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Design and evaluation of online microlearning tailored to learning styles

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ABSTRACT

Online microlearning delivers educational content in small, focused units to enhance learning outcomes and motivation, yet current research often lacks systematic design strategies grounded in learning theories, focusing instead on technical implementation without a thorough impact assessment. This study addresses this gap by proposing a learning style-based approach to designing online microlearning and evaluating its effects through a controlled experiment involving 67 programming learners divided into treatment (n=34, microlearning tailored to learning styles) and control groups (n=33, traditional online course). Results demonstrate that the proposed microlearning approach significantly improves learning gains and motivation compared to traditional methods, offering valuable implications for educators and suggesting future research directions.

1. Introduction

Given the vast amount of information individuals encounter daily while using personal, social, and educational online applications, it is essential to assist them in focusing on their respective tasks. In education, individuals who are employed and seeking to enhance their skills through lifelong learning, or students at various levels may struggle to dedicate enough time or require learning support in their quest for knowledge and the development of valuable skills. It is also essential for individuals to remain motivated during the learning process and to have access to as much relevant content as possible to meet their specific needs (Jing et al., 2023).

A viable strategy for facilitating learning is the implementation of microlearning. Microlearning aims to deliver concise, self-contained, and focused content that is easy to understand and applicable (Díaz Redondo et al., 2021; Hug, 2005). Microlearning can target each learning objective precisely with focused, direct, and concentrated content to transfer knowledge and skills effectively. In recent years, significant attention has been dedicated to researching online microlearning to support learners effectively (Alias and Razak, 2024; Lee, 2023). Microlearning differs from traditional learning methods, which involve extensive content delivered over lengthy courses and sessions lasting several weeks or months. These conventional methods have raised concerns due to their potential to demotivate learners and hinder quick knowledge acquisition, thus affecting long-term retention of knowledge. To address these challenges, microlearning is recommended for its capacity to facilitate swift and effective knowledge grasping and skills transfer (Rof et al., 2024). Microlearning can be offered independently to address specific knowledge acquisition and skill development or as supplementary materials that complement formal courses.

Published research studies typically explore microlearning by analyzing its benefits for learning, educational values, and the design of microlearning content (Conde-Caballero et al., 2024; Díaz Redondo et al., 2021; Hug, 2005; Khong and Kabilan, 2022; Lee et al., 2021; Romanenko et al., 2023; Sözmen et al., 2023). However, the current efforts do not consider learner preferences and learning styles when developing microlearning on online platforms (Alias and Razak, 2024; Lee, 2023; Rof et al., 2024). Learning style can be defined as an individual's preferred approach to learning (Felder and Brent, 2005; Felder and Silverman, 1988). For example, one person might favor specific learning sequences, hands-on activities, and visual materials, whereas another could lean toward verbal and reflective resources. Thus, the concept of learning style can inform the design and development of online microlearning. Research conducted up to August 2024 across multiple research databases, including

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Web of Science, IEEE Explore, Science Direct, and Springer, aimed to identify studies considering learning styles when designing and adapting online microlearning. By using keywords such as ("microlearning" OR "micro-learning") AND "learning style," limited studies were obtained, indicating unexpectedly limited research in this area. This study will address this research gap by examining learning styles and microlearning in online platforms from the perspectives of education and technology. To our knowledge, this study presents one of the first efforts at online microlearning according to learning style in online learning platforms through careful design and empirical assessment. As a result, this study introduces a new approach to designing online microlearning, supported by a comprehensive empirical evaluation of its effectiveness.

This study's main contribution is the proposed approach to designing microlearning based on a learning style grounded in a validated learning style model. The study also provides detailed descriptions of this approach from educational and technical standpoints. This approach can serve as a foundation for future online microlearning research and allows for further replication. Additionally, this study contributes by describing and conducting a controlled experiment to evaluate the proposed approach concerning learning efficacy and motivation. The primary research questions are as follows:

Q1: How can online microlearning be designed according to learning styles?
Q2: How does employing online microlearning based on learning styles affect learning gains?
Q3: How does employing online microlearning based on learning styles affect learning motivation?

The structure of the paper is as follows: Section 2 explains the theoretical background of microlearning and learning styles. Section 3 describes the proposed method for designing online microlearning based on learning styles. Section 4 outlines the evaluation method. Section 5 reports the experimental results, and Section 6 provides a discussion of these results. Finally, Section 7 presents the conclusion.

2. Theoretical foundations

2.1. Microlearning

The origin of microlearning can be traced back to early learning theories, including behaviorism, cognitivism, and constructivism. These theories focus on the processes through which individuals learn and retain knowledge. In the digital realm era, online microlearning has gained substantial attention as an instructional approach due to the ease of developing, maintaining, retrieving, and distributing learning content (Romanenko et al., 2023). Researchers have made many attempts to define microlearning, but a universally accepted definition has yet to be established (Denojean-Mairet et al., 2024). Despite this, there is widespread acknowledgment that microlearning is distinguished by three common attributes: a highly focused topic, shortened learning duration, and limited content. Many researchers have also adopted the microlearning definition introduced by Hug (2005). This definition of microlearning is based on seven dimensions: content, curriculum, format, learning type, medium, process, and time.

The content dimension includes small learning units or specific topics. The curriculum dimension includes segments of curricula, a series of modules, or aspects of informal learning. The format dimension includes fragments, knowledge episodes, or practical tasks. The dimension of learning types may represent behaviorist, constructivist, classroom-based, problem-based, or corporate approaches. The medium dimension may involve face-to-face interaction, multimedia, or learning objects. The process dimension refers to the structured and intentional approach to designing and providing microlearning content that can be stand-alone, situated, integrated, or iterative. The time dimension refers to relatively brief efforts or short learning duration processes.

An online microlearning course can be designed with a series of inter-connected micro lessons with a clear structure tailored for each concept or topic covered in the course. Each micro piece of content associated with a particular concept/topic is intentionally focused and structured to be learned briefly, requiring minimal instruction (Zhang and West, 2020). Microlearning can be integrated into traditional or online platforms and used as a standalone learning course (Hlazunova et al., 2024). The microlearning approach differs from purely conventional learning methods in several ways. Traditional learning usually involves lengthy, tedious lectures, classes, or training sessions, hindering critical thinking and cognitive engagement (Díaz Redondo et al., 2021). This could also increase course dropout rates, low student attendance, and disengagement from learning (Dolasinski and Reynolds, 2023). Knowledge retention is also pivotal in learning, particularly when examined within the cognitive theory framework (Sankaranarayanan et al., 2024). Thus, delivering large amounts of information over a long period can adversely affect learners' performance and motivation because of the limited cognitive processing capacity of short-term memory (Lee, 2023). Effective learning strategies are imperative not only to facilitate continuous knowledge acquisition but also to foster the long-term retention of information. Online microlearning can address these learning challenges by offering custom, on-demand, short-duration learning opportunities tailored to specific needs with interactive features to improve the performance and motivation of learners (Lee et al., 2021).

Some research has been undertaken to assess the efficacy of online microlearning, yielding encouraging results. According to the findings, microlearning has the potential to boost learner engagement significantly (Fidan, 2023), enhance learning outcomes (Yin et al., 2021), support practical skill development (Skalka et al., 2021), increase motivation (Sözmen et al., 2023), and address the issue of information overload (Fidan, 2023). The recent reviews of online microlearning underscore several critical areas that require attention (Alias and Razak, 2024; Lee, 2023). Firstly, it is observed that only 25% of the publications focus on the design of microlearning content, particularly in terms of reducing cognitive load and integrating interactive features, game elements, social media features, and virtual reality. However, it is noteworthy that there is a lack of microlearning design guidelines based on established learning theories (Hatamian, 2024). Secondly, there is a paucity of studies conducting controlled experimental evaluations of learning effectiveness and motivation in microlearning (Monib et al., 2024). In addition, online microlearning has been predominantly limited to the medical and health domains, thus emphasizing the necessity of expanding its implementation to other domains, such as language learning, science, and computing (Pham et al., 2024).

Given the existing research gaps, this study aims to develop online microlearning modules according to learning style. This unique approach takes learning style into account as a fundamental design factor backed by a validated learning style model. The approach also shows how it can be applied from the perspectives of education and technology. A carefully controlled experimental assessment will also be used to systematically evaluate the learning outcomes and motivational aspects. Since the study centers on learning style, its theoretical foundation is presented in the following sub-section.

2.2. Learning style

The concept of learning style is a subject that continues to provoke debate in the field of learning and education (Zrudlo, 2023). Despite facing some disparagement, numerous researchers emphasize its importance in learning (Wu and Wang, 2025). One of the earliest definitions of learning styles was provided by Keefe (1979); it includes effective and cognitive factors determining the way that a learner perceives and engages with a learning environment. A learning style involves observable behaviors, attitudes, and preferences that indicate how an individual prefers learning (Muhammad et al., 2024). With numerous learning style models and frameworks developed, the Felder-Silverman Learning Style Model (FSLSM) is commonly recognized as a prominent model in online education (Ayyoub and Al-Kadi, 2024). FSLSM was developed by refining and combining components of various established learning style models (Fayaza and Ahangama, 2024). It consists of four dimensions that can be viewed independently, each with two classes: information processing (active/reflective), input modality (visual/verbal), information understanding (sequential/global), and information perception (sensory/intuitive).

The dimension of information processing (active/reflective) refers to how learners process information. Active learners acquire knowledge through hands-on practice and interaction with peers, while reflective learners typically take the time to thoughtfully consider information on their own before acting. The input modality dimension (visual/verbal) concerns the favored information presentation mode. Learners with visual preferences can grasp information best through visual aids like pictures, videos, diagrams, and illustrations, while learners with verbal preferences can rapidly understand textual and audio format information. The sequential/global dimension of information understanding refers to different approaches to organizing information. Sequential learners understand information through structured, logical steps and pay attention to details. In contrast, global learners prefer broad overviews and random leaps through various information sets, emphasizing a broader knowledge perspective. The information perception dimension (sensory/intuitive) is focused on the most appropriate type of information for each learner. Sensory learners often thrive on concrete details, such as facts and examples, while intuitive learners usually excel with abstract concepts, like theories and mathematical models.

Learning styles are typically incorporated into adaptive and personalized e-learning systems alone or with other features, such as knowledge level and performance (Wang et al., 2025). These systems can adjust learning content and its order to align with the requirements and preferences of learners (Barbosa et al., 2023). Some research efforts aim to enhance adaptive systems based on learning styles through gamification to engage learners in learning by incorporating game elements while delivering relevant content (Alshammari, 2020). Other studies focus on the dynamic detection of learning preferences and styles while interacting with e-learning systems (Muhammad et al., 2024; Rasheed and Wahid, 2021). Many efforts that consider learning styles in online learning platforms suggest that learning styles are pivotal in optimizing the learning experience process (Wang et al., 2025).

Since existing research has overlooked online microlearning based on learning style, this study aims to address this research gap by designing online microlearning according to learning style and showcasing its beneficial effects on learning and motivation. The proposed approach is detailed in the following section.

3. The proposed approach

This section describes the proposed approach, which focuses on designing an online microlearning course based on learning style. This approach is presented through two perspectives: an educational perspective and a technical perspective.

3.1. The educational perspective

FSLSM is leveraged in the proposed approach as it is a well-validated and widely adopted framework for online learning (Fayaza and Ahangama, 2024). The dimensions of this model are also prevalent in numerous other learning style models (Domínguez et al., 2025), making it a versatile and highly relevant choice for this study's context. This approach aims to deliver a well-balanced learning experience for all learners, recognizing and accommodating their varying learning style preferences. Considering both dominant and non-dominant learning styles, it is crucial to address these preferences to support their overall learning journey.

Fig. 1 presents a generic approach to designing an online microlearning lesson based on the learning style model. Each lesson in the microlearning platform can contain four core parts, including the learning concept title. Part A involves the precise provision of an abstract conceptualization of the learning concept to support intuitive learners, and the explanation should include a balanced mix of visual and verbal elements and information. Part B offers a real-world example or application scenario to support the sensory learning style. Part C provides a hands-on activity of the learning concept and/or problem-solving exercise to support active/reflective learning styles. Part D is situated within the lesson to sequence forward or backward other lessons to accommodate a sequential learning style; this part can also be augmented with a course map to support the global learning style. This course map may present the overall interconnection of the learning concepts, giving a big picture of the course. Combining all these parts in each lesson allows learners to be supported with online microlearning based on their differing learning styles.

The proposed approach allows for the development of multiple lessons, thereby creating a comprehensive microlearning course that can be integrated into online learning platforms. This microlearning course can be seamlessly integrated into traditional learning (e.g., formal lectures) to provide learners with supplementary materials or used independently. Moreover, the proposed approach is designed to be flexible enough and versatile to accommodate various application domains and is not limited to specific learning subjects.

Before beginning the microlearning design based on this approach, defining the learning objectives is essential as the first crucial step. Subsequently, the proposed approach can be duly considered. Designers creating online microlearning content according to learning style following the proposed approach should ensure the inclusion and consideration of specific criteria. Each part of the microlearning course should:

- Be clear, specific, and to the point.
- Have a balanced mix of visual and verbal aids.
- Include an abstract conceptualization of the introduced learning concept.
- Incorporate a real-world example or scenario related to the concept.
- Feature a hands-on activity, problem-solving, or simulation.
- Offer control features to navigate through the microlearning course.
- Provide a course map illustrating the interconnected concepts in the course.

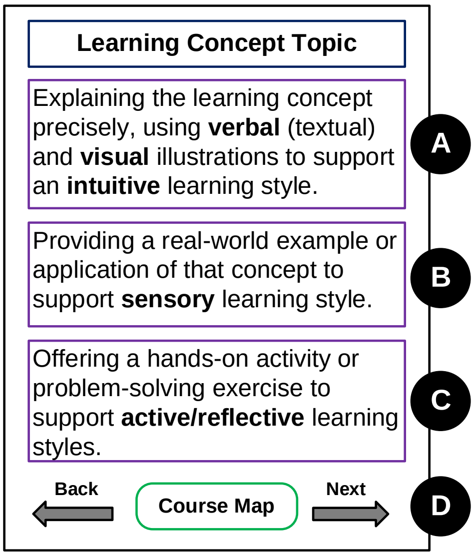

Fig. 1: The proposed approach for designing online microlearning based on learning style

3.2. The technical perspective

Most online educational research focuses on one aspect, either from an educational perspective or a purely technical standpoint (Alshammari and Qtaish, 2019; Betancur-Chicué and García-Valcárcel Muñoz-Repiso, 2023; Jing et al., 2023). However, both spectrums are interconnected and should be addressed in online learning research. Therefore, this study also emphasizes the technical aspects of the proposed approach to complement the established educational components.

Employing databases is one of the most effective methods for organizing microlearning course content. Fig. 2 illustrates an example of a database design for developing multiple microlearning courses that can be integrated into online learning platforms using the proposed approach. The database consists of four primary tables: course, topic, lesson, and fragment.

The course table includes a key identifier, course title, description, and creation date. It provides detailed information about the course to be delivered and integrated into the online learning platform. This information can also be retrieved and arranged appropriately according to the platform's design. Since each course can contain multiple topics, the course table is linked with the topic table to establish a one-to-many relationship. Table 1 illustrates a concrete example of how data can be stored in the course table within the database.

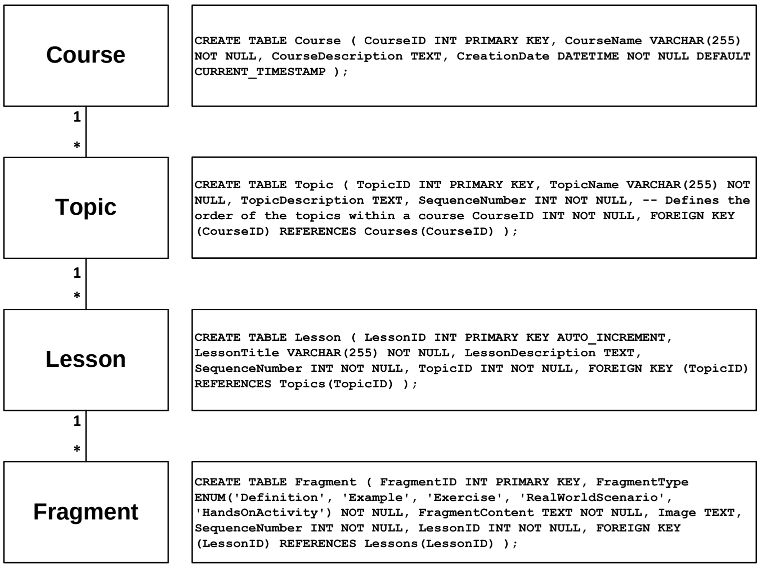

Fig. 2: Database design for creating multiple microlearning courses based on the proposed approach

Table 1: Data examples stored in the course table

CourseID	CourseName	CourseDescription	CreationDate
101	Introduction to Java	Learn the basics of Java programming	2024-12-10
102	Data Structures	Master essential data structures	2025-01-05

The topic table in the database includes the following properties: topic key identifier, topic title, description, topic sequence order, and a foreign key identifier linked to a specific course. The title and description properties provide essential descriptive information about the learning topic. The sequence order contains a number that designates the position of this topic among others. Consequently, the system can utilize the assigned order of the topic when retrieving the list of topics associated with a specific course, creating a predefined learning path that students can easily follow. It should be noted that each topic can contain at least one or more lessons associated with it. Therefore, the relationship between the topic table and the lesson table is one-to-many. Table 2 shows an example of data stored in the topic table aligned with the database design. For instance, topic 201 (i.e., Java conditions) is related to course 101 (i.e., linked to the course table, which is Introduction to Java), and its sequence among other course topics is 4.

Table 2: Data examples stored in the topic table

TopicID	CourseID	TopicName	TopicDescription	SequenceOrder
201	101	Java conditions	Explore if, if-else, switch	4
202	101	Java loops	Understand loops (for loop, while, do-while)	5

The lesson table includes the following properties: lesson key identifier, lesson title, lesson description, lesson sequence order, and a foreign key identifier linked to a specific topic. These properties can be utilized to create various lesson instances related to a particular topic. The lesson sequence order is an order number that determines the placement of the lesson among other lessons associated with the topic to ensure it is delivered correctly according to this defined sequence entry. Each lesson is also linked with one or more content fragments. A fragment represents a self-contained, focused microcontent that provides direct learning opportunities, which can be studied briefly. Table 3 illustrates an example of data stored in the lesson table pertaining to two lessons. For instance, lesson 308 (i.e., While loop) is linked to topic 202 (i.e., associated with the topic table, which covers Java loops), and its sequence among other lessons related to a topic is 3.

Table 3: Data examples stored in the lesson table

LessonID	TopicID	LessonTitle	LessonDescription	SequenceOrder
301	201	If Statement	Understand the if statement and its use in Java	1
308	202	While loop	Explain while loop in Java	3

The fragment table in the database includes the following properties: fragment key identifier, fragment title, fragment type (e.g., definition, example, real-world example, hands-on activity), fragment textual content, fragment image, fragment sequence order, and a foreign key identifier linked to a specific lesson. Essential information and a sequence order number for each content fragment must be included. Textual content and an image or diagram can also be added to enhance the microlearning content associated with a specific fragment. Table 4 illustrates some fragment content data stored in the fragment table within the database. In this example, three content fragments are connected to lesson 301 (i.e., mapped to the lesson table, the If Statement). For instance, fragment 402 contains a concrete example and an image link to enhance the presentation of this example. Additionally, the sequence number of this fragment is 2, indicating that when fetching the content related to lesson 301 (i.e., If statement), fragment 402 appears second among the other fragments. Since each fragment has a sequence number, multiple fragments associated with a specific lesson can be retrieved and organized in ascending order based on a predefined online page design template. The design of this online page can adhere to the proposed approach outlined in the previous section. This way, the educational and technical perspectives offered in this proposed approach can enhance one another.

Since the database is the core part illustrated in this technical perspective, Structured Query Language (SQL) can be utilized to effortlessly access the learning fragments linked to each lesson from the database, as shown in SQL Code 1. This code example retrieves information about a lesson (identified by its LessonID) and all its associated fragments. The steps (A-D) below explain how this query works:

A. Data selection:

- It fetches the lesson's details (LessonID, LessonTitle, LessonDescription, SequenceNumber) from the Lesson table.
- It also fetches the fragment's details (FragmentID, FragmentType, FragmentContent, SequenceNumber) from the Fragment table.

B. Join Operation:

- The Fragment table is joined with the Lesson table using the LessonID column, ensuring only the fragments associated with the specified lesson are included.

C. Filtering:

- The WHERE clause specifies that the query only applies to a particular lesson with LessonID = 3. (3 can be replaced with any desired lesson ID)

D. Ordering:

- The ORDER BY clause ensures that the fragments are listed in the order of their SequenceNumber.

Table 4: Data examples stored in the fragment table

FragmentID	LessonID	FragmentType	FragmentContent	FragmentImage	SequenceOrder
401	301	Definition	An if statement checks the condition and executes code if true.	Null	1
402	301	Example	int age = 21. if (age >18) System.out.println("Adult");	If_example.png	2
403	301	Exercise	Write an if-else statement to check if a number is even or odd.	Null	3

The information gathered from the SQL query can be aesthetically enhanced using web technologies such as HTML, CSS, and JavaScript in conjunction with server-side programming languages like PHP, Python, or Java. This versatile approach provides the flexibility to customize and adapt properties for each entity, showcasing the adaptability of these technologies. This technical perspective illustrates a methodology for implementing the proposed approach. Additional technologies may also be included. One alternative is to use structured file-based data storage formats such as JavaScript Object Notation (JSON) or eXtensible Markup Language (XML).

These formats are well-known for their effectiveness in storing, sharing, and exchanging data. However, the illustrated example is fundamentally based on a database design and can be readily converted into these technologies as needed by online learning platforms that prioritize microlearning.

4. Materials and methods

This section highlights the research hypotheses and evaluation phases of the proposed approach to designing an online microlearning course based on learning style. The evaluation process includes assessing the quality of learning content by domain experts, developing an experimental framework, identifying the necessary tools to evaluate learning gains and motivation, and detailing the experimental procedures and methods for data analysis used in this research.

SQL Code 1:

```
-- Fetch a lesson along with all its associated fragments
SELECT
   l.LessonID,
   l.LessonTitle,
   l.LessonDescription,
   l.SequenceNumber AS LessonSequence,
   f.FragmentID,
   f.FragmentType,
   f.FragmentContent,
   f.SequenceNumber AS FragmentSequence
FROM
   Lessons l
JOIN
   Fragments f ON l.LessonID = f.LessonID
WHERE
   l.LessonID = 3  -- Replace with the actual LessonID
ORDER BY
   f.SequenceNumber; -- Orders fragments by their sequence within the lesson
```

4.1. Research hypotheses

The study is based on two primary hypotheses: the first emphasizes learning gain, while the second focuses on learning motivation. These two hypotheses are presented as follows.

H1. Online microlearning based on learning style yields better learning gains than traditional online learning.
H2. Online microlearning based on learning style yields better learning motivation than traditional online learning.

4.2. Microlearning course development

A microlearning programming course based on the proposed approach was developed and seamlessly integrated into an online learning platform for undergraduate students at a university. The core subjects covered in the course included an introduction, variables, console I/O, conditional statements (if, if-else, and switch), and loops (for loop, while, and do-while). Micro-lessons were meticulously crafted for each concept. A simplified lesson from the course about the "IF" Java statement is displayed in Fig. 3. This example rigorously adheres to the proposed approach when designing learning content, aiming to accommodate diverse learning styles. The initial section of this lesson briefly explains the "IF" statement, including its definition, syntax, and visual representation. The next part of the lesson provides a concrete example for the students to engage in. The final segment offers an exercise for students to apply their newly acquired knowledge. Importantly, students have complete control over the learning process, allowing them to navigate forward and backward or get an overview of the inter-connected lessons through a course map.

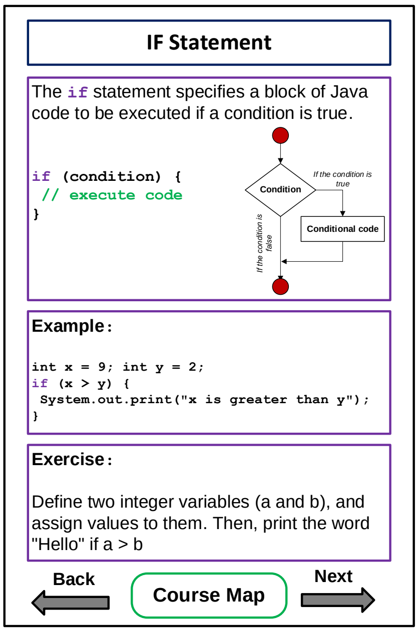

Fig. 3: A lesson example designed for online microlearning based on learning style

4.3. Course content quality

Five domain experts evaluated the content quality of the online microlearning course. Each expert thoroughly examined the platform and the course content to provide feedback on potential improvement areas. Subsequently, each expert was interviewed to offer insights based on specific factors, including accuracy, relevance, clarity, usability, and engagement, in addition to the criteria mentioned earlier in the proposed approach section. The consolidated feedback included recommendations for correcting code examples, adding more exercises, and enhancing interactivity levels to boost engagement. These suggestions proved invaluable, enriching the microlearning course and refining the proposed approach within this study. The underlying objective of this phase is to determine the readiness of the content before executing the experiment, ensuring the validity and high quality of the learning material.

4.4. Experimental design and tools

The study comprised two distinct groups: the treatment group and the control group. Participants were randomly assigned to each group. The treatment group used the online learning platform incorporating the microlearning introductory Java course, while the control group used a traditional online system for the same course. Both groups were offered equivalent learning opportunities in terms of content, differing only in the method of instruction, whether through the developed online microlearning course based on the proposed approach or conventional online content.

The study's main variables include learning gain and learning motivation. Learning gain was assessed through a pre-test and post-test approach. Both tests contained identical content but differed in question formulation and order, each having a normalized score of 100. These tests featured open-ended questions designed to measure various objectives related to knowledge, understanding, and skills within the application domain. Domain experts also refined and enhanced the tests to ensure their reliability. The pre-test is used to control prior knowledge, while the post-test is administered after the course to evaluate learning gain. Learning gain is calculated by subtracting the post-test result from the pre-test.

The assessment of learning motivation was facilitated by adapting the Students' Motivation Towards Science Learning (SMTSL) (Tuan et al., 2005). This validated and reliable tool contains 35 items, each with a 5-point Likert scale ranging from 1 '*strongly disagree*' to 5 '*strongly agree.*' SMTSL includes six distinct sub-scales: self-efficacy (n = 7 items), active learning strategies (n = 8 items), learning value (n = 5 items), performance goal (n = 4 items), achievement goal (n = 5 items), and learning environment stimulation (n = 6 items). Self-efficacy (SE) refers to an individual's belief in their ability to succeed in learning endeavors. Active learning strategies (AL) emphasize that learners take charge of their own learning process to build new knowledge based on their prior understanding. Learning value (LV) involves developing problem-solving skills, fostering inquiry, and enhancing critical thinking to engage learners actively in the educational process. The performance goals measure (PG) aims to evaluate learners' active involvement in learning by promoting collaborative relationships with peers and seeking recognition for their efforts. Achievement goals (AG) represent the satisfaction learners experience as they make progress in their educational journey. Finally, learning environment stimulation (LS) encompasses all elements of the learning experience, including the learning platform, feedback mechanisms, learning content, and instructional strategies, which ultimately impact learners' engagement and motivation to learn.

4.5. Experimental procedure

Fig. 4 depicts the experimental procedure. The participants were all male first-year undergraduate students majoring in computer science at a university. After being welcomed and briefed on the experiment's objectives, the participants willingly agreed to participate and completed a pre-test to assess prior knowledge of the course. They were then randomly assigned to either the treatment group (N=34) or the control group (N=33). The learning process in the experiment, where participants utilized the online learning platform according to their group assignment (online microlearning course or traditional online content), lasted approximately six weeks. Upon completing all experimental phases, participants were required to take the post-test and fill out the learning motivation questionnaire (SMTSL).

4.6. Data analysis

SPSS (version 29) was used for data analysis. After the data collection process, the normality assumptions of each experimental variable were assessed using the Shapiro-Wilk test. The results indicated that the data followed a normal distribution. Consequently, parametric tests were used to compare control and treatment groups. Since there were two independent groups in this study, an independent samples t-test was conducted to compare the variables across these groups. To measure the effect size, which indicates the strength of the relationship between the variables, Cohen's d was used.

5. Results

5.1. Learning gain

The learning gain variable is calculated by subtracting the pre-test results from the post-test results. Table 5 presents the average results of the pre-test, post-test, and learning gain variables for the treatment and control groups. The pre-test average results were nearly equal, while the post-test results and learning gain for the treatment group were higher than those for the control group. Fig. 5 also displays a boxplot diagram summarizing the overall learning gain (i.e., post-test – pre-test).

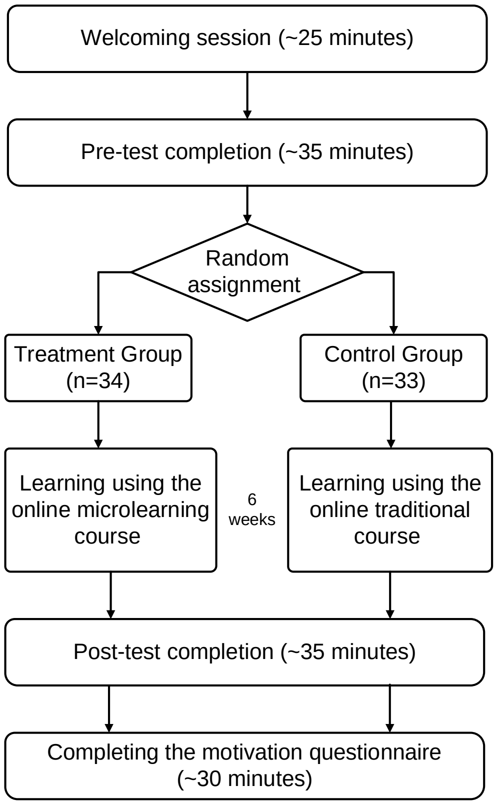

Fig. 4: The experimental procedure

Table 5: The results of the pre-test, post-test, and learning gain

Variable	Group	N	Mean	SD
Pre-test	Treatment	34	10.06	5.063
	Control	33	9.58	4.963
Post-test	Treatment	34	81.44	12.642
	Control	33	68.33	12.678
Learning Gain	Treatment	34	71.38	14.131
	Control	33	58.76	13.734

SD: Standard deviation

In the pre-test, there was no statistically significant difference between the average scores of the treatment group and the control group: $t(65) = 0.394$, $p = 0.695$. These findings indicate that both groups had similar prior knowledge of the study's application domain, allowing for reasonable comparisons between the groups regarding the post-test and learning gain.

In the post-test, there was a statistically significant difference between the average scores of the treatment group and the control group, with a large effect size: $t(65) = 4.237$, $p < 0.001$, $d > 0.80$. Similarly, the learning gain results confirmed a statistically significant difference between the average scores of the treatment group and the control group, with a large effect size: $t(65) = 3.707$, $p < 0.001$, $d > 0.80$. These findings support hypothesis H1, indicating that online microlearning based on learning styles yields better learning gains than traditional online learning.

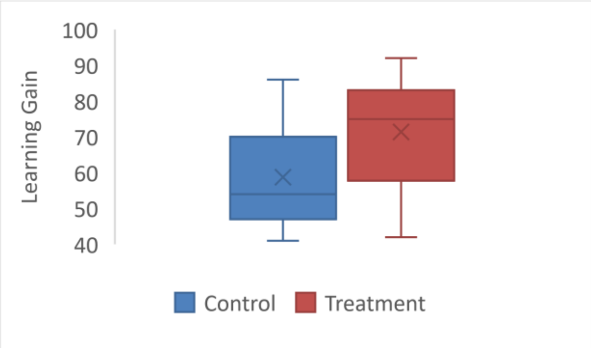

Fig. 5: The summary results for learning gain for the control and treatment groups

5.2. Learning motivation

The overall learning motivation and its sub-scale are reported. Table 6 summarizes the average findings for these variables. The treatment group's average results for all sub-scale variables were higher than those in the control group. Moreover, the treatment group had better overall learning motivation results than the control group.

Table 6: The results for the learning motivation and its sub-scale

Variable	Group	N	Mean	SD
SE	Treatment	34	3.53	1.107
	Control	33	2.24	1.119
AL	Treatment	34	3.26	1.189
	Control	33	2.39	1.273
LV	Treatment	34	3.59	1.158
	Control	33	2.82	1.014
PG	Treatment	34	3.41	1.076
	Control	33	2.70	1.104
AG	Treatment	34	3.65	1.178
	Control	33	2.39	1.088
LS	Treatment	34	3.06	1.013
	Control	33	2.58	1.062
LM	Treatment	34	3.41	.323
	Control	33	2.52	.430

SE: Self-efficacy; AL: Active learning strategies; LV: Learning value; PG: Performance goals; AG: Achievement goals; LS: Learning environment stimulation; LM: Learning motivation; SD: Standard deviation

There was a statistically significant difference between the treatment group and the control group regarding self-efficacy: $t(65) = 4.732$, $p < .001$. Regarding active learning strategies, there was also a statistically significant difference between the treatment group and the control group: $t(65) = 2.895$, $p = .005$. Similarly, for learning value perception, there was a statistically significant difference between the treatment group and the control group: $t(65) = 2.893$, $p = .005$. Both performance goal and achievement goal results also had statistically significant differences between the treatment group and the control group: $t(65) = 2.684$, $p = .009$, $t(65) = 4.521$, $p < .001$, respectively. However, for the learning environment simulation, there was no statistically significant difference between the treatment group and the control group: $t(65) = 1.906$, $p = .061$.

The variables mentioned above were sub-scales that can contribute to overall learning motivation. The results concerning overall learning motivation, when considering these sub-scales, were found to be statistically significant for the treatment group compared to the control group, with a large effect size: $t(65) = 9.652$, $p < .001$, $d > .80$. Accordingly, H2 is upheld, concluding that online microlearning based on learning styles yields better learning motivation than traditional online learning.

6. Discussion

This study aimed to address three previously identified research questions. First, it sought to propose a design for online microlearning based on learning style, focusing on the educational and technical aspects. Relevant studies typically focus on the educational aspects of microlearning in isolation of how they can be technically implemented and vice versa (Alias and Razak, 2024; Denojean-Mairet et al., 2024; Romanenko et al., 2023). The current study described the proposed approach, focusing on the two perspectives of education and technology. Second, using a controlled experimental evaluation, the current study examined the proposed approach's effect on learning gains. Third, it also investigated how the approach impacts learning motivation, an essential factor in learning.

This study presents an innovative approach to developing online microlearning based on learning style, targeting broad applicability across various learning domains. It aims to inspire further exploration and establish a strong foundation for online microlearning design. Previous studies have primarily concentrated on technological aspects, often separating them from instructional design (Skalka et al., 2021). The proposed approach, however, emphasizes using learning style as a primary driver for designing online microlearning, supported by a well-established learning style model.

An extensive experimental design was employed to evaluate the effectiveness of the proposed learning approach and measure improvements in both learning gain and motivation. Compared to traditional online methods, positive results were observed with the online microlearning course. This can be attributed to the fact that learners engaged with content tailored to their differing learning styles, as noted in this study. Relevant research considering learning styles has shown that they can significantly impact learning (Domínguez et al., 2025; Kulkarni et al., 2021). However, this study is unique in its design and provision of online microlearning content based on learning style. Other microlearning studies typically concentrate on various elements, such as adaptivity and the creation of student profiles (Monib et al., 2025).

The study also explored learning motivation, examining self-efficacy, active learning environments, learning value, achievement, goal perceptions, and simulation. These findings were positive, indicating its effectiveness in learning performance and increased learning motivation. As microlearning content was more focused and straightforward, learners may have been more motivated to learn, with their cognitive load implicitly balanced, as demonstrated in previous studies examining online microlearning (Fidan, 2023; Sözmen et al., 2023). The current study aims to enhance learning performance and motivation by conducting a controlled experimental evaluation to collect more evidence of its effectiveness in learning. These findings may support further research to adapt the proposed approach to different application domains, longer learning periods, and larger sample sizes in formal and informal learning contexts.

The proposed approach to designing microlearning content is not limited to specific types of systems, including desktop, web, or mobile learning applications, and can be adapted to any system requirements. By employing the same proposed design, artificial intelligence (AI) generative tools like ChatGPT can be used to request microlearning content dynamically and retrieve it for presentation to the end user (Crompton and Burke, 2024; Yin et al., 2021). For instance, prompts can be engineered to match the proposed online microlearning approach instead of manually creating learning materials; a prompt like "Define variables in Java programming in a short form with textual and verbal content" can be used, and the AI tool can automatically generate relevant content to fit within a particular module of a microlearning lesson. However, the learning content generated by AI tools must be carefully reviewed by teachers before being used in formal contexts (Tayan et al., 2024).

The proposed approach can also be improved by incorporating more interactive features, such as gamification, which integrates game elements within each micro-lesson and the overall micro-course (Babu and Moorthy, 2024; Shen et al., 2024). Future research should thoroughly assess their impact on learning effectiveness and motivation. When integrated into future studies, these enhancements demonstrate the broader applicability of the proposed framework for designing online microlearning based on learning style, as it can establish a foundational basis for further research that potentially adds to the existing body of knowledge.

7. Conclusion

This research presents a novel approach to designing online microlearning courses based on learning style. This approach is elaborated from the perspectives of education and technology, allowing for the development of microlearning courses across various application domains. Additionally, the study reports the results of a carefully controlled experiment involving male participants, which demonstrated significant enhancements in learning gains and motivation. The findings also addressed critical motivation-related factors, including self-efficacy, perceptions of learning value, achievement, learning goals, and overall satisfaction. These results were extensively discussed, providing valuable insights into stakeholders and identifying potential areas for development.

Future work will enhance learner engagement by adding another layer of interactivity through gamification, social features, or interactive short videos. To generalize the findings, an experimental evaluation will be conducted with a more extensive and diverse sample and extended learning period across various application domains. These enhancements show that the suggested approach for microlearning can serve as a critical foundation for future studies.

Compliance with ethical standards

Ethical considerations

This study was approved by the institutional ethics committee. Informed consent was obtained, and participant anonymity was ensured.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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