested, targeted studies specifically addressing the excretory system remain sparse (Jůzová et al., 2024; Reinoso et al., 2023). Additionally, limited research explicitly evaluates pedagogical strategies such as visual aids or interactive technologies specifically within the context of the excretory system (Mnguni & Moyo, 2021). Thus, this research aims to bridge these identified gaps by conducting a detailed analysis of students' difficulties in understanding the excretory system, focusing explicitly on the internal factor of student motivation and external factors such as educational facilities.

Several studies highlight the importance of both internal and external factors in influencing student learning outcomes. Internal factors, including students' cognitive capacities, motivation, and prior knowledge, significantly shape learning experiences

(Conrad et al., 2022; Merga, 2019). External factors, such as socio-economic status, familial support, educational infrastructure, and instructional quality, also critically affect student achievement, highlighting the need for comprehensive strategies that address both domains to enhance learning outcomes in biology education (Kersánszki & Nádai, 2020; Thompson et al., 2022; Yakut, 2021).

The present study investigates explicitly these internal and external factors in the context of the excretory system to provide targeted pedagogical strategies and instructional reforms. By addressing detailed educational challenges within specific subtopics rather than generalized biological concepts, the research aims to offer precise interventions capable of significantly improving student engagement and conceptual understanding. This targeted approach represents a significant contribution to educational practices, leveraging cognitive load theory and modern educational technologies to enhance the effectiveness of biology education (Alqarni, 2021; Yaman, 2023).

This study makes a unique contribution to educational research by integrating cognitive, instructional, and infrastructural perspectives to address specific conceptual difficulties encountered in learning about the excretory system. By providing detailed analyses and targeted instructional strategies, it effectively bridges existing research gaps, paving the way for enhanced biology education outcomes and fostering deeper student engagement and comprehension implications at the end of the introduction.

Method

This research employed a descriptive research design aimed at identifying and analyzing the specific internal and external factors influencing students' conceptual understanding of the excretory system. A descriptive approach was selected due to its efficacy in providing comprehensive insights into current phenomena within educational contexts (Khazaleh et al., 2024). This design facilitated an in-depth exploration of students' difficulties, motivations, cognitive capacities, and the influence of educational facilities.

Sample or Participant

Participants were selected using purposive sampling, ensuring a targeted representation of the population relevant to the study's objectives (Malahlela & Johnson, 2024; Sankoh et al., 2023). The sample consisted of 73 secondary school students from multiple schools with diverse socio-economic and educational backgrounds. Criteria for inclusion were based on students actively enrolled in biology courses covering the excretory system and varied in terms of academic performance and cognitive profiles.

Data collection

Data were collected using structured survey questionnaires specifically designed for this study and administered through Google Forms. The questionnaire comprised three sections:
Section A: Demographic information and previous academic performance.
Section B: Cognitive and motivational aspects affecting biology learning outcomes.
Section C: Perceptions of educational infrastructure and teaching quality.

The instruments underwent expert validation and reliability testing, resulting in a Cronbach's alpha value of 0.87, indicating high internal consistency (Goegan & Daniels, 2022). Participants were informed explicitly about their rights, including the right to withdraw at any point without consequences (Rose & Shevlin, 2019). Surveys were distributed anonymously to ensure confidentiality and encourage honest responses.

Data analysis

Data from the questionnaires were analyzed using descriptive statistical methods. Means, standard deviations, frequencies, and percentages were calculated to identify patterns in cognitive difficulties, motivational factors, and perceptions of educational infrastructure (Baboolal & Singaram, 2023).

Result

Identification of Difficult Subtopics in the Excretory System

This study aimed to analyze the difficulties encountered by high school students in comprehending topics related to the excretory system. Data obtained from the questionnaires distributed to 73 respondents revealed several critical insights. As illustrated in Table 1, the most challenging subtopics identified by students included: the process of urine formation in the nephron (85.7%), kidney structure and its components (71.4%), mechanisms of filtration, reabsorption, and secretion (68.6%), and disorders associated with the excretory system (45.7%). These findings align with existing literature, highlighting the significant cognitive demands posed by abstract physiological processes and complex structures inherent in human physiology (Abba & Rashid, 2020; Ellianawati et al., 2021).

Table 1: Students' Perceived Difficulties in Excretory System Subtopics

No	Subtopic	Percentage (%)
1	Process of urine formation in the nephron	85.7
2	Kidney structure and its components	71.4
3	Filtration, reabsorption, and secretion	68.6
4	Disorders of the excretory system	45.7

The complexity of these topics is primarily attributed to their abstract nature, requiring advanced visualization skills, spatial reasoning, and integrated understanding of cellular-level physiological processes.

Internal Factors Influencing Learning Difficulties

Analysis of internal factors revealed critical insights into the cognitive and motivational challenges faced by students. As detailed in Figure 1, difficulties in comprehending abstract concepts were most pronounced (82.9%), followed by memory retention issues (60%), limited intrinsic interest in the excretory system (48.6%), and insufficient visualization skills (45.7%). These internal cognitive barriers significantly impede effective learning, consistent with findings from Mnguni & Moyo (2021), who underscore the necessity of robust visualization capabilities in biology education. Additionally, the results align with Taylor & Digiacomo (2023) observations regarding students' struggles with information organization and conceptual application.

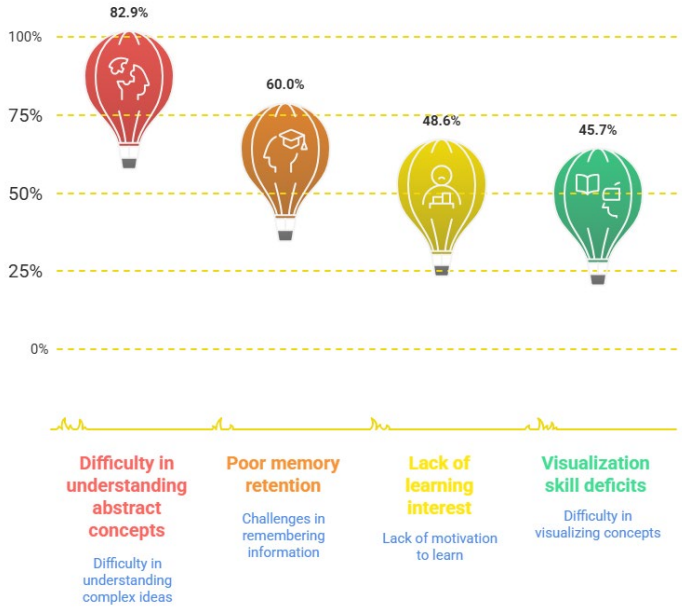

Figure 1: Internal Factors Affecting Student Learning in Excretory System

External Factors Influencing Learning Difficulties

Survey data also highlighted significant external factors affecting student learning outcomes. Participants identified monotonous teaching methods (77.1%), ineffective use of instructional media (71.4%), insufficient practical laboratory experiences (65.7%), and limited instructional time allocation (60%) as critical impediments to their learning. These findings emphasize the essential role of instructional quality and resource availability in biology education, reflecting arguments presented by (Branchaw et al., 2020; Förtsch et al., 2020) and Bellibaş et al. (2021) on the influence of instructional quality and supportive learning environments.

Table 2: External Factors Contributing to Student Difficulties

No	External Factors	Percentage (%)
1	Monotonous teaching methods	77.1
2	Ineffective instructional media	71.4
3	Lack of practical laboratory experiences	65.7
4	Limited instructional time	60

Interpretation and Hypothesis Confirmation

The data clearly confirm the research hypothesis, highlighting the combined influence of internal cognitive and motivational factors, as well as external educational infrastructure and instructional practices, on students' conceptual understanding of the excretory system. Specifically, the considerable difficulty associated with the nephron's physiological processes (filtration, reabsorption, and secretion) underscores the complexity and high cognitive demand associated with abstract biological concepts (Baboolal & Singaram, 2023).

Moreover, these findings support cognitive load theory, which posits that learning challenges arise when cognitive demands surpass the learner's working memory capacity, a situation exacerbated by inadequate instructional support (Okur & Aksoy, 2025). The evident struggles related to visualization and abstract reasoning also reinforce the critical need for employing varied and effective instructional methodologies and supportive educational environments, aligning with recommendations from previous research (Mnguni & Moyo, 2021).

Implications of Findings

The findings highlight the necessity of targeted instructional interventions aimed at enhancing students' visualization skills, abstract reasoning capabilities, and intrinsic motivation. Additionally, educational stakeholders must prioritize diversified teaching methods, effective multimedia resources, practical laboratory experiences, and appropriate instructional time allocations to mitigate external barriers effectively. By addressing both internal and external factors, educators can foster deeper conceptual comprehension, increased academic achievement, and sustained student engagement in biology education.

Summary of Key Findings

In summary, the research identified critical internal and external factors impacting students' comprehension of the excretory system, confirming the initial hypothesis. Specifically :

- Students predominantly struggle with understanding nephron physiology, kidney structure, and related processes due to the abstract nature of these concepts.
- Internal cognitive barriers, particularly abstract reasoning and visualization deficits, significantly impede effective learning.
- External instructional factors, including limited instructional variety, ineffective media utilization, insufficient practical engagement, and constrained teaching time, significantly exacerbate these difficulties.

- Comprehensive, targeted instructional strategies are necessary to overcome these barriers, underscoring the importance of addressing both cognitive capacities and educational infrastructure

These results provide valuable empirical evidence supporting targeted pedagogical interventions designed to enhance biology education outcomes.

Discussion

This study identified significant learning challenges among high school students related to the human excretory system, specifically in subtopics involving urine formation, kidney structures, and physiological mechanisms such as filtration, reabsorption, and secretion. Analysis indicated that difficulties primarily arose due to the abstract nature and cognitive demands inherent in these biological concepts. As shown in Table 1, the highest difficulty percentage was associated with understanding urine formation in the nephron (85.7%), supporting previous findings that biological processes involving complex cellular interactions and physiological mechanisms are particularly challenging for students (Ellianawati et al., 2021; Flores-Camacho et al., 2021). The complexity arises from the need to integrate multiple physiological concepts, cellular processes, and biochemical reactions, which requires students to mentally visualize dynamic processes occurring at the microscopic level.

The prominence of internal cognitive barriers identified in this study (Figure 1), particularly difficulties in abstract conceptualization (82.9%), aligns closely with existing literature, emphasizing that abstract reasoning and visualization significantly impact biological comprehension (Mnguni & Moyo, 2021). These cognitive barriers, including poor memory retention (60%) and limited intrinsic interest (48.6%), underline the critical role cognitive load plays in learning complex biological processes. According to Cognitive Load Theory, students' working memory can quickly become overwhelmed by intricate and detailed content, thereby reducing learning effectiveness (Okur & Aksoy, 2025). This study reinforces the importance of this theory, demonstrating that students' learning difficulties intensify when instructional materials fail to provide adequate cognitive scaffolding or sufficient visualization supports.

The identified visualization skill deficits (45.7%) further corroborate existing findings, suggesting that successful comprehension in biology heavily relies on effective visual representation tools (Mnguni & Moyo, 2021). Students who lack sufficient visualization abilities face notable challenges when interpreting abstract and multifaceted physiological processes. Consequently, educational interventions must prioritize the integration of visualization techniques, including diagrams, animations, and interactive digital models, to enhance learning outcomes. Such tools effectively bridge cognitive gaps by making abstract concepts more tangible and easier to comprehend (Merino et al., 2022; Mierdel & Bogner, 2020). Providing extensive visual learning resources could significantly enhance students' ability to conceptualize and retain complex information, ultimately improving educational outcomes.

External instructional factors were also found to have a significant impact on students' learning outcomes. Specifically, monotonous teaching methods (77.1%) and ineffective media utilization (71.4%) were identified as primary instructional concerns (Table 2). These findings are consistent with prior studies that underscore instructional quality as a critical determinant of academic success (Engida et al., 2024; Harrison et al., 2023). The lack of varied and interactive teaching approaches notably contributes to reduced student engagement and comprehension, demonstrating the necessity of dynamic and engaging instructional practices. Furthermore, the insufficient practical laboratory experiences reported by 65.7% of respondents highlight the essential role that experiential learning methods play in reinforcing theoretical knowledge. Active learning, supported by multimedia tools and practical experiments, can significantly facilitate student understanding by providing hands-on, experiential contexts that help demystify abstract concepts (Khasawneh, 2024; Nakamoto et al., 2024).

This study's confirmation of the hypothesized relationships between internal cognitive barriers, external instructional practices, and students' comprehension difficulties provides strong empirical evidence in support of targeted interventions. Interventions such as working memory enhancements, advanced visual learning tools, and augmented reality (AR) applications hold significant promise for improving educational outcomes. Research shows these strategies effectively reduce cognitive load, enhance visualization capabilities, and boost intrinsic

motivation, thereby improving overall learning efficacy (Merino et al., 2022; Mnguni & Moyo, 2021; Okur & Aksoy, 2025). Educators are encouraged to integrate these evidence-based approaches into their teaching practices to facilitate more profound comprehension and improved academic performance among students.

Additionally, motivational factors emerged as crucial determinants influencing students' learning experiences. The limited intrinsic motivation (48.6%) found in this study aligns closely with existing literature, which highlights that motivational deficits adversely affect student engagement and academic performance in complex scientific topics (Pérez et al., 2020; Winangun et al., 2024). Educational strategies that foster intrinsic motivation, such as gamified learning environments, interactive technologies, and student-centered learning activities, are recommended to enhance student engagement and academic achievement (Khasawneh, 2024). Enhanced motivation can lead to greater persistence and a more positive attitude toward learning, resulting in improved outcomes for complex biological subjects.

Furthermore, infrastructure limitations also emerged prominently as external constraints affecting students' learning experiences. This finding aligns with research demonstrating that inadequate instructional resources significantly hinder effective biology teaching (Mrad et al., 2025; Probst & Huwer, 2020). Students' reported concerns regarding limited instructional time (60%) underline the critical need for improved resource allocation, better educational planning, and effective time management within curricula. Addressing infrastructure deficiencies through increased resource availability, enhanced technological support, and targeted professional development for educators is crucial for enhancing teaching quality and improving educational outcomes. Improved infrastructure facilitates diverse teaching methodologies and supports the implementation of interactive and engaging learning activities.

This research makes a significant contribution to the existing body of literature by providing a detailed, empirical analysis of the learning challenges specific to the excretory system, an area notably underrepresented in biology education research (Reinoso et al., 2023). The findings identify specific cognitive and instructional barriers, offering clear, evidence-based strategies for targeted pedagogical interventions and curriculum development. By highlighting detailed difficulties at the subtopic level, the study enables educators to precisely address the identified learning barriers, thereby enhancing instructional effectiveness and student achievement.

Despite the contributions, several limitations must be acknowledged. Firstly, the relatively modest sample size (n = 73) limits the generalizability of these findings, suggesting future research should include larger, more diverse student populations to validate these results. Additionally, the reliance on self-reported questionnaires may introduce response biases, potentially limiting the depth and accuracy of insights into students' cognitive experiences and perceptions. Therefore, future studies should incorporate mixed-methods approaches, including qualitative methods such as interviews and classroom observations, to gain a richer and more comprehensive understanding of student learning difficulties and cognitive processes.

This research significantly enhances the existing knowledge base by demonstrating clearly that student comprehension difficulties related to the excretory system result from a combination of internal cognitive and external instructional factors. By precisely identifying challenging subtopics and specific barriers to learning, this study provides valuable insights for educators, researchers, and curriculum developers. The findings establish a robust foundation for implementing targeted educational strategies designed to improve visualization skills, diversify instructional methods, and elevate student motivation and engagement. Ultimately, this study advances the field by offering practical recommendations and contributing empirical evidence that can inform educational practices aimed at overcoming barriers in complex biological subjects, thus improving student learning outcomes and academic quality.

Conclusions

This study offers valuable insights into the learning difficulties of high school students related to the human excretory system, highlighting significant challenges within subtopics such as urine formation, kidney structure, and physiological processes, including filtration, reabsorption, and secretion. The findings underscore that these difficulties largely stem from both internal cognitive limitations, including deficits in abstract reasoning, insufficient visualization skills, and limited intrinsic motivation, as well as external instructional inadequacies such as monotonous teaching methods, ineffective media use, and inadequate

practical experiences. The clear identification of these cognitive and instructional barriers enriches current academic understanding by specifying the precise obstacles students face, particularly within the relatively underexplored area of excretory system education.

This research makes a significant contribution to educational science by advocating evidence-based interventions, such as enhanced visual learning tools, multimedia applications, and interactive instructional methods, to mitigate identified learning barriers effectively. Given the limited sample size and the reliance on self-report data, future studies are encouraged to employ mixed-methods approaches, incorporating qualitative observations and interviews, and include broader participant samples to deepen and expand the understanding of students' cognitive processes and educational experiences in complex biological topics.

Acknowledgments

The study acknowledges certain limitations inherent in descriptive research using survey instruments. These include potential response biases such as social desirability bias and context-dependent responses that may limit the generalizability of findings (Annuš & Kmeť, 2024; Christodoulidou & Sidiropoulou, 2024). Despite these limitations, comprehensive methodological precautions were employed to mitigate their impacts, ensuring robust and reliable results.

This structured methodological framework facilitated a detailed exploration of the internal cognitive and motivational factors and external educational infrastructure influences impacting students' understanding of the excretory system. By systematically addressing these components, the research ensures findings are both valid and applicable to enhancing educational practices in biology.

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