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Needs Analysis of Mobile-Based Biology Microlearning for Senior High School Students: Student and Teacher Perspectives

Nurhikmah H[1*], Abdul Malik Ramli[2], Maenuddin Bustanil Syah[3], Baso Asrul N. Bena[4]

[1] Educational Technology, Faculty of Education, Universitas Negeri Makassar, Makassar, South Sulawesi, Indonesia.
Email: nurhikmah.h@unm.ac.id
[2] Primary School Teacher Education, Faculty of Education, Universitas Negeri Makassar, Makassar, South Sulawesi, Indonesia.
Email: abdul.malik.ramli@unm.ac.id
[3] Educational Technology, Faculty of Education, Universitas Negeri Makassar, Makassar, South Sulawesi, Indonesia.
Email: maenuddin@unm.ac.id
[4] Primary School Teacher Education, STKIP Andi Matappa, Pangkajene, South Sulawesi, Indonesia.
Email: asrul@matappa.ac.id

***Corresponding Author**
Email: nurhikmah.h@unm.ac.id

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Abstract
Learning biology, particularly cells and metabolism, requires students to understand structures, sequences, and dynamic processes that are difficult to observe directly. This study aimed to analyze students' and teachers' needs as a basis for developing mobile-based biology microlearning for senior high school students. A descriptive needs analysis involved 31 Grade 11 students in the Mathematics and Natural Sciences track and three biology teachers at SMA Negeri 23 Makassar. Closed-ended data were analyzed using frequencies, percentages, means, and standard deviations, while open-ended responses were coded descriptively. Smartphones were the primary student devices (77.4%), and videos of 3–5 minutes were the most preferred duration (51.6%). All students needed offline access, 93.5% needed subtitles, and 90.3% agreed that short, stepwise materials could support their focus. The most frequently identified difficult topics were enzyme and coenzyme inhibition (32.3%), light-dependent reactions of photosynthesis (29.0%), and the fluid mosaic model of cell membranes (22.6%). Teachers emphasized dynamic media, curriculum-aligned materials, editable resources, formative question banks, data-efficient materials, and technical support, while only one teacher reported confidence in creating simple digital materials. The findings indicate that the initial design should provide 3–5-minute single-concept segments, 360p–480p video options, offline access, subtitles and transcripts, stepwise visualizations, and short quizzes with explanatory feedback. The study provides context-sensitive initial specifications for mobile-based biology microlearning, which should be followed by content validation, prototype development, usability testing, and effectiveness evaluation.

Keywords: biology education; microlearning; mobile learning; needs analysis; instructional media.

Introduction

Digital technology expands the range of learning resources and the times and places in which learning can occur, but the availability of technology does not automatically result in high-quality learning. Decisions about technology use should begin with pedagogical objectives, the characteristics of the subject matter, teacher readiness, and students' access conditions. The global education monitoring report emphasizes that new technology is beneficial when it is relevant to users' needs, affordable, and supported by the education system, rather than implemented as an end in itself (Global Education Monitoring Report Team, 2023). Inequalities in devices, connectivity, and data costs also remain important concerns in digital learning (UNICEF & International Telecommunication Union, 2020). Therefore, the development of instructional media should be grounded in local evidence about the intended users, the devices available to them, and how they will access the materials.

These considerations are particularly relevant to learning through mobile devices. Mobile devices offer flexibility across time and place, but the quality of the learning experience depends on the design of the activities, not merely on transferring materials to a smaller screen. Research in primary and secondary education shows that mobile devices can create pedagogical opportunities when they are used to transform how students interact with content and tasks (Crompton & Burke, 2020). At the same time, the relationship among mobile technology, learning processes, and outcomes is strongly influenced by how the technology is integrated (Bernacki et al., 2020). Mobile design must therefore account for screen size, internet stability, data allowances, file size, navigation, and cognitive load.

In biology education, these digital challenges intersect with the complexity of the subject matter. Processes such as membrane transport, enzyme activity, cellular respiration, photosynthesis, and cell division involve structure-function relationships, changes over time, and the transfer of matter or energy that are difficult to represent through verbal explanations alone. In protein synthesis, animations can help students construct knowledge when representations are segmented and connected to appropriate explanations (Strømme & Mork, 2021). Animations are useful when the learning objective requires an understanding of change or movement, whereas static images may be more effective for examining spatial arrangements; the choice of representation should therefore follow the type of knowledge being learned (Ploetzner et al., 2021). Research in biology education also indicates that interactive animation can support understanding of cell concepts (El Hammoumi et al., 2022). Guidelines for molecular animation further emphasize the importance of defining the audience, purpose, level of detail, and context of use from the outset of development (Patterson et al., 2022).

Microlearning is one approach suited to mobile use and to breaking down complex processes. It presents focused content in short units that can be accessed when needed. The literature shows that microlearning has developed across diverse contexts, with design, implementation, evaluation, and mobile-device use as dominant themes (Sankaranarayanan et al., 2023). Pedagogical reviews emphasize that the quality of microlearning is determined by content design and instructional flow, not simply by its short duration (Alias & Razak, 2023). Reviews of mobile microlearning also note potential benefits for engagement and retention while highlighting usability issues and the need to adapt microcontent to small screens (Lee, 2023). Thus, microlearning is not simply the division of a long video into short clips; each unit should have a specific objective, a meaningful activity, and a clear relationship to other units.

Recent evidence supports the cautious use of microlearning. A microlearning outcomes framework identifies specific objectives, small content units, interactivity, personalization, and appropriate media as core design components (Monib et al., 2025). Other reviews show that the approach has been used in secondary education, higher education, and training, although the evidence and practices remain varied (Cruz et al., 2022). In biochemistry education, microlearning activities based on active recall and critical thinking were associated with improved understanding of difficult concepts and course performance, particularly among students who initially struggled (Nowak et al., 2023). Flipped mobile-based microlearning has also shown potential to support access, engagement, retention, and learning outcomes among postgraduate students (Al-Zahrani, 2024). These findings provide a conceptual rationale for exploring microlearning in senior high school biology, but they do not replace the need for user analysis in the target context.

The quality of microlearning also depends on multimedia and assessment design. Multimedia learning theory emphasizes selecting relevant words and visuals, reducing unnecessary elements, signaling important information, and segmenting content so that processing capacity is not overloaded (Mayer, 2020). A systematic review indicates that these principles remain relevant across learning environments, although their application must be adapted to the technology and context (Çeken & Taşkın, 2022). Video can improve learning when it forms part of an active instructional design rather than serving merely as a delivery channel (Noetel et al., 2021). In science education, student-generated animations can even foster representation and knowledge construction when adequate scaffolding is provided (Farrokhnia et al., 2020).

In addition to visual presentation, microlearning requires retrieval activities and feedback. A meta-analysis of classroom learning shows that quizzes can improve learning compared with restudy, although the magnitude of the benefit depends on design and implementation conditions (Yang et al., 2021). Combining retrieval practice with spaced repetition can strengthen knowledge retention and transfer (Carpenter et al., 2022). Feedback is also more useful when it provides information that students can use to improve their work, strategies, or self-regulation, rather than merely indicating whether an answer is correct or incorrect (Wisniewski et al., 2020). Questions embedded in molecular biology videos were reported to improve overall scores and influence viewing behavior, although they did not consistently improve understanding of every concept assessed (Haagsman et al., 2020). Game elements can be added to encourage engagement, but meta-analytic evidence shows mixed effects; gamification should therefore support learning objectives rather than distract students (Bai et al., 2020; Sailer & Homner, 2020).

Teachers determine whether such designs can be implemented. Teacher digital competence encompasses interrelated technical, pedagogical, ethical, and professional capabilities (Falloon, 2020). Experiences during the transition to online teaching show that teachers' competence and learning opportunities influence their ability to adapt (König et al., 2020). Readiness for online teaching is also heterogeneous; support should account for differences in competence profiles and workload (Scherer et al., 2021). A systematic review highlights the importance of the school's technological climate, training, and pedagogical strategies in strengthening teacher digital competence (Yang et al., 2023). Other research indicates that digital competence is often measured through self-report and that teachers are more commonly positioned as users than as media designers, making ready-to-use designs and implementation support particularly relevant (Smestad et al., 2023).

Although previous studies explain general principles of microlearning, multimedia, and teacher digital competence, product specifications should be determined by the needs of the intended users. Contextual evidence is still needed that combines students' perspectives on access, preferred duration, format, and assessment with teachers' perspectives on difficult material, curriculum alignment, technical readiness, and implementation support. This study addresses that need through the analysis of two complementary survey datasets.

Previous studies have commonly examined microlearning, multimedia design, or teacher digital competence separately; limited evidence integrates student access constraints, difficult biology concepts, microcontent preferences, and teacher implementation requirements within one contextual needs analysis for senior high school biology. This study addresses this gap by translating student and teacher perspectives into initial design specifications.

Accordingly, the objectives of this study were to: (1) map students' access profiles and digital learning preferences; (2) identify needs related to content, visualization, assessment, accessibility, and biology topics; (3) describe teachers' needs for digital learning resources and implementation support; and (4) formulate initial specifications for mobile-based biology microlearning.

Research Method

This study employed a descriptive analysis design because its purpose was to characterize patterns of need and generate initial specifications. Participants comprised 31 Grade 11 students in the Mathematics and Natural Sciences (MIPA) track, all from the urban school SMA 23 Makassar, and three biology teachers. The teachers were purposively selected as key informants because they directly taught biology at the grade level and within the curricular context targeted by the proposed microlearning development. Two teachers used laptops as their primary devices for digital teaching, while one used a smartphone. Given the small and purposively selected teacher sample, the teacher data were used to identify contextual design requirements, including curriculum alignment, instructional needs, technological constraints, and implementation support, rather than to estimate patterns in the broader teacher population. Accordingly, the overall sample was treated as contextual and was not intended for population-level estimation.

The student questionnaire comprised 45 variables covering grade and access profiles; preferred learning formats; difficult topics; connectivity, data allowance, resolution, and file size; microlearning design needs; quiz preferences; accessibility; and three open-ended questions. The teacher questionnaire comprised 39 variables covering teaching and access profiles; challenging topics; media-use practices; curriculum and assessment needs; attitudes and digital confidence; implementation barriers; feature importance; and three open-ended questions. Attitudinal statements used four response categories ranging from strongly disagree to strongly agree. Teacher importance statements used four levels ranging from less/not important to very important. Categories were coded from 1 to 4. For reporting, the agreement percentage combined agree and strongly agree, while the mean indicated the relative tendency on the 1-4 scale. Because the instrument covered heterogeneous constructs and functioned as a needs questionnaire, the items were not treated as a single psychometric scale.

Data were read and analyzed using R Studio. Quality checks covered data dimensions, empty cells, duplicate responses, label consistency, and normalization of one residual delimiter character in the video-duration options. No empty cells or duplicate responses were found in either dataset. Categorical variables were summarized using frequencies and percentages. Likert items were summarized using the number of responses, mean, standard deviation, median, and percentage agreement. Multiple selections for difficult topics were counted by option; because respondents could select more than one topic, the percentages do not sum to 100%.

To support interpretation, the student items were also conceptually grouped into six domains: learning-format preferences, concept visualization, data-efficient access, adaptive microlearning design, gamification, and accessibility and navigation. Domain scores were calculated as the mean of item responses for each participant and then summarized on the 1-4 scale. These groupings were used as a map of design needs, not as validated constructs. Open-ended responses were coded using a directed procedure based on response content. Student categories included the need for visualization/animation, concept/process complexity, dense text or difficult language, internet constraints, and learning speed/time. Teacher categories included the complexity of biological processes, limited time, internet access, and technological skills. A response could be assigned to more than one category. Because coding was completed in a single analytical round without a second rater, theme frequencies were treated as indicative evidence for triangulation rather than as measures of prevalence.

Prior to data collection, formal research permission was obtained from the Provincial Government of South Sulawesi through research permit No. 19200/S.01/PTSP/2025. Permission to conduct the study and collect data at the research site was also obtained from the principal of SMA Negeri 23 Makassar. Before completing the questionnaires, participants were informed about the purpose of the study, the voluntary nature of their participation, and the use of the collected data for research purposes. Participants were also informed that their responses would be treated confidentially and reported in aggregate form without disclosing personally identifiable information. Participation in the study proceeded after participants indicated their willingness to take part.

Results and Discussion

A. Result

1. Students' Access Profiles and Technical Preferences

Smartphones were the primary device for 24 of the 31 students (77.4%), while seven students (22.6%) mainly used laptops. Primary internet access was distributed across school Wi-Fi (38.7%), personal mobile data (35.5%), and home Wi-Fi (25.8%). Although 80.6% of students rated their home connection as stable or very stable, six students (19.4%) reported an unstable connection. A total of 45.2% had a weekly data allowance of 1-3 GB, while 19.4% were unsure how much data was available to them.

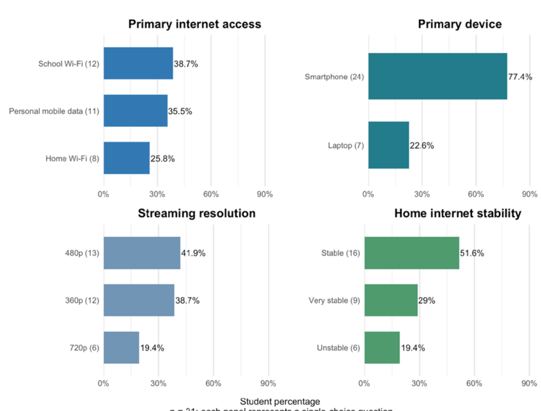

Figure 1. Students' Digital Access and Video Preferences

Usage patterns indicate a need for data optimization. The most commonly used resolutions were 480p (41.9%) and 360p (38.7%); only 19.4% selected 720p. A total of 45.2% of students were comfortable downloading files smaller than 20 MB, and 38.7% selected 20-50 MB. Thus, 83.9% of students had a maximum comfortable file size of 50 MB. All students agreed that content should be accessible offline (M = 3.42). These findings show that high smartphone ownership does not eliminate variation in connectivity and data costs.

Educationally, this pattern means that mobile availability should not be equated with unrestricted digital access. Students may own smartphones yet still regulate resolution, download size, and connection use to control data consumption. Consequently, data efficiency becomes part of instructional accessibility: if a learning unit is too large or depends on continuous streaming, students with the same curriculum access may experience unequal opportunities to review content.

Table 1. Students' Digital Access, Connectivity, and Content Consumption (n = 31)

Indicator	Category	n	%
Primary device	Smartphone	24	77.4
Primary internet access	School Wi-Fi	12	38.7
Home connection	Stable/very stable	25	80.6
Weekly data allowance	1–3 GB	14	45.2
Streaming resolution	360p–480p	25	80.6
Comfortable file size	≤50 MB	26	83.9
Need for offline access	Agree/strongly agree	31	100.0

Note: Categories show the dominant response or a relevant combination of categories. Source: Processed survey data, 2025.

2. Preferences for Duration, Format, and Assessment

Sixteen students (51.6%) preferred videos lasting 3-5 minutes, eight students (25.8%) preferred videos shorter than one minute, and seven students (22.6%) were comfortable with durations of 6-10 minutes. Playback speeds were 1.0x for 45.2% of students, 1.25x for 32.3%, and 1.5x for 22.6%. These results support providing core segments of approximately 3-5 minutes with flexible playback controls rather than prescribing a single speed for all users.

For quizzes, 54.8% of students preferred multiple-choice questions, followed by true-false (19.4%), matching (12.9%), and short-answer questions (12.9%). Preferred quiz duration was almost evenly divided: 48.4% selected a maximum of five minutes and 51.6% selected 6-10 minutes. Immediate feedback was endorsed by 87.1% of students (M = 3.32), while 83.9% endorsed graduated practice (M = 3.23). These preferences suggest that quizzes should be brief, diagnostically oriented, provide explanations for answers, and allow students to try again.

The variation in preferred video and quiz duration suggests that brevity alone is unlikely to meet all learners' needs. A flexible architecture is more defensible than a rigid time limit: short core explanations can reduce attentional demands, while optional recaps, replay controls, and enrichment segments can accommodate differences in prior knowledge and learning pace. The strong preference for immediate feedback also indicates that students expect microlearning to support active checking of understanding, not only passive viewing.

3. Students' Priority Microlearning Features

Offline access was the highest priority, with 100% agreement. Subtitles were needed by 93.5% of students. A total of 90.3% agreed that short, stepwise materials would help them focus; the same percentage was found for concise infographics, process animations, and glossaries and concept maps. Immediate feedback was needed by 87.1%, while one concept per segment, graduated practice, and step-by-step visualization were each endorsed by 83.9% of students.

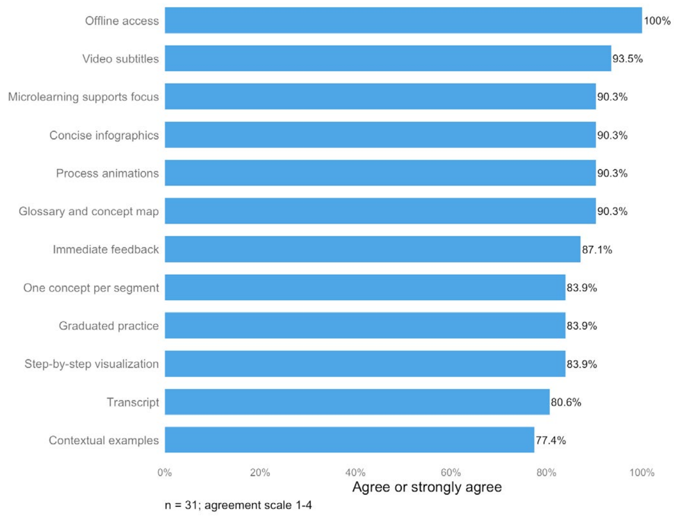

Figure 2. Students' Priority Microlearning Design Features

At the domain level, data-efficient access had the highest mean (M = 3.35), followed by adaptive microlearning design (M = 3.30), learning-format preferences (M = 3.17), accessibility and navigation (M = 3.12), gamification (M = 3.10), and concept visualization (M = 3.02). The relatively positive mean for gamification should be considered alongside variation across items: game features may appeal to some students, but they are not more urgent than access, animation, subtitles, and feedback.

The ordering of these domains is educationally meaningful. Access and adaptive design ranked above gamification, indicating that students prioritized reliable participation and comprehensible content over motivational embellishments. In product-development terms, offline access, manageable files, subtitles, visual explanations, and feedback should therefore be treated as core requirements, whereas game elements can remain optional enhancements.

Table 2. Students' Ten Highest-Priority Microlearning Design Needs (n = 31)

Feature	M (1-4)	Agreement (%)
Offline access	3.42	100.0
Video subtitles	3.29	93.5
Microlearning supports focus	3.42	90.3
Concise infographics	3.39	90.3
Process animation	3.29	90.3
Glossary and concept map	3.26	90.3
Immediate feedback	3.32	87.1
One concept per segment	3.26	83.9
Graduated practice	3.23	83.9
Step-by-step visualization	3.16	83.9

Note: Agreement = agree + strongly agree; M = mean. Source: Processed survey data, 2025.

4. Difficult Biology Topics

The most frequently selected difficult topic was enzymes, particularly competitive/noncompetitive inhibition and coenzymes (10 students; 32.3%). This was followed by the light-dependent reactions of photosynthesis (nine students; 29.0%), the fluid mosaic model of the cell membrane (seven students; 22.6%), cell-cycle control and cancer (six students; 19.4%), mitochondrial structure and function (six students; 19.4%), and pyruvate decarboxylation and the Krebs cycle (six students; 19.4%). These topics are dominated by sequences, molecular components, and changes in energy or structure.

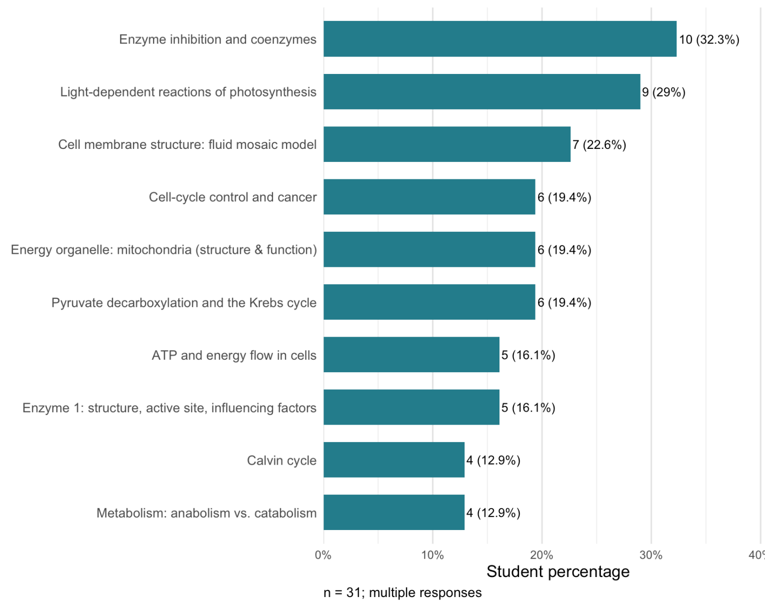

Figure 3. Biology Topics Most Frequently Identified as Difficult by Students

Teacher selections complemented this pattern. Although each teacher option represented only one person because n = 3, the selected topics included photosynthesis, respiration, membrane transport, and the cell cycle. All three teachers agreed that metabolism is difficult to teach with static media and that biological processes require animation or other dynamic representations. Convergence between the two data sources supports initial prioritization of enzymes and metabolism, photosynthesis, cell membranes, respiration, and the cell cycle.

The Results is not simply a list of difficult chapters; it points to a representational problem. The prioritized topics involve invisible molecular interactions, temporal sequences, and causal changes that are difficult to infer from static text or diagrams alone. This supports designing micro-units around process transitions and cause-effect relationships rather than reproducing textbook sections in shorter form.

5. Teacher Needs and Implementation Support

All three teachers reported a need for learning resources aligned with CP/ATP, ready-to-use activity sheets or RPP, formative question banks aligned with indicators, data-efficient materials, intuitive interfaces, editable assets, micro-training, and technical support. They also agreed that the academic quality of current digital resources varies. Curriculum-aligned learning materials received the highest importance rating (M = 4.00), followed by stepwise animation (M = 3.67). Formative quizzes, differentiation, and offline/adaptive-resolution modes each received M = 3.33.

Media-production readiness remained a gap. Only one teacher agreed that they were confident in creating simple digital materials (M = 2.33), and no teacher reported having a curated bank of digital learning resources (M = 1.67). At the same time, all three teachers held positive attitudes toward technology integration. This pattern indicates that acceptance of technology does not necessarily entail the capacity to design or produce media; the product should reduce preparation demands and provide support that can be used immediately.

This gap has direct implementation significance. If teachers are willing to integrate technology but lack time, curated resources, or production confidence, adoption is more likely when the product minimizes authoring demands while preserving teacher control. Editable, curriculum-mapped resources and brief implementation guidance can therefore function as adoption infrastructure rather than as supplementary features.

Table 3. Teachers' Primary Needs for Mobile-Based Biology Microlearning (n = 3)

Need	Agree (n)	M (1-4)	Interpretation
Learning materials aligned with CP/ATP	3	4.00	Very high
Stepwise process animation	3	3.67	Very high
Formative quizzes and feedback	3	3.33	High
Remedial-enrichment differentiation	3	3.33	High
Offline/adaptive-resolution mode	3	3.33	High
Ready-to-edit assets	3	3.67	Strongly needed
Micro-PD <=5 minutes	3	3.67	Strongly needed
Technical/community support	3	3.67	Strongly needed

Note: Because n = 3, the table emphasizes the number of teachers; means are descriptive only. Source: Processed survey data, 2025.

6. Open-Ended Barriers and Synthesis of Needs

In students' open-ended responses, a need for visualization or animation appeared in 17 responses (54.8%). Issues related to learning speed or time appeared in 11 responses (35.5%), dense text or difficult language in nine responses (29.0%), concept/process complexity in seven responses (22.6%), and internet access in five responses (16.1%). All teachers mentioned the complexity of biological processes; one teacher each also mentioned limited time, connectivity, and technological skills.

Triangulation identified four needs shared across groups. First, content should explain change and sequence through stepwise animations that still give users control. Second, materials should be concise but connected through concept maps so that content units do not become unstructured fragments. Third, access should be designed for smartphones, low bandwidth, and offline use. Fourth, teachers need an implementation package that combines student content, assessment, curriculum alignment, and editable assets.

Table 4. Student and Teacher Needs and Initial Product Specifications

Aspect	Evidence of need	Initial specification
Duration	51.6% preferred 3-5 minutes	One concept per 3-5-minute segment; micro-recap <1 minute; optional enrichment.
Access	100% needed offline access	Offline-first; last position retained; no dependence on repeated login.
Video	80.6% used 360p-480p	360p/480p options, speed control, pause, replay, and download.
File size	83.9% comfortable with <=50 MB	Core unit ideally <20 MB; one topic package approximately <=50 MB.
Accessibility	93.5% subtitles; 80.6% transcripts	Synchronized subtitles, transcripts, glossary, and concept map.
Visualization	90.3% needed animation	Stepwise animation + static diagrams; signaling and segmentation.
Assessment	87.1% needed feedback	Quiz <=10 minutes, explanatory feedback, retry, and graduated questions.
Teacher support	3/3 needed assets and micro-PD	CP/ATP mapping, editable slides, LKPD, question bank, and tutorials <=5 minutes.

Source: Synthesis of student and teacher data, 2025.

Discussion

1. Relevance of Microlearning to Students' Needs

The results show strong support for short, stepwise materials, but the principal value of microlearning in this context extends beyond duration. Students need one concept per segment, visual summaries, contextual examples, graduated practice, feedback, and connections among concepts. This finding is consistent with reviews that identify content design and instructional flow as the two main dimensions of microlearning (Alias & Razak, 2023). Bibliometric research also shows that design, implementation, evaluation, and mobile-device use are interconnected themes, meaning that decisions about duration cannot be separated from how units are used and evaluated (Sankaranarayanan et al., 2023).

The majority preference for 3-5-minute videos can serve as a starting point rather than an absolute rule. A recent microlearning framework emphasizes specific objectives, appropriate timing, interaction, personalization, and media selection (Monib et al., 2025). Because 25.8% of students preferred videos shorter than one minute and 22.6% preferred 6-10 minutes, a more adaptive architecture would provide 3-5-minute core segments, recap clips shorter than one minute, and longer optional enrichment segments. This approach also addresses mobile microlearning challenges related to usability and the adaptation of microcontent for small screens (Lee, 2023).

The difficult topics identified further support the relevance of this approach. Enzymes, photosynthesis, membranes, respiration, and the cell cycle contain subprocesses that can be divided into micro-objectives without losing their systemic connections. Evidence from biochemistry suggests that active-recall microlearning activities can reinforce difficult concepts, particularly for learners who need additional support (Nowak et al., 2023). However, the present study does not demonstrate that microlearning will improve senior high school students' outcomes. The findings indicate only a fit with users' needs; effectiveness must be tested through prototypes, measures of conceptual understanding, and appropriate comparisons.

2. Dynamic Visualization Design

The need for animation, step-by-step visualization, infographics, and glossaries appeared consistently in the closed- and open-ended data. This can be explained by the nature of the dominant topics: students must connect molecular components with the sequence and outcomes of a process. Animation is useful when change itself is the object of learning, but it is not always superior to static images for every purpose (Ploetzner et al., 2021). In protein synthesis, the benefits of animation depend on segmentation and the relationship between the representation and explanatory text (Strømme & Mork, 2021).

For the proposed product, multimedia design should emphasize only the information needed for the learning objective, signal key components, place labels near the objects they describe, and divide complex processes into learner-controlled steps (Mayer, 2020). These principles should be tested on actual smartphones because screen size, interaction, and visual load can alter how well a design works in practice (Çeken & Taşkın, 2022).

A practical segment sequence could combine a prompting question, an orientation map, stepwise animation, a prediction pause, a one-screen summary, and one to three retrieval questions. For enzyme inhibition, animation can compare binding interactions and their effects on reaction rate before a static comparison diagram; for photosynthesis, electron flow, proton-gradient formation, and ATP production can be layered sequentially. The level of molecular detail should match the audience and instructional purpose (Patterson et al., 2022), while evidence from biology education supports the potential value of interactive animation when appropriately designed (El Hammoumi et al., 2022).

3. Data Efficiency in Digital Learning

All students needed offline access; 83.9% were comfortable with files no larger than 50 MB, and most used 360p or 480p. These findings transform access from a technical issue into a pedagogical requirement. Materials that are conceptually sound but cannot be opened consistently will reduce learning opportunities, increase burdens beyond the task itself, and widen differences in participation. Global reviews warn that home connectivity and devices are not equally distributed (UNICEF & International Telecommunication Union, 2020), while education-technology policies must consider access, quality, and sustainability together (Global Education Monitoring Report Team, 2023).

An offline-first design is recommended: text, images, glossaries, and basic quizzes should work without a connection after a single download; videos should be available in 360p and 480p; and each topic package should remain under 50 MB, ideally under 20 MB for the core unit. The application or webpage should retain the user's last position, display download-size indicators, and avoid requiring repeated logins. Because smartphones are the primary devices, buttons, labels, and interaction areas should be tested on small screens. This is consistent with research showing that the pedagogical opportunities of mobile devices emerge only when their use goes beyond transferring content and supports appropriate interaction (Crompton & Burke, 2020). Future measurement should also distinguish device access, quality of use, learning strategies, and outcomes so that the relationship between technology and learning is not oversimplified (Bernacki et al., 2020).

Subtitles and transcripts should be understood as dual supports. They help when audio cannot be used, connectivity is unstable, new scientific terms are introduced, or students want to review a specific section. Glossaries and concept maps can then preserve connections across segments. This design not only improves accessibility but also provides multiple representational pathways without requiring users to stream content repeatedly.

4. Gamification as Learning Support

Multiple-choice questions were the most popular quiz format, and almost all students preferred a duration of no more than 10 minutes. This finding supports short diagnostic quizzes at the end of a segment or after several segments. Quizzes should not merely repeat definitions; they should ask students to distinguish mechanisms, predict the consequences of changes, sequence stages, and interpret diagrams. Meta-analysis demonstrates the benefits of retrieval practice in classrooms (Yang et al., 2021), particularly when practice is spaced and repeated at suitable intervals (Carpenter et al., 2022).

Feedback should explain why an answer is correct or incorrect and direct students to the relevant step or segment. Meta-analysis shows that feedback effects vary and are influenced by informational content (Wisniewski et al., 2020). A simple “correct/incorrect” message is therefore insufficient. A more useful pattern is to identify the misconception, provide a concise explanation and visual cue, and offer an opportunity to attempt a parallel question. In-video questions can help sustain attention and review behavior, but findings in molecular biology show that questions do not automatically improve every concept assessed (Haagsman et al., 2020). The frequency, difficulty, and placement of questions should be tested with users.

Gamification was not the highest priority and should be optional. Points or badges can indicate progress, but leaderboards may create unnecessary comparison. Two meta-analyses reported positive average but heterogeneous effects, so game elements should align with learning mechanisms and group characteristics (Bai et al., 2020; Sailer & Homner, 2020). For this product, the recommended forms of gamification are personal progress, mastery badges based on repeated attempts, and graduated challenges, rather than public competition as a primary feature.

5. Teacher Support Ecosystem

The teacher data reveal a gap between positive attitudes and media-production capacity. All teachers supported technology integration, but only one was confident in creating simple materials, and none had a curated bank of digital resources. This pattern aligns with the view that teacher digital competence is multidimensional and cannot be reduced to the ability to operate applications (Falloon, 2020). Adaptation to digital teaching is also influenced by learning opportunities and pedagogical competence, not simply by individual willingness (König et al., 2020).

The student product should therefore be accompanied by a "teacher package": mapping of objectives to CP/ATP, objectives for each segment, editable slides and infographics, activity sheets, a question bank with answer rationales, simple rubrics, and recommendations for remediation and enrichment. All teachers requested editable assets and micro-training lasting no more than five minutes. Such support is consistent with the need to build a school environment, training, and pedagogical strategies that foster digital competence (Yang et al., 2023). Teacher readiness also varies, so tutorials, examples of practice, and technical assistance should be available at several levels (Scherer et al., 2021).

The finding that teachers need ready-to-use designs should be interpreted as a need for efficiency, not a reduction in agency. Assets should be easy to adapt to the classroom context. Reviews of digital competence note a tendency to position teachers as users of finished designs; an effective product should offer a gradual pathway from using, to modifying, to redesigning materials (Smestad et al., 2023). Micro-

PD can follow the same pattern as student microlearning: one skill per tutorial, a brief demonstration, a completed example, and an immediate application task.

6. Practical Implications

For teachers, the findings imply that mobile microlearning should be integrated as a short learning sequence rather than used as an isolated video repository. Teachers can assign a core segment before or during class, use the embedded retrieval questions diagnostically, and direct students to remedial or enrichment units based on responses. Editable slides, activity sheets, and question banks can reduce preparation time while allowing adaptation to local examples and classroom pacing.

For schools, implementation should prioritize infrastructure and support conditions that make access dependable: local or offline distribution options, school Wi-Fi for initial downloads, device-compatible testing, shared repositories, and brief professional development. For instructional designers, the findings establish a priority hierarchy: first ensure low-bandwidth access and clear process visualization; then add feedback, navigation, and teacher-editable resources; finally consider optional gamification. This hierarchy helps prevent technically attractive features from displacing requirements that are more directly tied to participation and conceptual understanding.

7. Directions for Design and Development

Based on triangulation, an initial prototype could be developed in five priority modules: (1) enzyme activity and inhibition; (2) light-dependent reactions and the Calvin cycle; (3) membrane structure and transport; (4) cellular respiration from glycolysis to chemiosmosis; and (5) the cell cycle and checkpoint control. Each module would comprise a concept map, three to six segments, process visualizations, a summary, a quiz, and a remedial pathway. Short units should remain connected through an overarching question so that students can see the relationships among processes.

The next stage should employ user-centered design. First, content should be reviewed with teachers and biology experts for accuracy and curriculum alignment. Second, usability should be tested on smartphones with limited connectivity to assess loading time, readability, navigation, file size, and offline functionality. Third, small-group testing with interviews or think-aloud protocols should identify confusing parts of animations and quizzes. Fourth, revisions should be completed before an effectiveness study. This staged development is more appropriate than immediately assuming that the microlearning format will be effective.

8. Study Limitations

This study has several limitations. The sample comprised only 31 Grade 11 MIPA students and three teachers from the urban school SMAN 23 Makassar, without a sampling frame or response rate. The data were self-reported and did not measure conceptual ability, actual use behavior, or learning outcomes. The teacher group was too small for inferential analysis; one response represented 33.3%. The domain groupings were used for design mapping and have not been validated as scales. Open-ended responses were coded through a directed procedure without a second rater. In addition, the source files did not provide detailed information about survey administration or ethical procedures. The findings should therefore be used as a basis for contextual design and development hypotheses, not as a representation of the broader population of students or teachers.

Conclusion

This study identified the needs of students and teachers as a basis for developing mobile-based biology microlearning for senior high school students. The findings indicate that students require learning materials that are concise, visual, accessible through smartphones, and efficient in terms of data use. Offline access, subtitles, process animations, concise infographics, concept maps, and immediate feedback emerged as important design requirements, while enzyme inhibition, photosynthesis, cell membranes, respiration, and the cell cycle were identified as priority topics for visualization and microlearning development. Teachers emphasized the importance of dynamic and curriculum-aligned materials, formative assessment resources, editable learning assets, and implementation support. These findings show that mobile-based biology microlearning should be designed not merely as short digital content but as an integrated learning resource that considers access conditions, the representational characteristics of biological processes, assessment needs, and teacher readiness. Scientifically, the study provides context-sensitive initial design requirements that connect learner needs and teacher implementation conditions within a single framework for biology microlearning development. Practically, the findings provide a basis for developing low-bandwidth, smartphone-oriented learning resources and complementary teacher support materials. Further research should validate the content and design, develop and test the prototype for usability and accessibility, and evaluate its effects on students' conceptual understanding, engagement, and retention using larger and more diverse samples.

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