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Fostering mathematical creative thinking through instagram-based interactive microlearning in linear algebra

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Abstract

The expansion of social media has opened possibilities for mathematics education through flexible and interactive learning environments. Nevertheless, its use remains insufficiently explored to develop pre-service mathematics teachers' mathematical creative thinking in Linear Algebra, where abstract vector concepts require opportunities to generate, vary, and justify ideas. This study aimed to develop Instagram-based interactive microlearning for vector material and investigate its validity, practicality, and effectiveness in fostering mathematical creative thinking in terms of fluency, flexibility, and originality. Using a Research and Development approach guided by the ADDIE model, the study comprised Analysis, Design, Development, Implementation, and Evaluation stages. Product validity was examined by three experts, whereas practicality was assessed through a small-group trial with 10 pre-service mathematics teachers and an extended field trial with 20 participants. Effectiveness was evaluated using a quasi-experimental non-equivalent control-group pretest–posttest design involving 40 pre-service mathematics teachers, with 20 assigned to each group. Data were collected through expert validation sheets, student response questionnaires, and mathematical creative thinking tests. The developed media demonstrated high validity based on media (3.50), subject matter (3.58), and learning (3.83) expert assessments, and very high practicality in both the small-group (3.59) and field (3.55) trials. The experimental group increased from 6.28 to 8.58, compared with 5.88 to 7.93 for the control group. The N-Gain was 0.59 versus 0.47, with a significant difference, $t(38) = 2.31, p = .026, d = .73$. ANCOVA confirmed a significant group effect, $F(1,37) = 21.19, p < .001$, partial $\eta^2 = .364$. These findings establish Instagram-based interactive microlearning as a promising medium for strengthening mathematical creative thinking in Linear Algebra.

Keywords: Instagram; Mathematical creative thinking; Microlearning; Vectors

Introduction

Indonesia is undergoing rapid digital transformation, characterized by increasing public dependence on technology (Embaye et al., 2023). This transformation is also reshaping education, particularly as 75% of future jobs are expected to require competencies in science, technology, engineering, mathematics, and the Internet of Things (Fang et al., 2021). The internet has consequently become an essential medium for entertainment, communication, social interaction, public health, and well-being. The Indonesian Internet Service Providers Association known as APJII reported national internet penetration of 78.19% in 2023, including 79.79% in rural areas (Setiyadi et al., 2022). Such broad access to information is changing mindsets, learning preferences, and classroom practices (Fajri et al., 2024), creating a need for educational practices that are responsive to students' increasingly digital lives.

Digital-era learning provides opportunities to enhance students' learning experiences, access, and outcomes (Sagala et al., 2024). Digital technologies, including online learning platforms, virtual reality, and artificial intelligence, can facilitate more interactive and personalized learning (Indriyani, 2025). Social media platforms such as TikTok, Instagram, and YouTube further provide accessible environments through which lecturers can distribute learning resources anytime and anywhere. Instagram is particularly relevant because it is widely used by younger populations, including university students and pre-service mathematics teachers, many of whom belong to Generation Z (Carpenter et al., 2020). According to tekno.kompas.com, Indonesia has approximately 10 million active Instagram users. Moreover, APJII reported that social media (51.5%) and communication (32.9%) were among the primary purposes of internet use during 2019–2020. This widespread use creates opportunities for pre-service mathematics teachers and lecturers to incorporate social media into learning (Teto & Pule, 2022). Mathematics learning through social media has been perceived as more enjoyable than conventional learning (Al-Qaysi et al., 2020) and can increase student participation and understanding of basic concepts (Ishartono et al., 2025).

One approach to optimizing social media for mathematics learning is microlearning. Microlearning delivers concise learning content that allows pre-service mathematics teachers to study at their own pace. Its content may range from text to interactive multimedia but is characterized by brevity and focused learning objectives (Taylor & Hung, 2022). Microlearning commonly employs short videos, infographics, interactive modules, or quizzes that can be accessed anytime and anywhere (Sawarynski & Baxa, 2019). Integrating such focused content with an engaging and accessible social media platform may increase students' motivation to learn mathematics and support creative thinking (Adhipertama et al., 2020). Mathematical creative thinking is important for enabling students to solve problems through alternative perspectives and approaches (Kadir et al., 2022). It involves thinking in different ways (Silver, 1997), allowing students to employ varied strategies, solutions, and concepts when addressing mathematical problems (Ferdiani & Pranyata, 2022; Schoevers et al., 2020). It can be characterized through three dimensions: fluency, the ability to generate multiple ideas; flexibility, the ability to employ different strategies; and originality, the ability to generate unique solutions (Siswono, 2011).

Despite its importance, mathematical creative thinking remains a challenge in Indonesia, including in higher education. PISA 2018 results placed Indonesian students among the lower-performing participating countries, with average scores of 371 in reading, 379 in mathematics, and 396 in science across 79 countries (OECD, 2023). Although these results do not directly measure creative thinking, they indicate persistent challenges in mathematics learning. These challenges may extend into higher education, as Ferdiani et al. (2021) found that pre-service mathematics teachers' creative-thinking processes in posing and solving mathematical problems remained varied and suboptimal, partly because of limited creative-thinking skills.

This issue is also evident in the context of the present study. Preliminary observations conducted from March to May 2025 in a Linear Algebra course for Mathematics Education pre-service teachers at PGRI Kanjuruhan University Malang showed that seven of 15 pre-service mathematics teachers who completed the pretest had not achieved the flexibility and originality indicators. They tended to copy solutions from senior students or internet searches rather than develop their own mathematical ideas. Learning activities also relied primarily on WhatsApp and PowerPoint, whereas interviews indicated that the pre-service teachers accessed Instagram more frequently. This discrepancy suggests an opportunity to repurpose a familiar social media platform as a complementary environment for mathematics learning. In particular, vector concepts in Linear Algebra are highly abstract and may benefit from concise, progressive, and visual representations. Microlearning delivered through Instagram could therefore provide accessible opportunities for pre-service mathematics teachers to engage with vector concepts while developing creative mathematical ideas.

Previous studies have examined digital and social media technologies in relation to mathematics learning and creative thinking. Setiyadi et al. (2022) used creative videos through YouTube as a mathematics learning medium for upper-elementary students, while Suhardi and Putri (2023) found that WhatsApp positively influenced students' learning behavior in mathematics. Through a systematic literature review, Rohmaini et al. (2024) reported that augmented reality can influence pre-service mathematics teachers' creative thinking, although their study did not develop a learning-media product. Conde-Caballero et al. (2023) demonstrated the potential of TikTok as a microlearning tool in higher education. Setyo et al. (2026) further examined a multimodal digital textbook for supporting collaborative and creative mathematical thinking. However, limited research has developed Instagram-based interactive microlearning explicitly designed around the three dimensions of mathematical creative thinking, such as fluency, flexibility, and originality, within Linear Algebra. Therefore, this study develops Instagram-based interactive microlearning for vector material in Linear Algebra. Its novelty lies in integrating Instagram features with concise, interactive, and progressively structured microlearning explicitly aligned with fluency, flexibility, and originality. Through visualization and gradual presentation, this approach is intended to make abstract vector concepts more accessible while providing opportunities to strengthen pre-service mathematics teachers' mathematical creative thinking.

Methods

This study employed a Research and Development (R&D) approach to produce a learning-media product and evaluate its effectiveness (Sugiyono, 2019). The development model was ADDIE, comprising five stages: Analysis, Design, Development, Implementation, and Evaluation. In the Analysis stage, the researchers identified learning problems and examined the applicable curriculum of the Mathematics Education Study Program at Universitas PGRI Kanjuruhan Malang. The Design stage involved designing the microlearning media based on relevant references and developing validation instruments for media, subject matter, and learning experts, as well as practicality questionnaires and effectiveness tests. In the Development stage, the media was produced according to the design. The Implementation stage involved expert validation and product trials. In the Evaluation stage, validation results were analyzed to guide product revisions, followed by practicality testing and effectiveness evaluation involving pre-service mathematics teachers.

Product trials comprised three stages: (1) validity testing by media, subject matter, and learning experts; (2) practicality testing through a small-group trial involving 10 pre-service mathematics teachers and an extended field trial involving 20 pre-service mathematics teachers; and (3) effectiveness testing using a quasi-experimental non-equivalent control-group pretest–posttest design involving 40 pre-service mathematics teachers, with 20 participants in the experimental group and 20 in the control group.

The expert validators were lecturers in the Mathematics Education Study Program at Universitas PGRI Kanjuruhan Malang who had at least a doctoral qualification or relevant teaching experience. The collected data comprised qualitative data (i.e., validators' comments and suggestions) and quantitative data (i.e., validation scores, questionnaire responses, and mathematical creative-thinking test scores). The instruments consisted of media-expert validation sheets assessing image illustration, color illustration, and media use; subject-matter-expert validation sheets assessing the suitability of learning objectives, material, ease of understanding, systematic presentation, and availability of questions; learning-expert validation sheets assessing media use, color and image design, and material suitability; student response questionnaires for practicality; and creative-thinking tests for evaluating effectiveness. The data-analysis procedures are described below.

Validity Analysis of the Microlearning Media

The validity of the developed microlearning media was determined from expert validation scores. The mean score was interpreted according to the criteria presented in Table 1.

Table 1. Validity Criteria for the Microlearning Media

Score	Category
$3.25 < Y \leq 4.00$	Highly Valid
$2.50 < Y \leq 3.25$	Valid
$1.75 < Y \leq 2.50$	Moderately Valid
$1.00 < Y \leq 1.75$	Less Valid

Adapted from Widoyoko (2012), modified.

Practicality Analysis of the Microlearning Media

The practicality of the microlearning media was determined from the student response questionnaire. The questionnaire consisted of four response options with corresponding scores. The mean score for each product-assessment aspect was calculated using the following formula (Widoyoko, 2014):

$$Y = \frac{\sum x}{kn} \quad (1)$$

where Y represents the mean score for each product-assessment aspect, ∑x represents the total score for each product-assessment aspect, n represents the number of assessment items for each aspect, and k represents the number of respondents.

Score Analysis Practicality of Microlearning

The resulting mean scores were interpreted according to the criteria in Table 2.

Table 2. Practicality Criteria for the Microlearning Media

Score	Category
$3.25 < Y \leq 4.00$	Highly Practical
$2.50 < Y \leq 3.25$	Practical
$1.75 < Y \leq 2.50$	Moderately Practical
$1.00 < Y \leq 1.75$	Less Practical

Adapted from Widoyoko (2012), modified.

Effectiveness Analysis of the Microlearning Media

Pre-service mathematics teachers' mathematical creative thinking was assessed through three indicators: fluency, flexibility, and originality (Siswono, 2011). Each indicator was scored on a 0–4 rubric. Fluency measured the ability to generate multiple solution ideas; flexibility measured the ability to use different mathematical strategies or representations; and originality measured the ability to generate unique or uncommon solution strategies. The scoring rubric is presented in Table 3.

Table 3. Scoring Rubric for Mathematical Creative Thinking Skills

Indicator	Score	Criteria
Fluency	4	Generates three or more relevant mathematical ideas or solution possibilities correctly and completely.
	3	Generates two relevant mathematical ideas or solution possibilities correctly.
	2	Generates one relevant mathematical idea or solution.
	1	Provides an incomplete or largely irrelevant mathematical idea.
	0	Provides no relevant mathematical idea or solution.
Flexibility	4	Applies three or more different appropriate mathematical strategies or representations.
	3	Applies two different appropriate mathematical strategies or representations.
	2	Applies one appropriate strategy or representation.
	1	Attempts a strategy but does not demonstrate a clear alternative approach.
	0	Does not demonstrate an appropriate strategy or representation.
Originality	4	Produces a mathematically valid solution that is substantially different or non-routine.
	3	Produces a mathematically valid solution with an uncommon feature.
	2	Produces a valid but conventional mathematical solution.
	1	Shows a limited attempt to produce a different solution.
	0	Does not demonstrate an original mathematical idea.

Source: Adapted from Siswono (2011).

The same indicators and scoring criteria were applied to the pretest and posttest to ensure consistent assessment of changes in pre-service mathematics teachers' mathematical creative thinking before and after the intervention. Effectiveness was evaluated using a quasi-experimental non-equivalent control-group pretest–posttest design. Both groups completed the pretest before the intervention to establish their initial mathematical creative-thinking skills. The experimental group then received instruction using the Instagram-based interactive microlearning, whereas the control group received conventional instruction. Following the intervention, both groups completed the posttest using the same creative-thinking indicators and scoring framework.

For each participant, scores for fluency, flexibility, and originality were determined using the rubric. The total mathematical creative-thinking score was calculated by summing the scores across the three indicators and was subsequently converted into a percentage using the following formula:

$$Percentage\ score = \frac{total\ score\ obtained\ by\ the\ participant}{maximum\ possible\ score}\ x\ 100\% \qquad (2)$$

The pretest and posttest scores were compared to determine changes in mathematical creative thinking, both overall and for each indicator: fluency, flexibility, and originality. The normalized gain (N-Gain) was calculated to determine the magnitude of improvement using the following formula:

$$g = \frac{S_{post} - S_{pre}}{100 - S_{pre}} \qquad (3)$$

where S_{pre} represents the pretest score and S_{post} represents the posttest score. N-Gain was calculated for each participant and summarized for the experimental and control groups. The results were interpreted according to the criteria in Table 4.

Table 4. N-Gain criteria

N-Gain Score	Category
$g \geq 0.70$	High
$0.30 \leq g \leq 0.70$	Moderate
$g \leq 0.30$	Low

To determine whether improvement in mathematical creative thinking differed between the experimental and control groups, their N-Gain scores were compared. Before inferential analysis, the assumptions of normality and homogeneity of variance were examined using the Shapiro–Wilk and Levene tests, respectively. Parametric tests were applied when the assumptions were satisfied; otherwise, the Mann–Whitney U test was used. Effect size was calculated to determine the practical magnitude of the between-group difference. Thus, the effectiveness of the Instagram-based interactive microlearning was evaluated based on (1) changes in pretest and posttest scores, (2) N-Gain values, (3) statistical differences in N-Gain between the experimental and control groups, and (4) effect-size values.

Results and Discussion

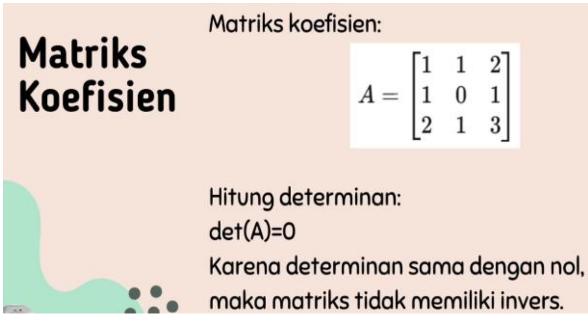
Product Design

The learning media developed was a microlearning platform uploaded to Instagram for the Vector topic, specifically the subtopic on span in vector space. Figure 1 shows the result of product design.

Microlearning cover view.

Display of material accompanied by sound explanation of the material

Example question display



Test question display

Figure 1. Comparison of Pre-Test and Post-Test Scores

Expert Validation Results

The developed media was validated by a media expert, a subject matter expert, and a learning expert before field testing. The validation results are presented in Table 5.

Table 5. Validation results by the three validators

Validator	Total Score	Average Score	Category
Media Expert	42	3.50	Very Valid
Subject Matter Expert	43	3.58	Very Valid
Learning Expert	46	3.83	Very Valid

All three validators rated the media within the interval $3.25 < \overline{x} \leq 4.00$, corresponding to the "very valid" category. The media expert recommended improvements to color selection and text placement, the subject matter expert recommended adding sample questions on vector subspaces, and the learning expert recommended adjustments to the lesson-plan format. All recommendations were addressed and used to revise the product before trials with pre-service mathematics teachers.

Small Group Trial Results

The small-group trial involved 10 pre-service mathematics teachers from class 2024A representing high, average, and low ability levels. The student response questionnaire assessed language, appearance, and interaction. The results are presented in Table 6.

Table 6. Student Response Questionnaire Results in the Small-Group Trial

Subject	Language	Appearance	Interaction	Total Score	Average	Category
1	6	18	11	35	3.5	Very Practical
2	7	20	12	39	3.9	Very Practical
3	7	14	10	31	3.1	Practical
4	8	18	9	35	3.5	Very Practical
5	8	20	10	38	3.8	Very Practical
6	7	19	9	35	3.5	Very Practical
7	8	18	11	37	3.7	Very Practical
8	7	17	10	34	3.4	Very Practical
9	8	19	11	38	3.8	Very Practical
10	7	18	12	37	3.7	Very Practical
Average				**35.9**	**3.59**	**Very Practical**

The small-group trial yielded an average response score of 3.59, which falls within the $3.25 < \bar{x} \leq 4.00$ interval and corresponds to the very practical category. The responses indicate that instagram-based microlearning provided understandable language, an attractive visual presentation, and opportunities for interaction during learning about vector concepts. These results indicate that the developed media met the practicality criterion and could proceed to broader implementation.

Extended Field Trial Results

The extended field trial involved 20 pre-service mathematics teachers. Student responses were assessed in terms of language, appearance, and interaction. The results are summarized in Table 7.

Table 7. Student Response Questionnaire Results in the Extended Field Trial

Name	Language	Appearance	Interaction	Amount	Score
Subject 1	7	19	10	36	3.6
Subject 2	8	18	11	37	3.7
Subject 3	6	18	10	34	3.4
Subject 4	8	17	10	35	3.5
Subject 5	7	19	11	37	3.7
Subject 6	6	19	11	36	3.6
Subject 7	8	17	9	34	3.4
Subject 8	7	17	10	34	3.4
Subject 9	6	18	11	35	3.5
Subject 10	7	18	9	34	3.4
Subject 11	8	17	11	36	3.6
Subject 12	8	17	10	35	3.5
Subject 13	7	16	11	34	3.4
Subject 14	7	19	11	37	3.7
Subject 15	6	16	9	31	3.1
Subject 16	8	18	12	38	3.8
Subject 17	7	20	10	37	3.7

Name	Language	Appearance	Interaction	Amount	Score
Subject 18	8	18	11	37	3.7
Subject 19	7	17	12	36	3.6
Subject 20	8	19	10	37	3.7
Average				**35.55**	**3.55**

The extended field trial produced an average score of 3.55, within the interval $3.25 < \bar{x} \leq 4.00$, corresponding to the very practical category. The results indicate that the language, visual presentation, and interactive features of the developed media were understandable, engaging, and consistent with the characteristics of digital-based learning.

Initial Equivalence: Pretest Results

The effectiveness of the Instagram-based interactive microlearning was examined using pretest and posttest assessments administered to the experimental and control groups. The pretest was conducted before the intervention to establish participants' initial mathematical creative-thinking performance and to examine the comparability of the two groups. Descriptive results are presented in Table 8.

Tabel 8. Descriptive Statistics of Pretest and Posttest Mathematical Creative Thinking Scores

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Mean Difference
Experimental	20	6.28	1.05	8.58	0.46	2.30
Control	20	5.88	1.03	7.93	0.36	2.06

The experimental group's mean score increased from 6.28 (SD = 1.05) at pretest to 8.58 (SD = 0.46) at posttest, representing a mean increase of 2.30 points. The control group increased from 5.88 (SD = 1.03) to 7.93 (SD = 0.36), representing a mean increase of 2.06 points.

An independent-samples t-test was conducted to examine whether the groups differed in their initial mathematical creative-thinking performance. The results are presented in Table 9.

Table 9. Initial Equivalence of the Experimental and Control Groups

Group	N	Mean	SD	t	df	p
Experimental	20	6.28	1.05	1.23	38	.225
Control	20	5.88	1.03			

The experimental group had a mean pretest score of 6.28 ($SD = 1.05$), compared with 5.88 ($SD = 1.03$) for the control group. The independent-samples t-test indicated that this difference was not statistically significant, $t(38) = 1.23, p = .225$. Thus, the groups did not differ significantly in mathematical creative-thinking performance before the intervention.

Comparison of Pretest and Posttest Scores

Paired-samples t-tests were conducted to examine changes in mathematical creative-thinking scores within each group because the pretest and posttest scores were obtained from the same participants. The results are presented in Table 10.

Table 10. Comparison of Pretest and Posttest Mathematical Creative Thinking Scores

Group	Pretest M	Posttest M	Mean Difference	t	df	p	Cohen's *dz*
Experimental	6.28	8.58	2.30	10.44	19	< .001	2.33
Control	5.88	7.93	2.06	9.26	19	< .001	2.07

The experimental group demonstrated a statistically significant increase from pretest ($M = 6.28, SD = 1.05$) to posttest ($M = 8.58, SD = 0.46$), $t(19) = 10.44, p < .001$, with a very large effect size ($Cohen's\ dz = 2.33$). The control group also demonstrated a statistically significant increase, from 5.88 to 7.93, $t(19) = 9.26, p < .001$, with a very large effect size ($Cohen's\ dz = 2.07$).

N-Gain Analysis

N-Gain was calculated to determine the magnitude of improvement in mathematical creative thinking. The results are presented in Table 11.

Table 11. N-Gain of Mathematical Creative Thinking

Group	N	Mean N-Gain	Category
Experimental	20	0.59	Moderate
Control	20	0.47	Moderate

The mean N-Gain was 0.59 for the experimental group and 0.47 for the control group. Both groups were therefore categorized as demonstrating moderate improvement. However, the experimental group showed a higher mean N-Gain than the control group.

To determine whether the magnitude of improvement differed significantly between groups, an independent-samples t-test was conducted on the N-Gain scores. The results are presented in Table 12.

Table 12. Independent-Samples t-Test of N-Gain Scores

Group	Mean N-Gain	t	df	p	Cohen's d
Experimental	0.59	2.31	38	.026	0.73
Control	0.47				

The independent-samples t-test indicated a statistically significant difference in N-Gain between the groups, $t(38) = 2.31, p = .026$, with a moderate effect size ($Cohen's\ d =$

0.73). Thus, although both groups demonstrated moderate improvement, the magnitude of improvement was significantly greater in the experimental group.

ANCOVA Analysis

Because the study used a non-equivalent control-group design, ANCOVA was conducted to further examine the effect of the intervention while controlling for initial mathematical creative-thinking performance. Posttest scores were entered as the dependent variable, group as the independent variable, and pretest scores as the covariate. The interaction between pretest and group was not statistically significant, $F(1,36) = 0.25, p = .621$, indicating that the homogeneity-of-regression-slopes assumption was satisfied. The ANCOVA results are presented in Table 13.

Table 13. ANCOVA Results for Posttest Mathematical Creative Thinking

Source	F	df	p	Partial η²
Pretest	4.23	1, 37	.047	—
Group	21.19	1, 37	< .001	.364

The ANCOVA revealed a statistically significant effect of group on posttest mathematical creative-thinking scores, $F(1,37) = 21.19, p < .001$, with a large effect size (partial η^2 = .364). After controlling for pretest scores, the experimental group demonstrated significantly higher posttest mathematical creative-thinking performance than the control group.

Overall, the findings indicate that the Instagram-based interactive microlearning group achieved greater improvement in mathematical creative thinking than the conventional-learning group. This pattern was evident in the higher mean N-Gain for the experimental group (0.59 versus 0.47), the statistically significant between-group difference in N-Gain, $t(38) = 2.31, p = .026, d = 0.73$, and the significant group effect in the ANCOVA, $F(1,37) = 21.19, p < .001$, partial η^2 = .364.

Discussion

The findings indicate that the Instagram-based interactive microlearning met the three product-quality criteria examined in this study: validity, practicality, and effectiveness. Regarding validity, the three mathematics education experts consistently rated the media in the very valid category, with scores of 3.50, 3.58, and 3.83. The consistency of these ratings suggests that the media was not only technically and visually appropriate but also aligned with essential pedagogical considerations for learning-media development. The expert feedback further contributed to product refinement: the media expert recommended improvements in color selection and text placement, the subject matter expert suggested adding sample questions on vector subspaces, and the learning expert recommended adjustments to the lesson-plan format. Addressing these recommendations before field testing strengthened the alignment between the media design, mathematical content, and instructional requirements.

Although the mean practicality score decreased slightly from 3.59 in the small-group trial to 3.55 in the extended field trial, both scores remained within the very practical category. This stability suggests that the usability of the media was maintained when implemented with a larger group of pre-service mathematics teachers. The high responses for language, visual presentation, and interaction indicate that the media was understandable, visually engaging, and sufficiently interactive for its intended users. This finding may be related to the participants' familiarity with Instagram as Generation Z learners, who are accustomed to interacting with digital platforms in their everyday lives (Laso et al., 2025). The alignment between the media characteristics and users' digital habits may therefore have supported media acceptance, consistent with previous findings that social-media-based learning can be more enjoyable than conventional learning and can increase student participation (Lau, 2018). Thus, the practicality observed in this study appears to derive not only from visual attractiveness but also from the compatibility of the learning environment with users established digital practices (Mangundu, 2022).

Regarding effectiveness, the quasi-experimental findings demonstrate that pre-service mathematics teachers who learned through Instagram-based interactive microlearning achieved greater improvement in mathematical creative thinking than those receiving conventional learning. Both groups demonstrated moderate improvement based on their N-Gain scores; however, the experimental group achieved a higher mean N-Gain (0.59) than the control group (0.47). The between-group difference was statistically significant, $t(38) = 2.31, p = .026$, with a moderate effect size ($Cohen's\ d = 0.73$). This result indicates that although conventional learning also supported improvement, the magnitude of improvement was greater when learning was supported by the developed microlearning. The ANCOVA provided further evidence by showing a significant group effect on posttest mathematical creative-thinking scores after controlling for pretest performance, $F(1,37) = 21.19, p < .001$, with a large effect size (partial $\eta^2 = .364$). Thus, the convergence of the N-Gain and ANCOVA results strengthen the evidence that the experimental group achieved superior post-intervention performance.

The ANCOVA result is particularly relevant because the study employed a non-equivalent control-group design. The non-significant pretest-by-group interaction, $F(1,36) = 0.25, p = .621$, indicated that the homogeneity-of-regression-slopes assumption was satisfied, supporting the use of ANCOVA to account for initial differences. After controlling for pretest performance, the experimental group continued to demonstrate higher posttest mathematical creative-thinking performance. This finding is consistent with the view that mathematical creative thinking comprises complementary dimensions of fluency, flexibility, and originality (Chirove & Ogbonnaya, 2026), and with evidence that microlearning can contribute to improving creative-thinking abilities that have previously been identified as low (Giurgiu, 2017). The concise structure of microlearning may have supported this development by presenting mathematical concepts in short, focused segments without requiring learners to process extensive information at once.

The improvement may also be explained by specific affordances of the Instagram-based microlearning. The developed media presents mathematical concepts through visual, flexible, and interactive formats. The integration of text, images, animation, and audio can support the understanding of abstract concepts by providing multiple representations that facilitate cognitive processing (Mayer, 2021). In addition, concise microlearning content allows pre-service mathematics teachers to learn independently and revisit materials as needed, potentially reducing the cognitive demands associated with processing mathematical concepts (Leong et al., 2021). Instagram's interactive features can further facilitate engagement, idea sharing, and discussion (Greenhow & Chapman, 2020). Such features may create opportunities for learners to consider alternative solution strategies and representations, thereby supporting fluency, flexibility, and originality in mathematical creative thinking (He, 2017). The combination of concise content, multimodal representation, accessibility, and interaction therefore provides a plausible pedagogical explanation for the observed improvement.

The findings also extend previous research by integrating elements that have generally been examined separately. Setiyadi et al. (2022) used YouTube-based creative videos for mathematics learning but did not specifically examine the three dimensions of creative thinking. Suhardi and Putri (2023) examined WhatsApp-based mathematics learning with a focus on students' learning behavior, whereas Rohmaini et al. (2024) reviewed the relationship between augmented reality and pre-service mathematics teachers' creative thinking without developing a validated learning product. Hudayanti (2022) developed a Canva-based digital module but did not integrate the product into a social-media learning environment. In contrast, the present study combines Instagram as the delivery platform, microlearning as the instructional format, and explicit mathematical creative-thinking indicators as the target outcomes. This integration is also consistent with the relevance of Instagram-based learning to the digital habits of Generation Z pre-service mathematics teachers (Mulenga & Marbán, 2020). The study therefore provides an alternative approach to addressing the development of mathematical creative thinking among pre-service mathematics teachers, particularly in Linear Algebra.

The novelty of the study lies not simply in using Instagram to deliver mathematical content but in integrating Instagram's affordances with an interactive microlearning design explicitly structured around fluency, flexibility, and originality in Linear Algebra. The product was subjected to systematic validity and practicality evaluation and then examined comparatively for its effectiveness against conventional learning. This combination extends previous research by connecting a familiar social-media environment with a structured pedagogical design for developing mathematical creative thinking. For pre-service mathematics teachers encountering abstract vector concepts, the progressive visualization and focused presentation offered through the media may provide a more accessible pathway for engaging with mathematical ideas while exploring multiple and potentially original solution strategies.

Conclusion

This study concludes that the Instagram-based interactive microlearning developed for Linear Algebra met the criteria of validity, practicality, and effectiveness and can support the development of pre-service mathematics teachers' mathematical creative thinking. The comparative findings showed that pre-service mathematics teachers who learned through the developed media demonstrated greater improvement in mathematical creative thinking than those who received conventional learning, after accounting for their initial performance.

The findings further demonstrate the potential of Instagram to be transformed from a platform primarily associated with communication and entertainment into a meaningful learning environment when its features are intentionally aligned with learning objectives, concise mathematical content, multimedia representations, and creative problem-solving activities. The integration of interactive microlearning provides flexible opportunities for pre-service mathematics teachers to access, revisit, and explore mathematical concepts, which may support the generation of ideas, consideration of alternative solution strategies, and development of different mathematical representations.

The main implication of this study is that social-media-based microlearning can provide an alternative digital learning approach for supporting higher-order mathematical thinking in mathematics teacher education. In particular, the developed media offers a familiar and accessible environment for engaging with abstract mathematical concepts such as vectors in Linear Algebra. Thus, the contribution extends beyond the development of a digital learning product by demonstrating how an existing social media platform can be pedagogically repurposed to support mathematical creative thinking.

Nevertheless, the findings are limited to the participants, institutional context, and Linear Algebra topic examined in this study. Future research should involve larger and more diverse learner populations, broader mathematical topics, and longer implementation periods to examine the transferability and sustainability of the observed learning effects. Such studies could further clarify whether the benefits of Instagram-based interactive microlearning extend across mathematical domains and persist beyond the immediate intervention period.

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Conflicts of Interest

The authors declare that no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely avoided by the authors. The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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