



Students' and Lecturers' Needs in the Design of the NanoPintar E-Module for Cell Biology Courses through Multiple Intelligences

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Abstract: Cell Biology is a crucial yet challenging subject in which students often struggle with abstract concepts, particularly cell organelles, a difficulty exacerbated by traditional teaching methods that utilize static materials, which yield inadequate results, especially among students with limited visual-spatial abilities. This research investigated the preliminary needs of both students and lecturers for the development of the NanoPintar e-module using diverse data collection methods, including questionnaires, interviews, student visualization tests, and multiple intelligence assessments. The results indicated very low scores in student visualization and multiple intelligence tests; however, interview and questionnaire outcomes strongly confirmed that both students and lecturers require a NanoPintar e-module for the Cell Biology course, identifying the Endoplasmic Reticulum material as the most difficult topic and thus highly suitable for the development of the e-module.

Keywords: ADDIE; Cell Biology; E-modul; Multiple IntelligenceE-modul; NanoPintar (Microlearning).

Introduction

The novelty of this research lies in the first systematic needs analysis for integrating an interactive microlearning framework into an e-module specifically designed to address visualization deficits and abstract concept comprehension in the Cell Biology course. This study, therefore, is crucial as it employs a data-driven approach, utilizing visualization tests and user feedback, to precisely define the specifications for the NanoPintar e-module, which is particularly needed for difficult topics in the Cell Biology course.

Cell Biology is commonly a mandatory course in higher education for biology and biology education disciplines. Challenges in Cell Biology lectures are usually encountered by both lecturers and students. These challenges may stem from the course material, teaching methods employed by lecturers, or students' learning strategies. One of the issues involves the complexity of concepts, as cell biology encompasses

various intricate topics, including cellular structure, function, and processes. The detailed mechanisms of cellular pathways, such as signal transduction pathways and metabolic cycles, can be particularly overwhelming. Students often struggle to grasp how these processes interconnect and contribute to overall cellular function, leading to confusion and frustration.

Additionally, many aspects of cell biology are abstract and not easily observable. For example, understanding the three-dimensional structures of organelles or the dynamic nature of cellular processes can be challenging without proper visualization tools. This abstraction makes it difficult for students to connect theoretical knowledge with real-world applications, affecting their engagement and comprehension. Furthermore, disparities in access to high-quality curriculum materials, evidence-based teaching practices, and technology can result in gaps in preparation and academic performance. Students lacking these resources are at a disadvantage, as

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reflected in their grades and overall understanding of cell biology (Mercy Frederick-Jonah & Tobi, 2022; Santhosh et al., 2024).

Preliminary observation data highlight the ineffectiveness of current traditional teaching methods in Cell Biology. While lecturers frequently incorporate group discussions and material reflection at the beginning of each session, active participation is limited, as only a few students actively respond to the presented outcomes, while the majority remain passive. Furthermore, the instructional materials primarily rely on available printed textbooks and static PowerPoint presentations. Although assignments include material summaries and discussion reports, these approaches have proven insufficient, resulting in certain complex concepts remaining difficult for students to fully grasp. This lack of engagement and sustained difficulty underscores the urgent need for instructional materials that can enhance motivation and facilitate independent learning, such as e-modules. E-modules are also referred to as self-learning media because they are equipped with guidelines for independent study (Kuncahyono, 2018). The use of e-modules has been proven effective in improving students' learning outcomes (Kumalasari et al., 2023).

An e-module is an instructional material presented in electronic or digital form. E-modules can include text, images, animations, and videos accessible via electronic devices such as computers and smartphones. This facilitates learning for students who may struggle to absorb material quickly, offering a more effective and engaging learning environment (Inanna et al., 2021). Furthermore, an e-module is a systematically arranged self-study resource organized into specific learning units and presented in an electronic format. These resources are often enriched with video tutorials, animations, and audio to provide a more comprehensive learning experience (Kemendikbud, 2018). As an instructional material, e-modules can be combined or supplemented with instructional videos, now commonly referred to as microlearning.

Learning through microlearning involves engaging with small chunks of information, a technique that has gained popularity in course design within e-learning environments (Hug et al., 2004; Mercy Frederick-Jonah & Tobi, 2022). Microlearning has emerged as a learning approach where information is processed in small segments, engaging students and providing microcontent in flexible learning environments such as mobile learning and mobile applications (Carter & Youssef-Morgan, 2022; Robles et al., 2023; Skalka et al., 2020; Zarshenas et al., 2022). Microlearning is designed to deliver information in small segments through various media formats, transforming content into "short content" that enables quick comprehension and allows

individuals to learn anytime and anywhere using information and communication technology devices (K. Y. R. Lee et al., 2023; Susilana et al., 2022; V. Austria & F. Banayo, 2024). The benefits of microlearning include simplified knowledge management, enabling students to repeat the learning process and environment, and encouraging them to personalize their learning experience (Mohammed et al., 2018; Prasittichok & Smithsarakarn, 2024; Zanyar Nathir Ghafar et al., 2023). Therefore, microlearning is combined within an e-module to overcome students' learning difficulties and to support lecturers' teaching materials.

Microlearning can be delivered in various forms, such as content displayed on social media, blogs, and websites. It comes in multiple formats, including podcasts, PowerPoint slides, infographics, motion graphics, explainer videos, interactive video conferencing, and gamification (Nugraha et al., 2021). Microlearning enhances learning by making content easier to understand, improving long-term retention, and increasing the effectiveness and efficiency of teaching and learning processes (Mohammed et al., 2018). It provides advanced practical solutions to training and education challenges (Dahlan et al., 2022). Media formats used in microlearning include infographics, interactive infographics, interactive PDFs, e-books, flipbooks, animated videos, interactive videos, webcasts or podcasts, expert videos, webinars or recorded webinars, mobile apps, and complex branching scenarios (Susilana et al., 2022).

Although e-modules and microlearning have been shown to be effective, no research has systematically analyzed the specific needs of Cell Biology students in leveraging this combined format within lectures. This integration is expected to significantly aid students in comprehending the challenging Cell Biology course material. At this stage, microlearning is integrated into the instructional material in the form of an e-module, referred to as the NanoPintar e-module, which is specifically designed to align with the Cell Biology curriculum. This research primarily aims to define the specifications and feasibility of the NanoPintar e-module by comprehensively analyzing the current challenges and the needs of both students and lecturers in the Cell Biology course. Specifically, the researchers conducted a preliminary needs analysis of students and lecturers as the initial step in the development process of the NanoPintar e-module for the Cell Biology course.

Method

This study is a developmental research project using the revised ADDIE model. The development of the NanoPintar e-Module was based on the systematic ADDIE instructional design model. The process began

with the Analysis phase, which involved the development of questionnaire instruments and interview protocols for both students and lecturers, alongside an extensive literature review. All instruments underwent expert validation prior to implementation. Findings from this phase revealed that both students and lecturers experienced difficulties in understanding the concept of the endoplasmic reticulum. Subsequently, the Design phase focused on determining the endoplasmic reticulum content, selecting appropriate learning theories—namely multimedia, cognitive, and behaviorist theories—and integrating microlearning principles. The design of the e-Module was further guided by the e-module development framework proposed by the Indonesian Ministry of Education and Culture (Kemendikbud, 2018).

The Development phase represented a critical stage, involving the expert validation of the questionnaires as well as the pre-test and post-test items. The development of the questionnaires addressed key dimensions, including validity, usability, motivation, and perception, which also encompassed the overall validity of the NanoPintar e-Module. Upon completion of development, the Implementation phase commenced with a pilot study to examine the reliability of the usability, motivation, and perception instruments, followed by a full-scale study involving a larger sample of students and lecturers. The final Evaluation phase focused on measuring the impact of the NanoPintar e-Module through a structured four-step procedure: administering a pre-test and motivation questionnaire prior to instruction, followed by a post-test along with motivation and usability questionnaires after instruction. The results demonstrate that the NanoPintar e-Module was successfully developed and is suitable for use by both students and lecturers (Robert Maribe Branch, 2009).

At this stage, the focus is on the Analysis phase, which identifies the initial needs for developing the NanoPintar e-Module. The research employs a mixed-methods approach, integrating qualitative and quantitative methodologies. The steps in this phase are as follows:

Visualization Test.

A visualization test was administered to 63 students via the link <https://intelligencetest.com/questions/visualization/index.html> using three easy-level questions. Data from this test were analysed descriptively with a percentage formula. The test can be seen in Figures 1, 2, and 4.

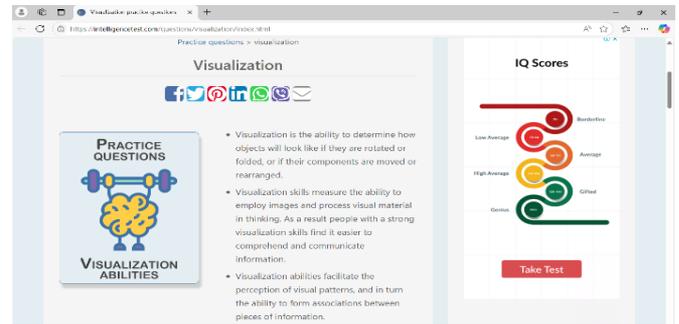


Figure 1. Visualization Test

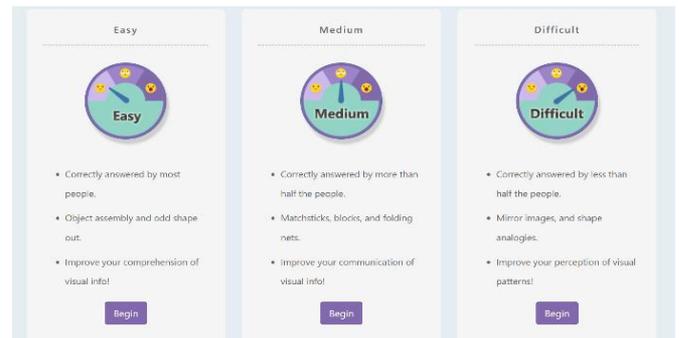


Figure 2. Phases of Visualization Test

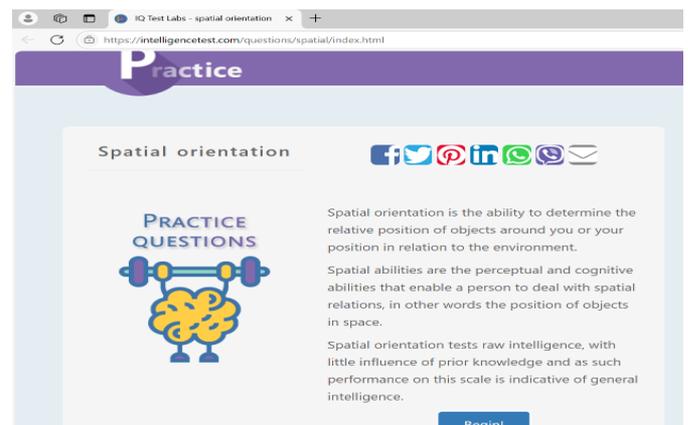


Figure 3. Multiple Intelligences Test

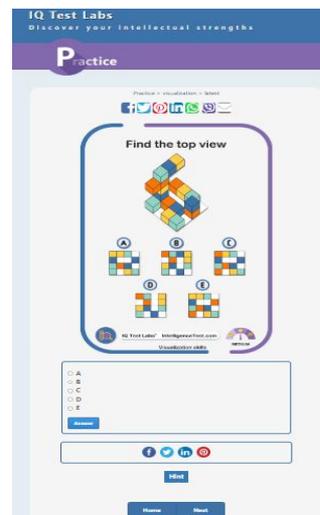


Figure 4. Example Questionnaire in Visualization Test.

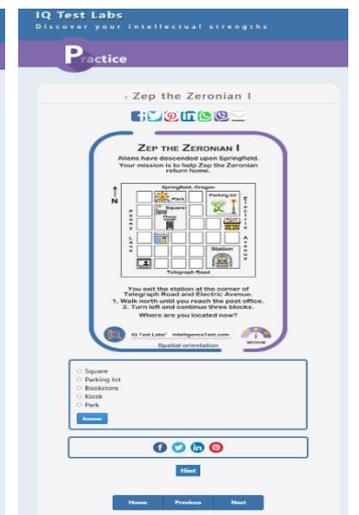


Figure 5. Multiple Intelligences Test Questionnaire

Multiple Intelligences Test

A multiple intelligences test was conducted with 32 students via the link <https://intelligencetest.com/questions/spatial/index.html> using 20 medium-level questions. Data from this test were analysed descriptively. The percentage values were calculated based on the relative number of samples for each value out of the total samples. To calculate the percentage, the formula used is Formula 1.

$$\text{Percentage} = \left(\frac{\text{Number of Samples for a Specific Value}}{\text{Total Samples}} \right) \times 100 \quad (1)$$

(Mann, 2010).

Steps to Calculate Percentage:

- Total Samples are calculated by summing all the values in the "Sample" column
- For each value in Sample, the percentage is calculated using Formula 2.

$$\text{Percentage for Value} = \left(\frac{\text{Sample for that Value}}{\text{Total Samples}} \right) \times 100 \quad (2)$$

For Value = 0, Sample = 1:

$$\text{Percentage for Value (0)} = \left(\frac{1}{32} \right) \times 100 = 3.13\%$$

The same process is applied for all other values. The multiple intelligences test can be seen in Figures 3 and 5.

Needs Analysis.

Needs analysis was conducted with students and lecturers using instruments distributed to 37 students and 4 lecturers. The data were analyzed descriptively. The questionnaire consisted of 18 questions, with 13 questions using multiple-choice options (1, 2, 3, 4) and the remaining questions allowing respondents to select multiple answers that best reflected their experiences.

Interviews

Interviews were conducted with 5 students and 3 lecturers using an instrument comprising 10 items grouped into 4 indicators. Data from this stage were analyzed qualitatively. The indicators for lecturers were time constraints and material preparation, curriculum alignment and content complexity, technological support, and student engagement. Meanwhile, the indicators for students were understanding course material, learning preferences, engagement and motivation, and access to technology. In this study, qualitative data were processed using a percentage formula to provide a quantitative representation of the findings (Formula 3).

$$P = \frac{f}{N} \times 100\% \quad (3)$$

Explanation: P= percentage; f = frequency of responses obtained for a specific category; N = Total respondents or overall frequency; 100% = Constant to convert the result into a percentage (Riduwan, 2019; Suriani Kiflee et al., 2017; Ummah et al., 2019).

Results and Discussion

The development of the NanoPintar e-Module was systematically based on the ADDIE instructional design model (Branch, 2009). The process began with the Analysis phase, which involved the development of questionnaire instruments and interview guidelines for both students and lecturers, alongside an extensive literature review (Borup & Archambault, 2023; Kong et al., 2025; Nagel & Troitschanskaia, 2025; Spangenberg et al., 2025; Telang et al., 2025). All instruments subsequently underwent expert validation prior to implementation. The findings from this phase indicated that both students and lecturers experienced difficulties in understanding the topic of the endoplasmic reticulum.

The Design phase focused on determining the content related to the endoplasmic reticulum, selecting appropriate learning theories—namely Multimedia Learning Theory, Cognitive Learning Theory, and Behaviorism—to underpin the e-module design, and implementing a microlearning approach (Asequia et al., 2025; Sardin et al., 2025; Margunayasa, 2026; Ramdiah & Putra, 2026; Rizka & Jalal, 2025). This phase also guided the structuring of the NanoPintar e-Module based on the e-module component framework proposed by the Indonesian Ministry of Education and Culture (Kemendikbud, 2018).

The Development phase was a critical stage that involved the validation of questionnaire instruments as well as the validation of pre-test and post-test items by subject-matter experts. The questionnaire development addressed four main aspects: validity, usability, motivation, and perception, which collectively also reflected the validity of the NanoPintar e-Module itself (Asadollahi et al., 2025; Altintas et al., 2025, 2025; Kamarudin et al., 2025; Monib et al., 2025; Bhal et al., 2026). Upon completion of the development process, the Implementation phase commenced with a pilot study to examine the reliability of the usability, motivation, and perception questionnaires among samples of students and lecturers (Deta & Saputra, 2026; Farahani et al., 2025; Fazrul et al., 2025; K. Y. R. Lee et al., 2023; Ngurah & Laksana, 2026). This was followed by a full-scale study involving a larger sample of students and lecturers.

The final phase, Evaluation, focused on measuring the impact of the NanoPintar e-Module. This was conducted through four main steps: administering a pre-test and a motivation questionnaire prior to learning,

followed by a post-test and motivation and usability questionnaires after the learning activities (Savaş et al, 2025; Başer & Şahin, 2025; Fazrul et al., 2025; E. Lee & Shin, 2025; Norouzkhani et al., 2025; Sari et al., 2025). These measures were used to compare the effects of e-Module usage. As a result, the NanoPintar e-Module was successfully developed for use by students and lecturers.

The results of this study are emphasized at the analysis stage.

Results from the Visualization Test

The results from the visualization test yielded the following data (Table 1). Table 1 presents the analysis of students' needs for the development of the e-module NanoPintar. The results indicate that 24 students (38.1%) responded "True," suggesting that they perceived a

Table 2. The results from the visualization test.

| Value | 0 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 |
|------------|------|-------|------|------|-------|------|------|------|------|------|------|
| Sample | 1 | 5 | 2 | 3 | 6 | 1 | 4 | 3 | 2 | 2 | 3 |
| Percentage | 3.13 | 15.63 | 6.25 | 9.38 | 18.75 | 3.13 | 12.5 | 9.38 | 6.25 | 6.25 | 9.38 |

Table 2 presents the results of the visualization test across different score values. The highest proportion of students achieved a score of 40, with 6 students (18.75%), followed by scores of 25 (5 students; 15.63%) and 50 (4 students; 12.5%). Other scores were more evenly distributed, each representing smaller percentages of the sample. Overall, the results indicate a varied distribution of visualization test scores, with most students achieving scores in the mid-range.

Analysis of Lecturers' and Students Perspectives on the Need E-Module NanoPintar Development

Table 3 describes cell biology material that is appealing to students. It is a table of elements that make students interested and motivated to learn cell biology: memorization, the things applicable to their real world, teaching methods, instructional approaches, textbooks, and so on. One of the most interesting findings was that 75 % of students cited memorization-based learning and the applicability of material to personal life to be both major determinants of engagement. This points to the forte of students who are comfortable with learning approaches that enable them to make a link between theoretical concepts and practical application based on rote memorization. In addition, 50 percent of the students said that books used in the teaching and the ways described by the lecturers affect the level of students' interest in the subject. This means that students should be more interested, interactive, and individualized in their learning style to teach materials. Additionally, 25% of students stated that methods for teaching count for a person's view of cell biology, easy

need for the e-module, while 39 students (61.9%) responded "False," indicating that the majority did not perceive a strong need for the development of the e-module NanoPintar. Overall, these findings show that more than half of the students had not yet identified the e-module as a necessary learning resource.

Table 1. Analysis regarding students' needs for the development of the e-module NanoPintar.

| Students | True | False |
|------------|------|-------|
| Students | 24 | 39 |
| Percentage | 38.1 | 61.9 |

Results from multiple intelligence test.

The results of the multiple intelligence test, the following data were obtained.

and interesting instructional strategies can boost the appreciation of cell biology greatly.

About 75% of the students said that extensive references to learning resource had an influence in the students' experience with the subject. Thus, while it is important for students to have access to information, it is also essential for the best way to access information is with a structure and presentation of the content to help with their interest. Finally, 50% of students mentioned that fun projects are also an element that makes cell biology more interesting. The major implication of this finding is the importance of integrating project-based learning, interactive assignments, and hands-on activities to enhance understanding and enjoyment of the subject.

Table 3. The factors influencing students' interest in cell biology, highlighting the elements that make the subject more appealing and engaging.

| Category | Value |
|--|-------|
| Memorization material | 50 |
| Material related to daily life | 25 |
| Methods used when teaching | 75 |
| Approaches used when teaching | 50 |
| Books used | 50 |
| Extensive learning resource references | 75 |
| Fun projects | 25 |

As is indicated in Table 3, students seem to be more attracted to learning experiences that are interactive, that are aligned with everyday life's applications, as well as structured in a way outside of ordinary memorization

practices. Here, that memorization is still a big challenge, we need innovative teaching strategies like gamification, visualization tools and self-directed e-learning modules like NanoPintar. These are potential tools to make the complex biological concepts easily understandable, interactive and memorable. Therefore, lecturers should also opt for case studies, real life examples, and hands on projects in their curriculums to increase students' engagement. The integration of the digital and the multimedia resources may bridge the gap between textbook knowing and experiential experiencing more further the cell biology so as to be more portable and interesting for the students.

The distribution of students' reported difficulties in studying cell biology in Table 4. The biggest percentage (100%) refers to students who find memorization difficult to learn, so much of cell biology learning is considered as rote memorization rather than an understanding of concepts. Furthermore, students reported challenges relating material to the daily life; 75% agreed with this suggestion that they may have a problem of relating theoretical knowledge to practical. Further 50% of students also found it hard to learn using the methods through which the teaching was taking place, suggesting that the present instructional processes do not ensure learning. Finally, 25% complained of difficulties associated with teaching approaches, books, and numerous references, the indicators of insufficient accessibility to interesting, student-oriented learning materials.

Table 5 shows how students experience difficulties in cell biology. It was observed that the highest proportion (75.7%) of students identified rote-based learning as the main problem. This is because cell biology cannot be learned by rote memorization but require for a more conceptual and interactive approach to learning. It was also reported by 27 percent of students in relation to difficulties caused by teaching approaches employed, which points out that instructional strategies must be more adaptive and student oriented. Methods of teaching (13.5%), books used (10.8%) and the link between material and daily life (8.1%) support other reasons to reform cell biology teaching in a manner that improves accessibility and engagement and facilitates understanding of ideas. Specifically, none of the students felt that referencing of learning materials was an issue. Instead, resources are not the problem, it is how the information is presented and structured that is ultimately the biggest hindrance.

The results of Table 4 and 5 underscore the importance of application of novel instructional approaches based on, for example, interactive e-modules, learning by visual means, and microlearning strategies in order to boost comprehension and engagement. As the reliance on memorization is very

high, e-modules NanoPintar must include interactive animations, real world implementation and gamified learning as a mode of shifting learning from rote recall to conceptualization. Further, it should teach rigorously with student engagement through self-guided learning methods to allow students to apply cell biology concept to real world scenes. These insights emphasize why we should deploy digital learning tools like NanoPintar that can supply personalized, adaptive and enhanced learning material to tackle the learning obstacles that students struggle to overcome in studying biology of cells.

Table 4. The challenges students face when studying cell biology, highlighting both the primary difficulties encountered by students.

| Category | Value |
|--|-------|
| Memorized material | 25 |
| Material related to daily life | 75 |
| Methods used when teaching | 50 |
| Approaches used when teaching | 100 |
| Books used | 50 |
| Extensive references to learning resources | 50 |

Table 5. The perceived reasons behind these difficulties.

| Category | Value |
|--|-------|
| Memorized material | 75.7 |
| Methods used when teaching | 8.1 |
| Books used | 3.5 |
| Others | 10.8 |
| Material related to daily life | 27.0 |
| Approaches used when teaching | 13.5 |
| Extensive learning resource references | 0 |

Based on the questionnaire results provided to lecturers, they specifically identified the endoplasmic reticulum as the most challenging topic to teach (Figure 6). The greatest consensus is among the students (48.6%) and lecturers (75%), in which it is agreed that the endoplasmic reticulum is difficult to learn and teach in terms of its chemical structure and function. This topic, therefore, emerges as the most challenging and consequently requires a more effective pedagogical strategy such as visual tools and interactive learning materials. The chemical structure and function of ribosomes are also another complex subject, with 43.2% of students and 50% of lecturers reporting it as difficult. These results indicate that educational challenges and frustrating learning topics for students are primarily related to molecular structures and intracellular functions.

Some other topics that were particularly hard for students to understand were the concept of mitochondria (5.41%) and the concept of the nucleus and chromosomes (8.11%), and lecturers reported that these topics were hard to teach (50%), as they are complex.

Furthermore, microbodies like peroxisomes, glyoxysomes, and lysosomes were reported by 8.11% of students as difficult, and 25.1% and 35.1% of lecturers, respectively, reported them as difficult to explain. This implies that some cellular components are more straightforward for students, whereas lecturers feel that such instruction is more involved, possibly because the cellular components are too abstract.

Remarkably, some discrepancies emerged between the perceptions of students and lecturers. Lecturers reported the topically related concepts of the Golgi complex and plastids as difficult (25–16.2%), but none of the students marked them as particularly challenging. On the other hand, students reported that the concepts of cytosol and cytoskeleton were not difficult, whereas 27% of lecturers acknowledged difficulty in teaching them. Additionally, 13.5% of lecturers identified the concepts of plasma membranes and intercellular relationships as difficult, yet they were not mentioned by students as a major issue. The implications of these findings are that students find biochemical and molecular processes difficult to understand, while lecturers find it difficult to communicate the structural and functional aspects of the cell. This analysis resulted in the conclusion that targeted instructional interventions are necessary to reduce gaps in student comprehension and enhance teaching competency.

Since visualization, interactivity, and microlearning techniques are commonly agreed upon as suitable approaches for addressing the difficulty of the endoplasmic reticulum and ribosomes, implementing them is justifiable in the development of the NanoPintar e-Module. The integration of 3D visualization, augmented reality (AR), and gamified learning into cellular models and biochemical processes would help students understand these complex structures and processes more effectively. Moreover, microlearning strategies, which associate complex topics with smaller and more digestible learning units, can help students and lecturers overcome instructional barriers.

To support educators further, additional materials such as lecture-ready presentations, interactive simulations, and case studies can be developed for topic areas that lecturers find difficult. These resources can help bridge instructional gaps by delivering more engaging and accessible learning experiences for learners and reducing the instructional burden on lecturers. With the use of these strategies, the NanoPintar e-Module can significantly improve teaching and learning effectiveness in Cell Biology by rendering abstract and complex concepts easier for students to understand and supporting lecturers in enhancing instructional delivery.

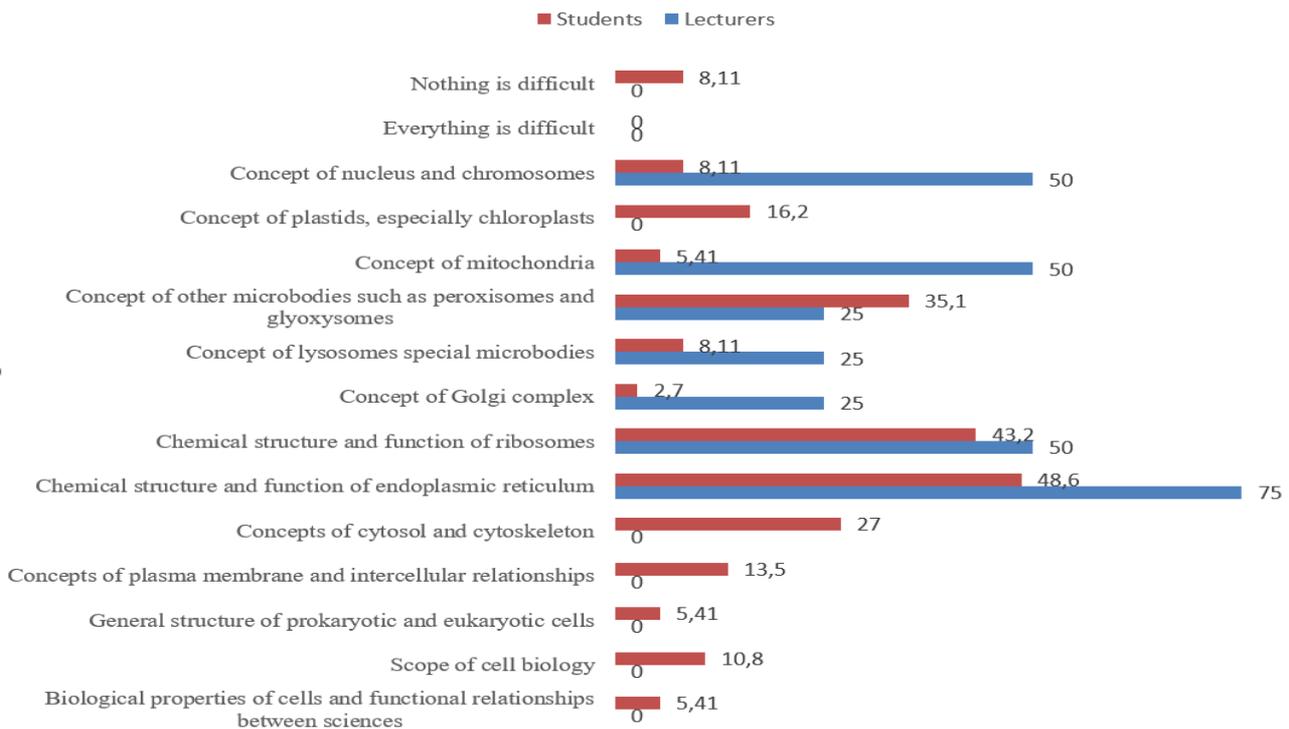


Figure 6. The figure presents a comparative analysis of students’ and lecturers’ perspectives on the most challenging topics in cell biology.

Most of the lecturers used books that were in line with the curriculum in use (100%), as it is impossible for

the fundamental concepts not to be covered (Table 6). In addition, 50% of lecturers were able to use materials

consisting of theoretical concepts and practice questions, which help students reinforce their understanding of theoretical content. Additionally, lecturers accessed practical or project sheets in 50% of cases, indicating efforts to incorporate practical or project-based activities into the curriculum.

Unfortunately, however, there are still significant gaps, particularly regarding the inaccessibility of contextualized learning materials. Indeed, only 25% of lecturers had access to resources with real-world contextual problems, meaning that such applications are lacking in most instructional materials that link Cell Biology concepts to everyday life. Additionally, none of the lecturers reported having access to fully digital-based teaching materials, meaning there is a clear need for digital learning solutions such as interactive e-modules and mobile-friendly resources. Moreover, none of the respondents stated that all required materials were readily accessible, emphasizing the necessity for more comprehensive and accessible teaching materials.

These results indicate a need to update and expand teaching materials for Cell Biology courses. Current instructional practices have not yet incorporated fully digital-based resources and context-based problem-solving materials that can be developed into interactive digital learning tools utilizing microlearning, gamification, and real-world applications. These gaps, however, can be addressed through the NanoPintar e-Module, which offers adaptive and mobile-friendly educational content designed to enhance student engagement and comprehension.

Future efforts should focus on digitizing instructional materials, integrating real-life applications into lesson plans, and developing interactive resources that promote self-directed learning. Through these approaches, educators can provide more engaging learning experiences and ultimately enable students to understand and retain complex biological concepts more effectively.

Table 6. The availability of teaching materials used by lecturers for cell biology courses. The data highlight the different types of instructional resources currently in use and identify gaps in the availability of digital and real-world context-based materials.

| Category | Value |
|---|-------|
| Consists of material and practice questions | 50 |
| There are practical or project sheets | 100 |
| Context problems in everyday life | 50 |
| Books that meet the current curriculum | 25 |
| Already digital-based | 0 |
| Everything is available | 50 |

Table 7 shows that lecturers are very aware of and very interested in NanoPintar and microlearning as

innovative educational tools for teaching Cell Biology. All respondents are acquainted with the notion of microlearning and NanoPintar and were in favor of the introduction of NanoPintar in Cell Biology lectures. This indicates that pedagogical challenges in teaching complex biological concepts are identified, along with the need for more engaging and digital learning solutions.

Regarding the use of e-modules in general, all lecturers have been exposed to e-modules, but 75% have never used e-modules to teach their Cell Biology lectures. This means that the adoption of digital instructional tools in teaching is in fact low, perhaps because there are no easily accessible and content-rich e-modules that would facilitate the adoption of digital instructional tools for complex biological topics. When lecturers were asked whether they would adopt e-modules integrated with NanoPintar, they were willing to use them if they were available. The strong positive response reaffirms the necessity of developing and distributing NanoPintar e-modules to enhance self-directed learning, visualization of complex cellular processes, and participation in STEM education.

Table 7. Analysis of the needs for making NanoPintar.

| Indicator | Value |
|---|-------|
| Do you know about Microlearning or NanoPintar? | 100 |
| In your opinion, is there a need for NanoPintar in cell biology lectures? | 100 |
| Have you ever used NanoPintar? | 0 |
| Can cell biology lectures be taught using NanoPintar? | 100 |
| Do you know about electronic modules (e-modules)? | 100 |
| Have you ever used electronic modules (e-modules) in cell biology lectures? | 25 |
| Do electronic modules in cell biology lectures equipped with NanoPintar already exist? | 0 |
| If electronic modules in cell biology lectures equipped with NanoPintar were available, would you use them? | 100 |

Table 8 indicates a high level of awareness and interest among lecturers regarding the use of NanoPintar and microlearning in Cell Biology teaching. All respondents are aware of the concept of microlearning and agree that NanoPintar is required for teaching Cell Biology lectures. This demonstrates that pedagogical challenges in the teaching of complex biological concepts require more dynamic and digitally oriented learning solutions.

Regarding the use of e-modules in general, all lecturers are aware of them, and 25% have used them in their Cell Biology lectures. This relatively low level of adoption suggests that, although digital instructional

tools are well understood, their implementation in teaching has not been widespread. However, all lecturers affirmed their willingness to use e-modules integrated with NanoPintar if they were available. This strong positive response highlights the urgent need for the development and implementation of NanoPintar e-modules that can transform self-directed learning, visualization of complex cellular processes, and engagement in STEM education.

Table 8. Analysis regarding students' needs for the development of the e-module NanoPintar.

| Indicator | Value |
|---|-------|
| Do you know about Microlearning or NanoPintar? | 100 |
| In your opinion, is there a need for NanoPintar in cell biology lectures? | 100 |
| Have you ever used NanoPintar? | 0 |
| Can cell biology lectures be taught using NanoPintar? | 100 |
| Do you know about electronic modules (e-modules)? | 100 |
| Have you ever used electronic modules (e-modules) in cell biology lectures? | 25 |
| Do electronic modules in cell biology lectures equipped with NanoPintar already exist? | 0 |
| If electronic modules in cell biology lectures equipped with NanoPintar were available, would you use them? | 100 |

Table 9 suggests the main features that students would like to have included to facilitate their learning of Cell Biology concepts, especially given the complexity of such concepts. The feature indicating that the e-module should make the material easier to understand is the most significant factor (83.8%). This indicates that learners strongly prefer simplified explanations and well-structured content that enable them to grasp difficult biological processes. Similarly, 67.6% of students stated that animations and images were important, implying that visual representations contribute substantially to improving comprehension and engagement in Cell Biology learning.

Table 9. Analysis of students' preferences regarding the desired presentation style of an e-module for cell biology.

| Category | Value |
|---|-------|
| Others | 0 |
| Interactive | 24.3 |
| Has varied practice questions and HOTS | 32.4 |
| Makes it easier for you to understand the material in cell. | 32.4 |
| The material is short | 18.9 |
| Interesting views | 32.4 |
| Displaying animations (pictures) | 67.6 |

Furthermore, 32.4% of students mentioned the necessity for varied practice questions and HOTS exercises, which help support deeper and more interactive assessments. Another 32.4% of students preferred e-modules with interesting visual elements, confirming the importance of aesthetically engaging content in stimulating student motivation.

Among all students, 24.3% preferred an interactive e-module over 18.9% who preferred concise and straightforward material. This implies that conciseness can be helpful in some cases, but the most important thing is to present clear structure with explanations backed up by visuals and interactive elements.

Interview Results with Lecturers

The following conclusions were drawn from the interviews with the lecturers: lecturers prepare courses by aligning materials with the curriculum and learning objectives, primarily using textbooks, YouTube videos, PowerPoint, and projectors due to time constraints in developing their own teaching materials. While these tools are effective, challenges include designing innovative content, assessing learning outcomes, and addressing difficult topics like ribosomes, the endoplasmic reticulum, and cell formation. Students engage best through lectures, discussions, and media, with educational videos being particularly helpful for understanding complex concepts.

Results from Student Interviews

The following conclusions were drawn from the student interviews: students find Cell Biology engaging as it deepens their understanding of living organisms but face challenges with complex topics like the endoplasmic reticulum and ribosomes due to difficulties in grasping concepts, limited time, and a lack of visual aids. They prefer visual learning methods, such as videos and modules, and are most engaged by practical work, life-related materials, and discussions. Common tools used include laptops, smartphones, and projectors, though poor internet connectivity and technical issues can hinder learning.

The results of the analysis explain that the problems faced by lecturers and students in cell biology courses include difficulties with cell biology materials, understanding challenging content, using teaching materials, and the relationship between students' visual abilities and multiple intelligences. Regarding the challenges in cell biology courses, students stated that they had difficulty memorizing the material, while other difficulties were related to the textbooks used. On the other hand, lecturers stated that students did not master the content because the material was closely related to everyday life, required extensive learning resources, involved a difficult teaching approach to follow, and

relied on textbooks and learning projects. This is supported by expert opinions stating that the complexity of cell biology involves various intricate concepts, including structure, function, and cellular processes (Schwarz & Blower, 2016).

On the other hand, the detailed mechanisms of cellular processes, such as signal transduction pathways and metabolic cycles, can be particularly confusing. Students may struggle to understand how these processes interrelate and contribute to overall cellular function, leading to confusion and frustration (Santhosh et al., 2024). Another statement asserts that cell biology, as an abstract subject, makes it difficult for students to grasp material that contributes to processes occurring within the cell (Kara Rogers, 2024). Additionally, the lack of engaging and comprehensive teaching materials can further hinder students' understanding of these complex topics (Mercy Frederick-Jonah & Tobi, 2022).

The use of teaching materials also became a topic of concern during the interviews and questionnaire responses. It was found that faculty members primarily used PowerPoint presentations and did not have additional teaching materials to help students understand the challenges they faced with the material, citing insufficient time during lectures. However, in relation to Law No. 37 of 2009, in addition to teaching, faculty members are also responsible for creating teaching materials and modules for students (President of the Republic of Indonesia, 2009). Therefore, the development of teaching materials in the form of modules is crucial for faculty members to assist students' learning anytime and anywhere.

According to (Depdiknas, 2008), modules should at least include learning objectives, learning content, and evaluation. The purpose of developing modules is to ensure that students can master the competencies intended to be achieved in learning activities to the maximum extent possible (Rahmi et al., 2021). Through pre-test and post-test mechanisms and a mastery system for each module topic, students can skip certain topics while studying a series of modules, thereby accelerating the learning process (Alshaya & Oyaid, 2017).

Today, modules are also presented in the form of e-modules, which can facilitate students who are slower in absorbing lessons by providing an atmosphere that is more effective and engaging (Inanna et al., 2021). An e-module is a digital-based, non-print teaching material product that is designed for students to study independently. E-modules are also considered a medium for self-learning because they include guidelines for independent study (Kuncahyono, 2018). The use of e-modules has proven to be effective in improving student learning outcomes (Kumalasari et al., 2023).

Based on the results of the students' visual abilities, it is evident that their visual abilities are still low. According to the interview results, students require teaching materials in the form of visual aids. Visual elements such as images, animations, and videos can clarify students' understanding of the material, especially regarding content they consider difficult, such as the endoplasmic reticulum. Faculty members, according to the analysis results, also stated that this material is difficult to teach, highlighting the need for teaching materials that can provide visualizations and improve student comprehension. The more students practice solving problems related to images/visuals, the better their visual thinking will become (Kania, 2013). In addition, visualization can enhance understanding of spatial elements in problem-solving (Aini & Hasanah, 2019). Thus, the connection between verbal and visual information helps students make connections, understand relationships, and remember related details (Nurannisa, 2017). This will ultimately support the development of complex teaching materials that can be presented in the form of e-modules and NanoPintar.

Another important finding from the analysis is the students' low multiple intelligences. According to the theory, humans inherently possess multiple types of intelligence, not just IQ as is commonly understood (Anita, 2020). Therefore, if the results are unsatisfactory, there must be factors contributing to this outcome. Multiple intelligences include intellectual intelligence (IQ), emotional intelligence (EQ), and spiritual intelligence (SQ) (Hikmah, 2022).

Daniel Goleman, in the 1980s, stated that a person's success in life is only 20% determined by intellectual intelligence, while the rest of the success is determined by other types of intelligence, including emotional intelligence (Flynn, 2007; Giulivi et al., 2022; Goleman, 1995). Students with recognized linguistic intelligence, for example, should be given the opportunity to read, write, and listen to words related to the subject matter being taught (Pratita et al., 2021). Therefore, when explaining the material, it should also aim to enhance the multiple intelligences of students. The teaching materials used should aim to improve the students' multiple intelligences.

The teaching materials desired by both lecturers and students are e-modules supported by NanoPintar. This e-module is designed based on the components set by the Ministry of Education of Indonesia. To enhance visual skills and multiple intelligences of students, we include NanoPintar, or in other words, microlearning, which features animations, images, and videos. The presence of visual elements will improve the students' capabilities. Visual thinking can also enhance students' mathematical skills. The more students practice solving problems related to images/visuals, the better their

visual thinking becomes (Kania, 2013). With the support of NanoPintar, the focus is placed on one topic at a time, allowing students to acquire specific knowledge in the most efficient manner (Nikkhoo et al., 2023). Microlearning can also serve as a solution for students who require additional independent learning (Cyly et al., 2023).

Conclusion

These preliminary needs analysis successfully defined the specifications and validated the necessity for the development of the NanoPintar e-module by comprehensively assessing the learning challenges and instructional requirements of students and lecturers in the Cell Biology course. The key findings confirmed that students face significant difficulties with abstract concepts (e.g., cell organelles) due to limited visual-spatial abilities, as evidenced by very low visualization test scores, which conventional teaching methods rely heavily on static materials fail to address. Specifically, the research identified the endoplasmic reticulum as the most challenging material to learn and teach, thus validating its suitability as the primary focus for e-module development. Furthermore, the analysis of student preferences and user feedback validated the necessity of developing the NanoPintar e-module to incorporate interactive features such as 3D visualization, self-paced learning capabilities, and gamification elements. In conclusion, this study provides a data-driven framework for integrating microlearning into Cell Biology instruction, moving beyond traditional methods to address students' specific visual-spatial deficits. This research contributes to the field of educational technology by establishing essential design features for developing effective instructional materials that address abstraction and visualization challenges in advanced biological concepts.

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Conceptualization, D.S., and S.D.; methodology, D D.S., and S.D.; formal analysis, D.S., and S.D.; investigation, D.S., and S.D.; resources, D.S., and S.D.; writing – original draft, D.S. and S.D.; writing – review and editing, S.D; visualization, D.S.; supervision, S.D.; project administration, D.S.; funding acquisition, D.S., and S.D.; All authors have read and approved the published version of the manuscript.

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Conflicts Of Interest

The Authors Declare That There Are No Conflicts of Interest Related to This Study. All Authors Have Disclosed That They Have No Financial, Personal, Or Professional Relationships That Could Have Influenced the Outcomes and Interpretation of This Research.

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