Journal of Infrastructure, Policy and Development 2024, 8(11), 8644.
https://doi.org/10.24294/jipd.v8i11.8644

Article

The impact of LMS-based mechanics course on the creativity of prospective physics teachers in the post-pandemic era: A quasi-experimental study

G. Gunawan[1,*], Ahmad Harjono[1], Ni Made Yeni Suranti[2], Lovy Herayanti[3], Nina Nisrina[1]

[1] Department of Physics Education, Universitas Mataram, Mataram 83115, Indonesia
[2] Elementary School Teacher Education, Universitas Mataram, Mataram 83115, Indonesia
[3] Department of Physics Education, Universitas Pendidikan Mandalika, Mataram 83115, Indonesia
*** Corresponding author:** G. Gunawan, gunawan@unram.ac.id

CITATION

Gunawan G, Harjono A, Suranti NMY, et al. (2024). The impact of LMS-based mechanics course on the creativity of prospective physics teachers in the post-pandemic Era: A quasi-experimental study. Journal of Infrastructure, Policy and Development. 8(11): 8644. https://doi.org/10.24294/jipd.v8i11.8644

ARTICLE INFO

Received: 17 July 2024
Accepted: 27 August 2024
Available online: 15 October 2024

Abstract: This quasi-experimental study examined the effect of a mechanics course delivered through a Learning Management System (LMS) on the creativity of prospective physics teachers at a teacher training college in Mataram, Indonesia. The study was conducted in the post-pandemic era. Using a pretest-posttest one-group design, the researchers evaluated changes in creativity across three domains: figural, numeric, and verbal. The results showed significant improvements in overall creativity, with the most critical gains observed in the figural domain. Further analysis revealed that fluency was the creative indicator with the most enhancement. In contrast, other indicators displayed varying degrees of improvement. These findings highlight the potential of LMS-based instruction in fostering creativity among future physics educators, particularly in the figural, numeric, and verbal domains. This study adds to the growing body of evidence supporting technology integration into teacher education, especially during times of crisis. Future research should explore more targeted instructional strategies within LMS environments and utilize comprehensive creativity assessment methods further to enhance creative learning experiences for prospective physics teachers.

Keywords: creativity; learning management system; mechanics concepts; post-pandemic; prospective physics teacher

1. Introduction

Creativity is a crucial aspect of science education, particularly in the 21st century, as it drives scientific progress and innovation (Liu and Chang, 2017; Kupers et al., 2019; Ward et al., 2013). It encompasses producing original research (Saleh and Brem, 2023) and fostering a deep understanding of scientific concepts and a love for learning (Beghetto and Kaufman, 2007). However, traditional teaching methods often hinder creative development by prioritizing content mastery over fostering creative thinking (Kaplan, 2019). This method leaves students ill-equipped for activities that demand creative thinking despite creativity being a skill that can be nurtured through deliberate practice and experience (Cassels, 2024; Cioca and Nerișanu, 2020).

Interactive learning approaches incorporating technology, such as electronic books, computer simulations, virtual laboratories, and augmented reality, have shown promise in stimulating creative processes and enhancing student creativity (Gunawan et al., 2019; Ratnawati et al., 2023; Sanabria and Arámburo-Lizárraga, 2017). Moreover, many students reported feeling less anxious during the learning process when using technology like adaptive gamification, which enhanced their focus in class and increased their motivation to improve in science lessons (Zourmpakis et al., 2023).The rise of Industry 4.0 further emphasizes the need for technology-based

education to cultivate 21st-century skills, including creativity (González-Pérez and Ramírez-Montoya, 2022). Education 4.0, a response to the learning preferences of the current generation and the changes brought about by the Fourth Industrial Revolution, has embraced online learning (Aziz Hussin, 2018).

The COVID-19 pandemic has necessitated a rapid shift to online learning, which has reshaped the educational landscape globally. Instructors have increasingly relied on the Learning Management System (LMS) to deliver formative assessments in online, on-ground, and hybrid courses. At the same time, university administrators have prioritized improving the quality of online instruction (Cassels, 2024). In the post-pandemic era, the LMS continues to be significant, particularly in higher education, where its effectiveness in fostering critical skills such as creativity among prospective teachers is crucial. However, the extent to which LMS-based courses can enhance the creativity of prospective physics teachers remains underexplored.

LMS have emerged as valuable tools for administration, documentation, reporting, and facilitating teaching and learning activities, including e-learning and online training. It aims to effectively deliver information to students and assess its practicality in the teaching and learning process (Triswidrananta et al., 2022). LMS are recognized for their effectiveness in knowledge and competency development, fostering collaboration and interactive communication between students and instructors (Kerimbayev et al., 2020; Ouadoud et al., 2018). The next generation of online course platform should integrate key lessons from open, distance, and flexible learning post-pandemic, focusing on educational support, instructional design, and quality assurance (Papadakis, 2023). However, online learning also presents challenges, such as face-to-face interaction and collaboration limitations.

In the realm of physics education, mechanics is a subject that demands a deep and clear understanding. Practical mechanics teaching requires dynamic classroom interactions (Duit et al., 2014). It should prioritize the development of students' soft skills through active learning, enabling them to grasp and creatively apply concepts (Rosana et al., 2014). Nurturing creativity within mechanics learning is, therefore, essential. Hockicko et al. (2015) suggest incorporating information technology or interactive multimedia in mechanics instruction can enhance students' thinking skills. However, more research needs to be conducted explicitly exploring how LMS impact the creativity of prospective physics teachers, especially in the context of mechanics. The challenge lies in adapting traditional mechanics courses to an online format that not only maintains educational rigor but also stimulates creativity.

This study aims to address this gap by investigating the effects of an LMS-based mechanics course on the creativity of aspiring physics teachers. By integrating course materials and resources into the LMS, students can learn anytime and anywhere while still benefiting from interaction with instructors who act as facilitators. This approach aims to enhance learning effectiveness and foster creativity development in physics education, particularly during the challenges of the pandemic and post-pandemic era. By measuring changes in specific aspects of creativity—verbal, figural, numeric, and procedural skills—this study will provide valuable insights into the potential of LMS platforms to nurture creativity among future physics educators. The findings are also expected to contribute to the broader discourse on optimizing online education to develop essential skills in future educators.

The research utilized a LMS developed on the MOODLE platform for e-learning. This LMS incorporates features like videos, virtual labs, teaching materials, and chat forums for mechanics-related discussions. Students can take assessments online through the LMS's quiz menu and complete creativity exercises within the platform. These exercises are in essay format, with students providing answers in designated fields or uploading relevant images related to the problems they solve.

2. Method

2.1. Participants

This quasi-experimental study, conducted at a Mataram teacher training college, focused on 41 third-semester Physics Education students enrolled in a Mechanics course who were explicitly exposed to the LMS-based mechanics instruction that served as the intervention in this study. These students were purposively selected to investigate the impact of LMS-based mechanics instruction, aligning with sample size recommendations by Creswell and Creswell (2017).

2.2. Learning materials

The learning process utilized a custom-developed LMS built on the Moodle platform. In this study, the learning tools and materials were carefully developed, including the Semester Program Plan (SPP), Student Assignment Plan (SAP), Course Learning Outcomes (CLOs), Student Worksheets (SWs), instructional materials, and creativity assessment instruments. Each of these components was rigorously tested for validity and reliability. The results confirmed that these tools are both valid and reliable, making them suitable for use in mechanics instruction aimed at facilitating creativity among students. This rigorous preparation and validation process further strengthens the credibility of the study's outcomes. The instructional materials and SWs were integrated into the LMS to provide resources and learning activities for the students. Additionally, the LMS had discussion forums and practice exercises to allow students to practice and improve their skills at their own pace and convenience.

2.3. Instruments

Creativity was assessed using a 15-item essay test administered after the LMS-based mechanics course. The test items were designed to measure four aspects of creativity: verbal, figural, numeric, and procedural. Each item was scored based on four indicators: fluency, flexibility, originality, and elaboration. These indicators were adapted from Guilford's (Guilford, 1950) Structure of Intellect model. The test underwent expert validation, which resulted in a validation percentage of 85.61%, indicating its high validity. Inter-rater reliability was assessed by measuring the agreement rate among three experts, resulting in a reliability of 93.65%, indicating high reliability.

2.4. Experimental design and procedure

This study utilized a quasi-experimental pretest-posttest one-group design. It was conducted as part of the developmental testing phase of a more extensive research and

development project. The intervention consisted of an eight-week online mechanics course delivered through the LMS. Before the intervention, the participants completed a pretest to evaluate their baseline creativity levels. After completing the course, the participants took a posttest to measure any changes in creativity. The improvement in creativity was analyzed using the normalized gain (N-gain) score, a standardized measure of learning gain that considers the initial performance (Hake, 1998). The calculated N-gain scores are interpreted based on the improvement categories proposed by Cheng (2004), as shown in the following **Table 1**.

Table 1. The calculated N-gain scores are interpreted based on the improvement categories.

N-gain Range (g)	Percentage Conversion (%)	Improvement Category
$g < 0.3$	$g < 30$	Low
$0.3 \leq g < 0.7$	$30 \leq g < 70$	Medium
$g \geq 0.7$	$g \geq 70$	High

Source: Cheng (2004).

The results of the study indicate that the LMS-based mechanics course had a differential impact on various aspects of creativity. While there was improvement in all aspects, the most significant gains were observed in figural and numeric creativity. This suggests that the LMS's visual and interactive features were particularly effective in fostering these skills. This finding is consistent with previous research that has emphasized the potential of technology-enhanced learning environments to promote visual and spatial reasoning (Chiang et al., 2014). The analysis of creative thinking indicators revealed that fluency and flexibility showed the greatest improvement across all dimensions of creativity. This suggests that the LMS facilitated the generation of a wide range of ideas and encouraged students to approach problems from different perspectives. However, the lower average scores in originality and elaboration indicate that students may still face challenges in producing unique ideas and developing them in detail. This finding highlights the importance of further research and instructional design interventions that specifically target these aspects of creative thinking within LMS-based learning environments.

3. Results

This study examined the impact of a Learning Management System (LMS) on the creativity development of prospective physics teachers in the context of mechanics learning in the post-pandemic period. The study focused on four aspects of creativity: verbal, figural, numeric, and procedural. The findings revealed significant variations in mean achievement across these different aspects.

The following data (**Figure 1**) represents the average pretest and posttest scores for student creativity, along with the N-Gain score. Overall, the increase in creativity falls within the moderate category. This indicates that the LMS mechanics used in the study effectively enhanced student creativity to a moderate extent.

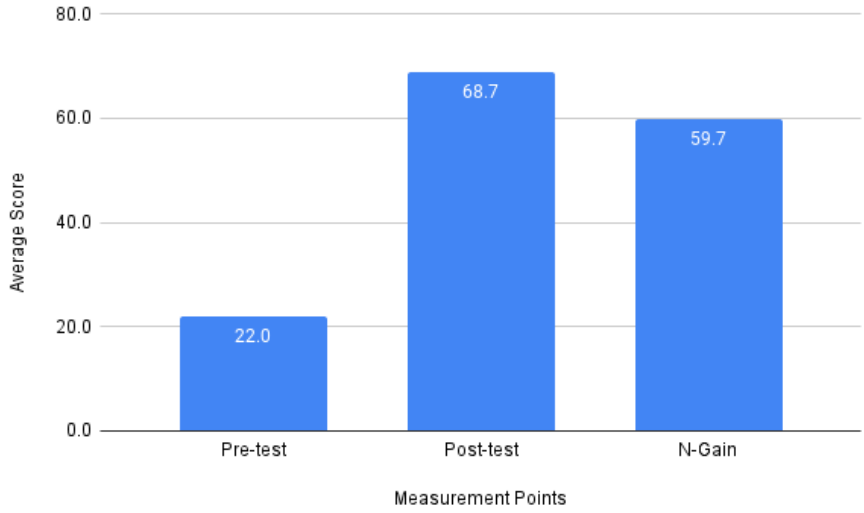

Figure 1. Average scores of pretest, posttest, and N-Gain in student creativity.

The data shows an average pretest score of 22.0, a posttest score of 68.7, and an N-Gain score of 59.7. The moderate increase in creativity suggests that the LMS mechanics provided a beneficial platform for students, though there remains potential for further improvements to enhance creativity even more.

Furthermore, the analysis of creative thinking indicators, such as fluency, flexibility, originality, and elaboration, provided valuable insights into the influence of LMS usage on students' creative thinking abilities. Creativity was measured using a 15-item essay test encompassing verbal, figural, numeric, and procedural aspects. Students completed this test as a pretest before the intervention to establish baseline creativity levels. Following the LMS-based mechanics course, students completed the same test again as a posttest to measure any changes in creativity. **Figure 1** illustrates the increased creativity scores observed for each aspect after the intervention.

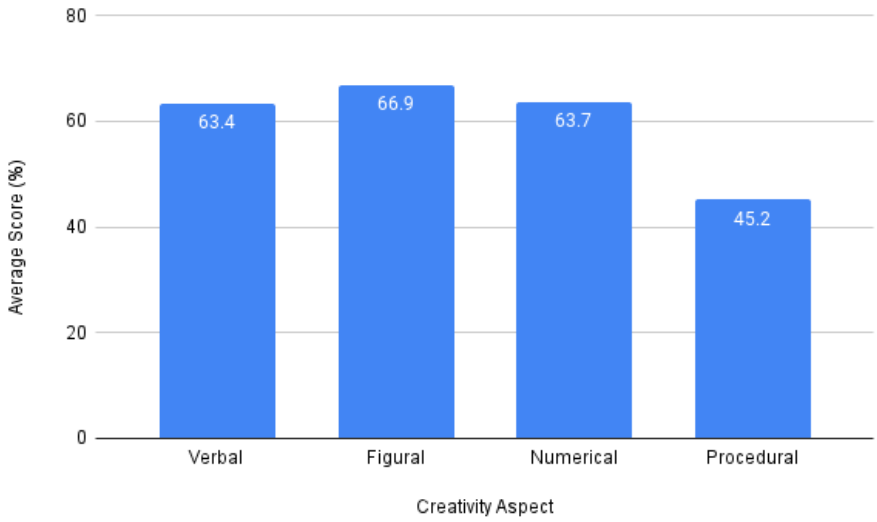

Figure 2. Comparison of mean N-Gain scores across creativity aspects.

As shown in **Figure 2**, the most significant improvement was seen in figural

creativity, while procedural creativity showed the most minor progress. However, the improvement in every aspect of creativity fell into the moderate category, as defined by Hake (1998). To further explore the development of creative thinking, the study examined the improvement based on specific indicators of creativity: fluency, flexibility, originality, and elaboration. **Figure 3** presents a thorough overview of the comparative improvement in each indicator.

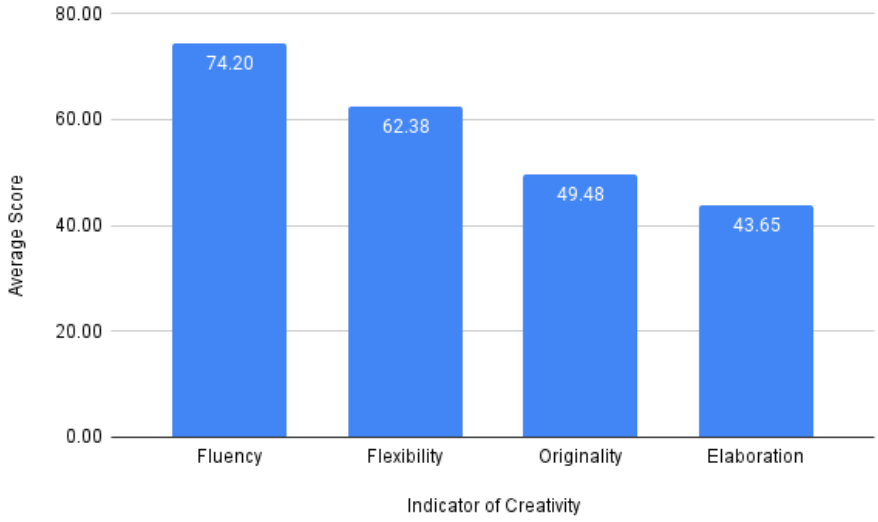

Figure 3. Comparison of average creativity indicator scores.

Figure 3 illustrates that the fluency indicator showed the most significant improvement, achieving a score of 74.20. This indicates that students progressively enhanced their ability to generate ideas or solutions within the context of mechanics throughout the study period. The flexibility indicator also demonstrated substantial improvement, reaching a score of 62.38, highlighting the student's capacity to engage diverse perspectives and approaches in problem-solving. On the other hand, although there was an improvement in the originality indicator, with a score of 49.48, this value suggests that students may still face challenges in generating genuinely unique or original ideas. The elaboration indicator scored 43.65, indicating that students need further attention on their ability to develop or expand their ideas into more profound concepts.

These findings provide valuable insights into the development of students' creativity across different indicators. They can serve as a basis for refining instructional strategies to enhance creativity among prospective physics teachers. The significant improvement in fluency and flexibility suggests that the learning environment based on the Learning Management System (LMS) effectively fostered idea generation and encouraged diverse thinking. The comparatively minor improvements in originality and elaboration suggest potential areas for targeted instructional interventions to enhance creative thinking skills further.

In this study, hypothesis testing was conducted to determine the effect of using an LMS-based Mechanics system on student creativity. Before conducting the hypothesis test, it is essential to check the normality of the data. Normality tests determine whether the data follows a normal distribution, which influences the choice

of statistical test.

The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to assess the normality of pre-test, post-test, and N-Gain scores. These tests help identify whether the data meets the normality assumption required for parametric analysis. If the data is not normally distributed, a non-parametric test like the Wilcoxon test will be used for hypothesis testing. The **Table 2** shows the normality test for the data.

Table 2. The normality test.

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pre-test	0.088	41	0.200*	0.987	41	0.912
Post-test	0.185	41	0.001	0.935	41	0.021
N-Gain	0.091	41	0.200*	0.966	41	0.252

Note: "*" means this is a lower bound of the true significance; "a" means Lilliefors Significance Correction.

The normality tests for the creativity scores include the Kolmogorov-Smirnov and Shapiro-Wilk tests. Both tests indicate normal distribution for the pretest scores, with *p*-values of 0.200 and 0.912, respectively. The N-Gain scores are also normally distributed, with *p*-values of 0.200 (Kolmogorov-Smirnov) and 0.252 (Shapiro-Wilk). However, the posttest scores show mixed results: the Kolmogorov-Smirnov test indicates a non-normal distribution with a *p*-value of 0.001. In contrast, the Shapiro-Wilk test suggests a normal distribution with a *p*-value of 0.021. Due to the Kolmogorov-Smirnov test showing significance, the posttest scores are considered non-normally distributed. As a result, hypothesis testing for the creativity scores will be conducted using the Wilcoxon test to accommodate the non-normal distribution of the posttest data.

The Wilcoxon Signed Rank Test was chosen for this hypothesis testing because the posttest data was found to be non-normally distributed, as indicated by the Kolmogorov-Smirnov test. The Wilcoxon test is a non-parametric statistical test used to compare paired samples, making it suitable for data that do not meet the normality assumption. It evaluates whether there is a significant difference in the median of differences between two related groups. In this study, the following hypotheses were tested:

- Null Hypothesis (H0): LMS-based Mechanics do not affect student creativity. This means the median of differences between pretest and posttest scores equals 0.
- Alternative Hypothesis (Ha): There is an effect of using LMS-based Mechanics on student creativity. This means the median of differences between pretest and posttest scores does not equal 0.

The hypothesis test summary (**Table 3)** shows that the Wilcoxon Signed Rank Test yielded a significance value (Sig.) of less than 0.001. Since this *p*-value is less than the significance level of 0.050, we reject the null hypothesis (H0). Rejecting the null hypothesis indicates a statistically significant difference between the pretest and posttest scores. This result supports the alternative hypothesis (Ha), suggesting that the use of LMS-based Mechanics has a substantial effect on improving student

creativity.

Table 3. Hypothesis test summary.

Null Hypothesis	Test	Sig.[a,b]	Decision
The median of differences between Pre-test and Post-Test equals 0.	Related-Samples Wilcoxon Signed Rank Test	<0.001	Reject the null hypothesis.

Note: "a" means the significance level is 0.050; "b" means Asymptotic significance is displayed.

4. Discussion

The study revealed a significant improvement in students' overall creativity. This significant improvement emphasizes the value of incorporating LMS tools in educational settings to foster creativity. Specifically, verbal creativity, assessed through the student's ability to articulate their thoughts (Gunawan et al., 2017), showed a notable increase. This finding aligns with Maliyah (2012) research, which highlighted the importance of verbal skills in physics, including the mastery of technical terms. Many students demonstrated their understanding by explaining mechanics concepts and everyday phenomena.

Furthermore, Sun et al. (2019) suggested that the improvement in verbal creativity may be attributed to its positive correlation with cognitive abilities. Students with strong verbal creativity tend to think spontaneously and make connections between different concepts. Additionally, He et al. (2021) found that enhanced verbal creativity is influenced by individuals' ability to efficiently associate information, facilitated by a more efficient semantic memory structure.

The results indicated variations in mean scores across different aspects of creativity. Verbal creativity scored 63.4, figural creativity scored 66.9, numeric creativity scored 63.7, and procedural creativity scored 45.2. These differences are influenced by the unique characteristics of each creativity aspect and the impact of the Learning Management System (LMS) on mechanical learning. The significant increase in figural creativity can be attributed to the LMS's support for visual and spatial understanding of mechanics. The interactive features of the LMS, such as simulations and visualizations, facilitate exploration and visual representation, allowing students to express their ideas more creatively and intuitively. According to Saputro et al. (2021), the LMS is impactful, efficient, and forward-thinking, offering more than just interactivity for instructors and students in the learning process. It enables instructors and students to exchange materials, assign and submit tasks, and communicate online. Furthermore, Rizal et al. (2020) stated that high student satisfaction with the LMS positively influences the implementation of physics learning activities. Synchronous learning activities facilitated by the LMS create opportunities for effective communication and interaction between students and teachers, fostering a robust psychological connection that encourages students' creativity.

Students' figural creativity was associated with expressing ideas through force diagrams based on Newton's Laws of Motion. The Learning Management System (LMS) used during online learning effectively facilitated this aspect of creativity. Including virtual experiments and practice, problems fostered creative thinking and enhanced practical skills. Fluency was the highest-scoring indicator of figural creativity, while elaboration was the lowest. This suggests that students were skilled

at expressing multiple ideas through patterns or images but faced challenges in expanding upon those ideas. This contrasts with Kao (2020) findings, which showed that fluency scored the lowest in the figural aspect and originality scored the highest. Duncan (2020) suggest that instructional designs incorporating images and animations, such as games, can effectively facilitate student learning experiences, promoting collaboration, communication, creativity, and critical thinking skills.

Despite overall improvement, verbal creativity may have experienced a slightly smaller increase than figural creativity. This could be due to challenges in expressing ideas verbally or in written form through digital platforms, which may only sometimes optimally support verbal expression. The increase in numeric creativity, which closely paralleled verbal creativity, could be attributed to the LMS providing diverse tools and resources to facilitate understanding of numerical concepts in mechanics. Interactive approaches to the LMS could help students creatively develop their numerical skills. Overall, the LMS positively contributes to students' understanding of mechanics concepts, making it an effective tool in mechanics education, including for future physics teachers (Gunawan et al., 2021).

The aspect of numeric creativity demonstrated moderate improvement, ranking second among all aspects of creativity in percentage increase. This aspect is associated with students' ability to discover new equations. Throughout the learning process, students were given access to practice problems within the e-learning system, which likely contributed to developing their numeric creativity. According to Piaget's theory of cognitive development, the notable improvement in numeric creativity could also be attributed to the study's sample of prospective teachers within the formal operational stage. This suggests that these students possess the capacity for abstract, logical, and systematic thinking, enabling them to solve mathematical problems readily. This finding is supported by Assmus and Fritzlar (2022), who concluded a positive correlation between mathematical creativity and students' age, with mathematical creativity increasing at each educational level or grade.

Additionally, they suggest that initiatives to promote mathematical creativity are suitable for students who achieve high scores in mathematics classes. Procedural creativity showed moderate improvement, with the lowest increase compared to other aspects. This could be attributed to students' unfamiliarity with the assessment method used for procedural creativity. Development of this aspect was only facilitated during certain phases of the learning process, such as completing worksheets and engaging in virtual experiments. The improvement in procedural creativity was less significant than in other areas due to the challenges of controlling activities that foster this type of creativity within the online system.

Although students could complete worksheets effectively, the instructor needed more visibility. This highlights the need for educators to incorporate teaching and training methods that specifically target the development of procedural creativity. Regular practice in fostering creativity, as suggested by Fink et al. (2020), can enhance fluency, flexibility, and originality in expressing ideas. Environmental factors, as highlighted by Studente et al. (2016), also play a role in stimulating creativity. Furthermore, activities like reading and writing, as found by (Segundo Marcos et al., 2020), contribute to improving students' creative thinking.

Creativity is a crucial factor in supporting the performance of exceptional science

teachers. It is a strong predictor that influences teachers' attitudes and stimulates optimal behavior in their work, as stated by Ramdani et al. (2022). Gunawan et al. (2023) further point out that achievement motivation correlates positively with student creativity in mechanics learning using blended learning models. This suggests that efforts to increase motivation can be an effective strategy for developing the creativity of future physics teachers.

The relatively low improvement in procedural creativity in mechanics learning through online platforms can be attributed to the complexity of the subject and the challenges associated with transferring procedural skills. Procedural learning often requires face-to-face interaction and direct observation, which may only partially be achieved in a digital environment.

In conclusion, the differences in improving various aspects of creativity in mechanics learning through Learning Management Systems (LMS) reflect how each element can be supported. Future research should focus on tailoring online learning strategies to develop procedural creativity and enhance the use of interactive LMS features to improve verbal expression. The analysis of creativity improvement, based on creativity indicators, falls under the moderate enhancement category. The fluency and flexibility indicators show the highest improvement.

The high average achievement in the fluency indicator indicates that students can generate multiple ideas or solutions within mechanics. The use of LMS facilitated idea generation through interactive tools and collaborative features. Previous studies have also shown that LMS can foster idea generation and brainstorming. Although slightly lower than fluency, the significant average achievement in the flexibility indicator suggests that students can consider diverse perspectives or approaches in problem-solving. This demonstrates the effectiveness of LMS in stimulating creative thinking. Research has consistently shown the positive impact of technology-enhanced learning environments on students' flexibility in problem-solving. During the mechanics learning activities, students were primarily taught to find information independently through videos and teaching materials. They were then guided to produce diverse answers to problems, and they were provided with worksheets as guides for conducting virtual experiments. These worksheets helped to stimulate their verbal, figural, numeric, and procedural creativity. The students conducted virtual experiments and practiced exercises related to Newton's Laws of Motion, Work and Energy, and Simple Harmonic Motion. For the topic of Newton's Laws of Motion, they learned through videos and practice problems involving motion system diagrams. This likely contributed to their figural solid creativity in the fluency and flexibility indicators, as they could express various ideas quickly.

After being taught using the developed learning tools, students who had a deeper understanding of the material tended to provide answers from different perspectives. The most significant improvement in the figural aspect of flexibility was likely due to their ability to create illustrations using different thinking processes based on observing object shapes. An sthat students explained the material they learned using their language and thinking based on the experiments and discussions they conducted. This suggests that the learning environment based on the Learning Management System encouraged students to articulate their understanding in their own words, promoting a more profound comprehension and creative expression.

Research in other fields of creativity shows similar trends, with verbal and figural creativity often showing a positive correlation. However, the strength of this relationship depends on the specific interventions and assessment instruments used to measure creativity (Wechsler, 2006). Students generally view LMS positively, appreciating features like accessibility, flexibility, interactivity, and the availability of learning materials. LMS can positively impact student achievement and perceptions. However, some students express negative views due to technical issues, limited interaction with instructors, and inadequate support (Furqon et al., 2023). Online session in using LMS has had a significant impact on various learning activities. In higher education, online learning has proven effective in enhancing interactivity and active student participation (Blieck et al., 2019). Online learning with innovative design can improve performance on creative tasks and foster deeper understanding (Wu, 2016). Integrating technology into education provides enriched learning experiences and opportunities, allowing quicker resolution of learning challenges (Ketsman, 2019). Virtual media can also enhance students' abilities to think divergently, enabling them to combine ideas verbally more effectively than through visual representations (Akçayır and Akçayır, 2018).

The results also demonstrate the effectiveness of LMS-based Mechanics in enhancing student creativity, validating the alternative hypothesis (Ha) that using LMS-based Mechanics has an effect on student creativity. This significant improvement suggests that LMS platforms' structured and interactive nature can foster a more engaging and effective learning environment. Furthermore, this finding is consistent with existing literature, which highlights the positive impact of technology integration in education. Web-based asynchronous and synchronous approaches enhance interactivity, allowing personalized, flexible learning anytime and anywhere, based on students' schedules and needs (Suartama et al., 2020). Additionally, project-based learning supported by virtual media effectively enhances students' creativity in physics. This indicates the potential of technology in developing the creativity of future physics teachers (Gunawan et al., 2019). Research in secondary schools has found that figural creativity tends to be higher than verbal creativity, with students preferring visual learning methods such as sketches and graphs over verbal explanations (Dău-Gaşpar and Marinca, 2016). However, Gunawan et al. (2019) found contrasting results, showing that computer-based learning significantly improved procedural creativity while having a lesser impact on verbal and figural creativity. Other studies have also demonstrated that computer-based systems can positively affect learning outcomes. For example, interactive multimedia learning has been shown to enhance critical thinking skills (Ramadhani et al., 2019), problem-solving abilities (Widodo et al., 2023), and conceptual understanding (Harjono et al., 2020).

It is important to note that this study has certain limitations. It focuses solely on creativity within the cognitive domain, specifically verbal, figural, numeric, and procedural aspects, using indicators such as fluency, flexibility, originality, and elaboration. The study also covers mechanics, including Newton's Laws of Motion, Work and Energy, and Simple Harmonic Motion. The sample size consisted of second-semester students, which may restrict the generalizability of the findings. Therefore, further research is needed to test the developed tools on more diverse samples. Additionally, there is potential for further development of the Mechanics

LMS, including exploration of other sub-topics and broader indicators of creativity.

The lower average achievement in the originality indicator suggests that although students could generate many ideas and think in various ways, they may have needed help producing genuinely unique or original ideas. This could be an area to focus on if we want to enhance students' creativity. Likewise, the lower average achievement in the elaboration indicator indicates that students needed help to develop or expand upon their generated ideas. Therefore, it may be necessary to create instructional strategies or provide support that encourages the elaboration of ideas.

5. Conclusion

This quasi-experimental study examines the significant impact of a Learning Management System (LMS)-based mechanics course on enhancing creativity among prospective physics teachers in the post-pandemic era. Through its interactive features and visual representations, the LMS proved effective in facilitating different aspects of creativity, especially figural and numeric creativity. However, procedural creativity could have been improved, indicating the importance of targeted instructional strategies in online learning environments to address this aspect. The study also revealed that fluency and flexibility were the creative indicators that showed the most improvement, while originality and elaboration require further attention in future instructional designs.

Future research should investigate instructional strategies within Learning Management System (LMS) environments that enhance procedural creativity and elaboration in the context of mechanics. This could involve integrating more interactive simulations, virtual labs, and project-based activities that encourage the practical application and expansion of theoretical concepts. Moreover, further exploring students' perceptions and experiences with the LMS would be valuable in optimizing its utilization for fostering creativity in physics teacher education.

Author contributions: Conceptualization, GG and AH; methodology, GG and NMYS; software, GG, AH and NMYS; validation, AH and LH; formal analysis, NN and LH; investigation, NMYS and NN; resources, NMYS and NN; data curation, GG; writing—original draft preparation, NMYS and NN; writing—review and editing, GG and AH; visualization, GG; supervision, LH; project administration, NMYS; funding acquisition, GG. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We would like to thank the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia for funding this research. We also thank all parties who helped prepare the instruments, carry out the study, and publish this article.

Conflict of interest: The authors declare no conflict of interest.

References

Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. Computers & Education, 126, 334–345. https://doi.org/10.1016/j.compedu.2018.07.021

Assmus, D., & Fritzlar, T. (2022). Mathematical creativity and mathematical giftedness in the primary school age range: an

interview study on creating figural patterns. ZDM – Mathematics Education, 54(1), 113–131. https://doi.org/10.1007/s11858-022-01328-8

Aziz Hussin, A. (2018). Education 4.0 Made Simple: Ideas for Teaching. International Journal of Education and Literacy Studies, 6(3), 92. https://doi.org/10.7575/aiac.ijels.v.6n.3p.92

Beghetto, R. A., & Kaufman, J. C. (2007). Toward a broader conception of creativity: A case for "mini-c" creativity. Psychology of Aesthetics, Creativity, and the Arts, 1(2), 73–79. https://doi.org/10.1037/1931-3896.1.2.73

Blieck, Y., Kauwenberghs, K., Zhu, C., et al. (2019). Investigating the relationship between success factors and student participation in online and blended learning in adult education. Journal of Computer Assisted Learning, 35(4), 476–490. Portico. https://doi.org/10.1111/jcal.12351

Cassels, A. M. (2024). Leveraging LMS Technology to Deliver Formative Assessment in the Post-Pandemic Era. Exploring Technology-Infused Education in the Post-Pandemic Era, 335–352. https://doi.org/10.4018/979-8-3693-2885-9.ch011

Cheng, K. K., Thacker, B. A., Cardenas, R. L., et al. (2004). Using an online homework system enhances students' learning of physics concepts in an introductory physics course. American Journal of Physics, 72(11), 1447–1453. https://doi.org/10.1119/1.1768555

Chiang, T H., Yang, S J., Hwang, G. J. (2014). An Augmented Reality-based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities. JSTOR, 17(4), 352-365.

Cioca, L.-I., & Nerișanu, R. A. (2020). Enhancing Creativity: Using Visual Mnemonic Devices in the Teaching Process in Order to Develop Creativity in Students. Sustainability, 12(5), 1985. https://doi.org/10.3390/su12051985

Creswell, J W., Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches, 5th ed. Sage Publications.

Dău-Gaşpar, O., Marinca, A. (2016). Secondary-school pupils' creativity in relation with school performance. In: Proceedings of Theoretical and Applied in Psychology SICAP23. p. 39.

Duit, R., Schecker, H., Höttecke, D., Niedderer, H. (2014). Teaching physics. In: Handbook of Research on Science Education (Volume II). Routledge.

Duncan, K. J. (2020). Examining the Effects of Immersive Game-Based Learning on Student Engagement and the Development of Collaboration, Communication, Creativity and Critical Thinking. TechTrends, 64(3), 514–524. https://doi.org/10.1007/s11528-020-00500-9

Fink, A., Reim, T., Benedek, M., et al. (2019). The Effects of a Verbal and a Figural Creativity Training on Different Facets of Creative Potential. The Journal of Creative Behavior, 54(3), 676–685. Portico. https://doi.org/10.1002/jocb.402

Furqon, M., Sinaga, P., Liliasari, L., et al. (2023). The Impact of Learning Management System (LMS) Usage on Students. TEM Journal, 1082–1089. Portico. https://doi.org/10.18421/tem122-54

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review. Sustainability, 14(3), 1493. https://doi.org/10.3390/su14031493

Guilford, J. P. (1950). Creativity. American Psychologist, 5(9), 444–454. https://doi.org/10.1037/h0063487

Gunawan, G., Harjono, A., Herayanti, L., et al. (2019). Problem-Based Learning Approach with Supported Interactive Multimedia in Physics Course: Its Effects on Critical Thinking Disposition. Journal for the Education of Gifted Young Scientists, 7(4), 1075–1089. https://doi.org/10.17478/jegys.627162

Gunawan, G., Harjono, A., Sahidu, H., et al. (2019). Project-based learning on media development course to improve creativity of prospective physics teacher. In: Proceedings of the 2nd international conference on science, mathematics, environment, and education. https://doi.org/10.1063/1.5139764

Gunawan, G., Harjono, A., Suranti, N. M. Y., et al. (2021). The impact of learning management system implementation on students' understanding of mechanics concepts. Journal of Physics: Conference Series, 1747(1), 012020. https://doi.org/10.1088/1742-6596/1747/1/012020

Gunawan, G., Sahidu, H., Harjono, A., et al. (2017). Effectiveness of Project Based Learning Model Assisted by Virtual Media on Physics Creativity of Students (Indonesian). Jurnal Cakrawala Pendidikan, 36(2). https://doi.org/10.21831/cp.v36i2.13514

Gunawan, M., Suranti, N., Nisrina, N., et al. (2017). Investigating Students Creativity Based on Gender by Applying Virtual Laboratory to Physics Instruction. In: Proceedings of the International Conference on Teacher Training and Education 2017 (ICTTE 2017). https://doi.org/10.2991/ictte-17.2017.54

Gunawan, Suranti, N. M. Y., & Harjono, A. (2023). Students' creativity based on achievement motivation in learning mechanics with blended model. AIP Conf. Proc., 2619, 090006. https://doi.org/10.1063/5.0123136

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American Journal of Physics, 66(1), 64–74. https://doi.org/10.1119/1.18809

Handhika, J. (2012). Learning physics through guided inquiry with experimental and demonstration methods in terms of student activity and attention (Indonesian). Jurnal Penelitian Pembelajaran Fisika, 1(1). https://doi.org/10.26877/jp2f.v1i1/april.104

Harjono, A., Gunawan, G., Adawiyah, R., et al. (2020). An Interactive e-Book for Physics to Improve Students' Conceptual Mastery. International Journal of Emerging Technologies in Learning (IJET), 15(05), 40. https://doi.org/10.3991/ijet.v15i05.10967

He, L., Kenett, Y. N., Zhuang, K., et al. (2020). The relation between semantic memory structure, associative abilities, and verbal and figural creativity. Thinking & Reasoning, 27(2), 268–293. https://doi.org/10.1080/13546783.2020.1819415

Hockicko, P., Krišťák, L., & Němec, M. (2014). Development of students' conceptual thinking by means of video analysis and interactive simulations at technical universities. European Journal of Engineering Education, 40(2), 145–166. https://doi.org/10.1080/03043797.2014.941337

Kao, C.-Y. (2020). How Figurativity of Analogy Affects Creativity: The Application of Four-Term Analogies to Teaching for Creativity. Thinking Skills and Creativity, 36, 100653. https://doi.org/10.1016/j.tsc.2020.100653

Kaplan, D. E. (2019). Creativity in Education: Teaching for Creativity Development. Psychology, 10(02), 140–147. https://doi.org/10.4236/psych.2019.102012

Kerimbayev, N., Nurym, N., Akramova, A., et al. (2019). Virtual educational environment: interactive communication using LMS Moodle. Education and Information Technologies, 25(3), 1965–1982. https://doi.org/10.1007/s10639-019-10067-5

Ketsman, O. (2019). Perspectives of Pre-Service Teachers About Blended Learning in Technology Integration Courses. International Journal of Mobile and Blended Learning, 11(4), 15–31. https://doi.org/10.4018/ijmbl.2019100102

Kupers, E., Lehmann-Wermser, A., McPherson, G., et al. (2018). Children's Creativity: A Theoretical Framework and Systematic Review. Review of Educational Research, 89(1), 93–124. https://doi.org/10.3102/0034654318815707

Liu, H.-Y., & Chang, C.-C. (2017). Effectiveness of 4Ps Creativity Teaching for College Students: A Systematic Review and Meta-Analysis. Creative Education, 08(06), 857–869. https://doi.org/10.4236/ce.2017.86062

Ouadoud, M., Nejjari, A., Chkouri, M. Y., & El-Kadiri, K. E. (2018). Learning Management System and the Underlying Learning Theories. Springer. pp. 732–744. https://doi.org/10.1007/978-3-319-74500-8_67

Papadakis, S. (2023). MOOCs 2012-2022: An overview. Advances in Mobile Learning Educational Research, 3(1), 682–693. https://doi.org/10.25082/amler.2023.01.017

Ramadhani, R., Umam, R., Abdurrahman, A., et al. (2019). The Effect of Flipped-Problem Based Learning Model Integrated With LMS-Google Classroom for Senior High School Students. Journal for the Education of Gifted Young Scientists, 7(2), 137–158. https://doi.org/10.17478/jegys.548350

Ramdani, Z., Hadiana, D., Amri, A., et al. (2022). The Mediating Role of Attitude in the Correlation between Creativity and Curiosity regarding the Performance of Outstanding Science Teachers. Jurnal Pendidikan IPA Indonesia, 11(3), 412–419. https://doi.org/10.15294/jpii.v11i3.37272

Ratnawati, N., Purnomo, A., Wahyuningtyas, N., et al. (2023). Effectiveness of Team-Based Project Integrated E-books in Improving Student Self-Directed Learning and Creativity. International Journal of Interactive Mobile Technologies (IJIM), 17(24), 136–152. https://doi.org/10.3991/ijim.v17i24.45955

Rizal, R., Rusdiana, D., Setiawan, W., et al. (2020). Studentsâ€™ Perception of Learning Management System Supported Smartphone: Satisfaction Analysis in Online Physics Learning. Jurnal Pendidikan IPA Indonesia, 9(4), 600–610. https://doi.org/10.15294/jpii.v9i4.25363

Rosana, D., Jumadi, J., Pujianto, P. (2014). Development of soft skills of international class program students through context-based learning to improve the quality of the process and learning outcomes of mechanics (Indonesian). Jurnal Pendidikan IPA Indonesia, 3(1), 12-21.

Saleh, R., & Brem, A. (2023). Creativity for sustainability: An integrative literature review. Journal of Cleaner Production, 388, 135848. https://doi.org/10.1016/j.jclepro.2023.135848

Sanabria, J. C., & Arámburo-Lizárraga, J. (2017). Enhancing 21st Century Skills with AR: Using the Gradual Immersion Method to develop Collaborative Creativity. EURASIA Journal of Mathematics, Science and Technology Education, 13(2). https://doi.org/10.12973/eurasia.2017.00627a

Saputro, B., Tortop, H. S., Zuhri, M., et al. (2021). The Effectiveness of the Learning Management System of Saqural Learning Application on the Scientific Interpretation Learning Outcomes. Jurnal Pendidikan IPA Indonesia, 10(1), 111–120.

https://doi.org/10.15294/jpii.v10i1.27677

Segundo Marcos, R. I., López Fernández, V., Daza González, M. T., et al. (2020). Promoting children's creative thinking through reading and writing in a cooperative learning classroom. Thinking Skills and Creativity, 36, 100663. https://doi.org/10.1016/j.tsc.2020.100663

Studente, S., Seppala, N., & Sadowska, N. (2016). Facilitating creative thinking in the classroom: Investigating the effects of plants and the colour green on visual and verbal creativity. Thinking Skills and Creativity, 19, 1–8. https://doi.org/10.1016/j.tsc.2015.09.001

Suartama, I. K., Setyosari, P., Sulthoni, S., et al. (2020). Development of Ubiquitous Learning Environment Based on Moodle Learning Management System. International Journal of Interactive Mobile Technologies (IJIM), 14(14), 182. https://doi.org/10.3991/ijim.v14i14.11775

Sun, J., Liu, Z., Rolls, E. T., et al. (2018). Verbal Creativity Correlates with the Temporal Variability of Brain Networks During the Resting State. Cerebral Cortex, 29(3), 1047–1058. https://doi.org/10.1093/cercor/bhy010

Triswidrananta, O. D., Pramudhita, A. N., & Wijaya, I. D. (2022). Learning Management System Based on Assessment for Learning to Improve Computational Thinking. International Journal of Interactive Mobile Technologies (IJIM), 16(04), 150–158. https://doi.org/10.3991/ijim.v16i04.28979

Ward, W. B., & Younis, M. Z. (2013). Steps Toward a Planning Framework for Elder Care in the Arab World. In: SpringerBriefs in Aging. Springer New York. https://doi.org/10.1007/978-1-4614-5978-1

Wechsler, S. (2006). Validity of the Torrance Tests of Creative Thinking to the Brazilian Culture. Creativity Research Journal, 18(1), 15-25. https://doi.org/10.1207/s15326934crj1801_3

Widodo, W., Mahdiannur, M. A., Suryanti, S., et al. (2023). Mobile Interactive Multimedia to Assist Prospective Science Teachers Holding Conceptual Understanding in Problem-Solving Electrical Circuits. TEM Journal, 2251–2263. Portico. https://doi.org/10.18421/tem124-36

Wu, Y. (2016). Factors impacting students' online learning experience in a learner-centred course. Journal of Computer Assisted Learning, 32(5), 416–429. Portico. https://doi.org/10.1111/jcal.12142

Zourmpakis, A.-I., Kalogiannakis, M., & Papadakis, S. (2023). Adaptive Gamification in Science Education: An Analysis of the Impact of Implementation and Adapted Game Elements on Students' Motivation. Computers, 12(7), 143. https://doi.org/10.3390/computers12070143