Al Qodiri: Jurnal Pendidikan, Sosial dan Keagamaan
Volume 24 Issue 2, 72-82.
e_ISSN: 2598-8735
https://al-qodiri.unikhams.ac.id/index.php/alqodiri/index

The Influence of Discovery Learning Strategy on Learning Engagement and Knowledge Construction in Asynchronous Online Learning

Abuddar*
Universitas Nurul Jadid
Paiton Probolinggo,
INDONESIA

Chusnul Muali
Universitas Nurul Jadid
Paiton Probolinggo,
INDONESIA

Article Info

Article history:

Received: Feb 15, 2026
Revised: April 26, 2026
Accepted: May 02, 2026

Keywords:

Asynchronous online learning;
Discovery learning;
Knowledge construction;
Learning engagement.

Abstract

Asynchronous online learning offers flexibility in time and pace; however, it is frequently associated with low student engagement and superficial knowledge construction. This study aims to examine the effect of discovery learning strategies on students' learning engagement and knowledge construction in an asynchronous learning environment. A quantitative quasi-experimental design with a posttest-only control group was employed, involving 64 tenth-grade students of SMA Nurul Jadid, divided into an experimental group (n = 32) and a control group (n = 32). The experimental group engaged with Moodle-based modules structured according to discovery learning stages, while the control group used conventional expository modules over four learning sessions on the topic of prayer. Data were collected using an adapted Student Engagement Scale (Cronbach's alpha = 0.87) and an analytical rubric to assess knowledge construction (inter-rater reliability = 0.85). Multivariate analysis (MANOVA) revealed a significant difference between the groups (Pillai's Trace = 0.520; F(2, 61) = 33.006; p < 0.001). Univariate results indicated that the experimental group achieved higher learning engagement (M = 82.45, SD = 6.12) than the control group (M = 70.10, SD = 7.45), F(1, 62) = 52.505; p < 0.001, and demonstrated superior knowledge construction (M = 85.20, SD = 5.89) compared to the control group (M = 72.35, SD = 8.10), F(1, 62) = 52.680; p < 0.001. These findings conclude that discovery learning is an effective instructional strategy for enhancing engagement and fostering deeper, more meaningful knowledge construction in asynchronous online learning environments..

To cite this article: Abuddar, & Muali, C. (2025). The influence of discovery learning strategy on learning engagement and knowledge construction in asynchronous online learning. *Al Qodiri: Jurnal Pendidikan, Sosial dan Keagamaan, 10*(1), 1–13.

INTRODUCTION

Asynchronous online learning has become an increasingly prominent feature of contemporary education, particularly as institutions seek to expand access and flexibility in learning environments. This mode allows students to regulate their own learning pace, revisit instructional materials, and manage study schedules independently, which aligns with the demands of modern, technology-mediated education (Lee, 2021; Li & Wong, 2025; Mcguire, 2026; Nikolopoulou, 2023; Okoye et al., 2021). However, the flexibility offered by asynchronous systems does not automatically ensure the quality of learning experiences. In many cases, students engage in learning activities only at a procedural level, focusing on fulfilling administrative requirements such as accessing content or submitting assignments without engaging in meaningful cognitive processing (Barkley & Major, 2020; Bean & Melzer, 2021; Hew, 2016; Nückles et al., 2020). Such patterns suggest that flexibility alone is insufficient to promote deep learning. Without intentional instructional design, asynchronous learning environments risk fostering passive engagement rather than active knowledge construction (Czerkawski & Lyman, 2016; Ho, 2024; Mansour, 2024; Soydan Oktay & Yüzer, 2024). Therefore, the effectiveness of asynchronous learning depends heavily on how learning activities are structured to promote meaningful intellectual engagement.

Empirical observations indicate that many asynchronous learning environments struggle to maintain high levels of student engagement. Engagement, as conceptualized by Martin & Borup (2022) and Wong & Liem (2022), encompasses behavioral, emotional, and cognitive dimensions that

* **Corresponding author:**
Chusnul Muali, Universitas Nurul Jadid Paiton Probolinggo, INDONESIA
chusnulmuali@unuja.ac.id

collectively determine the quality of learning experiences. In online contexts, engagement should not be limited to mere participation indicators such as attendance or task completion, but should reflect deeper involvement, including critical thinking, sustained attention, and active contribution to discussions (Chen et al., 2018; Conrad & Openo, 2018; Lan & Hew, 2020; Ouyang & Chang, 2019). However, several studies have reported declining levels of engagement in asynchronous settings, where students often feel isolated and disconnected from both peers and instructors (Cain et al., 2024; Collıns et al., 2019; Fabriz et al., 2021). This condition results in learning that is mechanical rather than meaningful, reducing opportunities for conceptual understanding. As a consequence, students may complete tasks without fully internalizing the knowledge being presented. These challenges highlight the need for pedagogical strategies that actively foster engagement in asynchronous learning environments.

Beyond engagement, another critical issue in asynchronous learning lies in the process of knowledge construction. From a constructivist perspective, learning is viewed as an active process in which learners interpret information, integrate new knowledge with prior experiences, and construct meaning through cognitive activities (Brau, 2016; Cakir, 2022; Zajda, 2021). In asynchronous settings, this process becomes more complex due to the absence of immediate feedback and real-time interaction (Moorhouse & Wong, 2022; Varkey et al., 2022; Vlachopoulos & Makri, 2019; Zydney et al., 2020). Consequently, students may struggle to move beyond surface-level understanding, especially when learning tasks are not designed to stimulate higher-order thinking. Effective learning, therefore, should be reflected in students' ability to analyze, synthesize, and apply knowledge rather than merely recalling information. This implies that asynchronous learning environments must provide opportunities for reflection, exploration, and critical engagement with content (Galikyan & Admiraal, 2019; Kahn et al., 2017; Osborne et al., 2018). Without such opportunities, learning outcomes are likely to remain limited and fragmented.

Given these challenges, there is an urgent need to identify instructional approaches that can simultaneously enhance engagement and support knowledge construction in asynchronous contexts. One promising approach is discovery learning, which emphasizes active exploration and learner-centered knowledge construction. Rooted in Bruner's theory, discovery learning encourages students to engage with problems, formulate hypotheses, analyze information, and draw conclusions independently (Chusni et al., 2020; Ozdem-Yilmaz & Bilican, 2025; Siregar, 2025). This approach positions learners as active agents in the learning process rather than passive recipients of information. In asynchronous environments, where direct interaction is limited, such an approach may help sustain cognitive engagement and promote deeper understanding. Moreover, discovery learning aligns well with the need for independent learning skills, which are essential in online education. Therefore, integrating discovery-based strategies into asynchronous learning design represents a theoretically grounded and pedagogically relevant solution.

Previous studies have extensively examined the effectiveness of discovery learning and its variants across different educational settings (AlGerafi et al., 2023; de-Marcos et al., 2016; Hilton, 2016; Marougkas et al., 2023; Simamora et al., 2019). Research has shown that guided discovery learning, in particular, can improve student engagement, critical thinking, and learning outcomes by providing structured support while maintaining opportunities for exploration (Alanazi et al., 2024, 2025; Nadjamuddin et al., 2026). Recent studies also indicate that learning designs incorporating challenges, feedback, and opportunities for knowledge production significantly enhance student engagement in online environments (Arghode et al., 2018; Cheung et al., 2021; El-Sabagh, 2021; Rienties et al., 2018). Furthermore, empirical evidence suggests that discovery-oriented approaches contribute to the development of higher-order cognitive skills, such as problem-solving and analytical reasoning (Ena et al., 2024; Lethulur et al., 2025). Despite these positive findings, most existing research has been conducted in synchronous or blended learning contexts, where interaction and guidance are more readily available. As a result, the applicability of these findings to fully asynchronous settings remains uncertain.

The limited focus on asynchronous environments represents a significant gap in the literature. Unlike synchronous or blended learning, asynchronous learning requires learners to exercise higher levels of self-regulation, autonomy, and cognitive responsibility (Alhazbi & Hasan, 2021; Eggers et al., 2021; Van Laer & Elen, 2017). These distinct characteristics mean that instructional strategies effective in other contexts cannot be assumed to yield similar outcomes in asynchronous settings. While discovery learning theoretically aligns with the principles of independent learning, its effectiveness in fostering engagement and knowledge construction in asynchronous environments has not been sufficiently explored. Additionally, few studies have simultaneously examined both engagement and knowledge construction as interconnected outcomes of instructional design. This lack of integrated analysis limits our understanding of how pedagogical strategies influence learning quality in online contexts. Therefore, further research is needed to provide empirical evidence on the effectiveness of discovery learning in asynchronous learning environments.

Based on this gap, the present study aims to examine the effect of discovery learning-based asynchronous modules on students' learning engagement and knowledge construction. Specifically, this study investigates whether students exposed to discovery-oriented learning designs demonstrate higher levels of engagement compared to those using conventional expository modules. In addition, it explores whether such approaches enhance students' ability to construct knowledge, as reflected in analytical thinking, conceptual integration, and argument development. Theoretically, this study contributes to the expansion of constructivist learning frameworks within asynchronous online education. Practically, the findings are expected to provide insights for educators in designing more effective and engaging asynchronous learning environments. By addressing both engagement and knowledge construction, this study offers a more comprehensive understanding of learning quality in digital contexts. Ultimately, this research seeks to bridge the gap between instructional theory and practice in asynchronous education.

METHOD

This study employed a quantitative approach using a quasi-experimental design, specifically a posttest-only control group design, to examine the effect of instructional treatment on two comparison groups (A. Singh, 2021). This design was selected due to practical constraints in the field, where the intervention was implemented within naturally formed classroom settings, thereby preventing random assignment of participants. Despite the absence of individual randomization, the selection of experimental and control groups was conducted based on the principle of group equivalence. This equivalence was evaluated through several indicators, including students' prior academic achievement, accessibility to learning technologies, and previous experience with online learning environments. These considerations were essential to ensure that both groups shared relatively comparable baseline characteristics, allowing for a valid and objective comparison of outcomes following the intervention.

The research was conducted at SMA Nurul Jadid during the second semester of the 2024/2025 academic year. This setting was selected due to its implementation of online learning systems, particularly the use of a Learning Management System (LMS) that supports asynchronous instructional delivery. The context provided a relevant environment for examining the effectiveness of discovery learning strategies in asynchronous settings, as students were already accustomed to digital learning platforms and independent learning routines. The population of this study consisted of tenth-grade students enrolled in the school. A total of 64 students participated in the study, drawn from two intact classes. A purposive sampling technique was employed to select these classes based on their comparability in key characteristics, including average achievement in Islamic Religious Education (PAI), availability of digital devices, and stability of internet access during learning activities (Obilor, 2023). These criteria were considered crucial as they directly influence students' readiness to engage with online instructional interventions. The selected classes were then assigned as the experimental and control groups, each consisting of 32 students. Class X IPS A served as the experimental group, while class X IPS B functioned as the control group. This assignment followed the existing classroom structure to maintain the natural learning environment and ensure the continuity of academic activities without disruption.

The independent variable in this study was the discovery learning strategy implemented through the Moodle Learning Management System, which facilitated the delivery of asynchronous instructional modules. The dependent variables included student engagement and knowledge construction. Student engagement was measured using an adapted version of the Student Engagement Scale, consisting of 20 items distributed across four dimensions: attention, persistence, participation, and cognitive engagement. Each item was rated on a five-point Likert scale ranging from 1 to 5, reflecting the intensity of students' responses to their learning experiences (Idkowiak et al., 2023). Knowledge construction was assessed through an analytical rubric applied to digital artifacts produced by students, including analytical essays, concept maps, and short presentations. These outputs were selected as they represent students' cognitive processes and their ability to organize, interpret, and synthesize knowledge.

The validity and reliability of the instruments were carefully established prior to data collection. The engagement questionnaire demonstrated high internal consistency, with a Cronbach's alpha coefficient of 0.87, indicating that the instrument was reliable for measuring student engagement. For the assessment of knowledge construction, a rubric with a scoring range of 1 to 100 was developed based on four key indicators: conceptual accuracy, depth of analysis, integration of sources, and originality of synthesis. To ensure scoring objectivity, two independent raters evaluated the student artifacts. The inter-rater reliability test produced a coefficient of 0.85, indicating a high level of agreement and confirming the reliability of the assessment process.

The data collection procedure was carried out in several structured stages. Initially, the researchers prepared instructional materials and ensured that both groups had access to the same learning content and duration. The intervention was conducted over four asynchronous learning sessions focusing on the topic of procedures and prayer readings. In the experimental group, learning modules were designed according to the stages of discovery learning, beginning with stimulation through contextualized cases, followed by problem identification facilitated through online discussion forums. Students then engaged in data collection using curated digital resources and processed information through structured worksheets to identify patterns and relationships. The next stage involved concept verification, where students critically compared their findings with established principles of Islamic education. Finally, students constructed generalizations in the form of digital learning artifacts. In contrast, the control group received instruction through expository modules consisting of structured explanations, worked examples, and independent exercises. At the end of the intervention, all participants completed the engagement questionnaire and submitted their digital artifacts as posttest data.

Data analysis was conducted using IBM SPSS Statistics 25 to ensure accuracy and reliability in statistical procedures. The initial phase involved testing statistical assumptions, including the Shapiro–Wilk test for normality, Levene's test for homogeneity of variances, and Box's M test for homogeneity of covariance matrices as prerequisites for multivariate analysis (Wara et al., 2025). After confirming that all assumptions were met, the data were analyzed using Multivariate Analysis of Variance (MANOVA) to examine the simultaneous effects of the instructional strategy on both dependent variables. This technique was selected because it allows for the evaluation of multiple dependent variables within a single analytical model. To further explore the specific effects on each variable, follow-up analyses were conducted using tests of between-subjects effects. Additionally, effect sizes were reported using partial eta squared to provide a more comprehensive interpretation of the magnitude of the treatment effects beyond statistical significance.

Ethical considerations were carefully addressed throughout the research process. Participation was voluntary, and informed consent was obtained from all participants prior to data collection. Students were assured that their responses would remain confidential and would be used solely for research purposes. Anonymity was maintained by assigning codes to participants instead of using identifiable personal information. Furthermore, the research was conducted in accordance with academic integrity principles, ensuring that all procedures respected participants' rights and did not interfere with their regular learning activities.

RESULTS AND DISCUSSION

Results

This section presents the primary findings of the study, which were derived from the quasi-experimental implementation of discovery learning-based asynchronous modules in comparison with conventional expository instruction. The results are organized systematically to highlight both descriptive and inferential aspects of the data, including the distribution of learning engagement and knowledge construction scores, the outcomes of prerequisite statistical tests, and the results of multivariate and univariate analyses. Furthermore, this section provides a comprehensive examination of how the instructional intervention influenced students' engagement levels and their ability to construct knowledge in an asynchronous learning environment. Taken together, the findings demonstrate that structured discovery-oriented learning, supported by digital platforms, can enhance both cognitive and behavioral dimensions of student learning. These results offer empirical evidence that pedagogically designed asynchronous learning environments can move beyond procedural participation toward deeper intellectual engagement and meaningful knowledge construction.

Data Description and Prerequisite Testing

The initial analysis focused on describing the distribution of student scores across the two dependent variables, namely learning engagement and knowledge construction, in both the experimental and control groups. This descriptive analysis provides an overview of the comparative performance between groups prior to conducting inferential statistical testing. Table 1 presents the descriptive statistics of learning engagement and knowledge construction scores for both groups.

Table 1. Descriptive Statistics of Learning Engagement and Knowledge Construction Scores

Variable	Group	n	Mean ± SD	Min–Max	Category
Learning Engagement	Experimental	32	82.45 ± 6.12	68.54–94.53	High
Learning Engagement	Control	32	70.10 ± 7.45	57.04–84.09	Medium
Knowledge Construction	Experimental	32	85.20 ± 5.89	73.21–98.47	High
Knowledge Construction	Control	32	72.35 ± 8.10	59.77–90.79	Medium

As shown in Table 1, the experimental group achieved higher mean scores than the control group across both variables. In terms of learning engagement, the experimental group reached a high category, while the control group remained in the medium category. This indicates that students exposed to the discovery learning-based modules demonstrated stronger attention, persistence, participation, and cognitive engagement during the learning process. A similar pattern is observed in the knowledge construction variable, where the experimental group also outperformed the control group. The higher scores in this variable suggest that students in the experimental group were more capable of producing structured, analytical, and integrative outputs. Their digital artifacts reflected deeper reasoning, more coherent argumentation, and more mature processing of information compared to those produced by students in the control group.

Before conducting hypothesis testing, prerequisite statistical analyses were performed to ensure that the data met the assumptions required for multivariate analysis. These tests included normality, homogeneity of variance, and homogeneity of covariance matrices. Table 2 summarizes the results of the prerequisite assumption tests.

Table 2. Summary of Prerequisite Analysis Test

Assumption	Indicators	Statistics	p	Decision
Normality	Learning Engagement (Experimental)	W = 0.987	0.964	Normal
Normality	Learning Engagement (Control)	W = 0.965	0.377	Normal
Normality	Knowledge Construction (Experimental)	W = 0.979	0.772	Normal
Normality	Knowledge Construction (Control)	W = 0.953	0.179	Normal
Homogeneity of Variance	Levene Learning Engagement	F = 1.509	0.224	Homogeneous
Homogeneity of Variance	Levene Knowledge Construction	F = 3.552	0.064	Homogeneous
Homogeneity of Covariance Matrix	Box's M	M = 5.168	0.173	Homogeneous

The results in Table 2 indicate that all statistical assumptions required for MANOVA were satisfied. The Shapiro–Wilk test shows that all data distributions are normal, as evidenced by significance values greater than 0.05. Similarly, Levene's test confirms that the variance between groups is homogeneous for both dependent variables. In addition, the Box's M test indicates that the covariance matrices are also homogeneous. These findings confirm that the dataset meets the necessary conditions for conducting multivariate analysis, thereby ensuring the validity and robustness of subsequent hypothesis testing.

Hypothesis Test Results

Following the confirmation of statistical assumptions, hypothesis testing was conducted using Multivariate Analysis of Variance (MANOVA) to examine the simultaneous effect of the instructional strategy on both learning engagement and knowledge construction. Table 3 presents the results of the multivariate MANOVA analysis.

Table 3. Multivariate MANOVA Test Results

Effect	Value	F	df Hypothesis	df Error	Decision
Pillai's Trace	0.520	33.006	2	61	Significant
Wilks' Lambda	0.480	33.006	2	61	Significant

As shown in Table 3, the multivariate test results indicate a statistically significant effect of the discovery learning strategy on the combined dependent variables. The Pillai's Trace value of 0.520 and Wilks' Lambda of 0.480, with $F(2,61) = 33.006$ and $p < 0.001$, demonstrate that the differences between the experimental and control groups are statistically significant. These findings suggest that the observed differences did not occur by chance but are associated with the instructional treatment applied. Furthermore, the magnitude of the Pillai's Trace value indicates that a substantial proportion of the variance in learning engagement and knowledge construction can be explained by the treatment. Thus, the overall hypothesis that discovery learning has a significant multivariate effect is supported.

To obtain a more detailed understanding of the treatment effects on each dependent variable, further analysis was conducted using tests of between-subjects effects. Table 4 presents the results of these follow-up analyses, including effect size measurements.

Table 4. Tests of Between-Subjects Effects and Effect Influence

Dependent Variable	JK Galat	Mean Square	F	p	Partial η^2	Cohen's d
Learning Engagement	2881.664	2440.360	52.505	< 0.001	0.459	1.812
Knowledge Construction	3109.365	2641.960	52.680	< 0.001	0.459	1.815

The results in Table 4 show that the discovery learning strategy has a statistically significant effect on each dependent variable. For learning engagement, the F value of 52.505 with $p < 0.001$ indicates a significant difference between the experimental and control groups. Similarly, for knowledge construction, the F value of 52.680 with $p < 0.001$ confirms a significant treatment effect. These findings demonstrate that the instructional strategy contributes meaningfully to differences in both engagement and knowledge construction outcomes.

In addition to statistical significance, the magnitude of the treatment effect is also substantial. The partial eta squared value of 0.459 for both variables indicates a large effect size, suggesting that approximately 45.9% of the variance in each dependent variable can be attributed to the instructional treatment. This is further supported by the Cohen's d values of 1.812 and 1.815, which fall within the category of very large effects. These results indicate that the discovery learning strategy is not only statistically effective but also practically impactful in improving student engagement and enhancing knowledge construction in asynchronous online learning environments.

Discussion

The findings of this study indicate that the implementation of discovery learning in asynchronous online environments significantly enhances students' learning engagement. This result suggests that instructional designs that position learners as active agents rather than passive recipients can effectively transform the nature of student participation. Conceptually, this aligns with the construct of multidimensional engagement, which encompasses behavioral, emotional, and cognitive involvement in learning (Martin & Borup, 2022; Wong & Liem, 2022). The structured stages of discovery learning, beginning from problem stimulation to knowledge generalization, create a continuous cognitive demand that sustains student attention and persistence. This finding supports recent research emphasizing that engagement in asynchronous settings is highly dependent on task design rather than platform presence (Khatter et al., 2024; Soydan Oktay & Yüzer, 2024). Compared to previous studies that reported low engagement due to passive learning structures (Cain et al., 2024; Fabriz et al., 2021), this study demonstrates that engagement can be substantially improved when learning is framed as an inquiry-driven process. Thus, the effectiveness of discovery learning in this context extends existing theories by showing its applicability in fully asynchronous environments, which traditionally suffer from reduced interaction.

A deeper analysis reveals that the increase in engagement is not merely behavioral but also involves emotional and cognitive dimensions. Students in the experimental group demonstrated higher levels of curiosity, sustained effort, and willingness to engage with complex tasks, indicating the activation of intrinsic motivational processes. From a theoretical standpoint, this finding reinforces the argument that meaningful engagement emerges when learners perceive relevance and autonomy in learning activities (Chen et al., 2018; Lan & Hew, 2020). The integration of contextual problems at the beginning of each module appears to play a critical role in triggering emotional involvement, which subsequently supports cognitive engagement. This result is consistent with findings by Zakiyyah and Abdullah (2025), who highlight the importance of challenge and meaningful task design in increasing engagement. However, unlike prior studies that primarily focused on synchronous interaction, this research shows that emotional engagement can also be cultivated in asynchronous contexts through well-structured learning pathways. Therefore, the study contributes to expanding the conceptual understanding of engagement by demonstrating that emotional and cognitive involvement can be sustained without real-time interaction.

The role of digital scaffolding in supporting engagement also emerges as a significant factor in this study. The presence of guided steps within the discovery learning framework helps students navigate complex tasks without losing autonomy, thereby balancing structure and independence. This finding is consistent with the theory of guided discovery, which posits that structured support enhances learning effectiveness compared to unguided exploration (Hatip & Setiawan, 2021; Alanazi et al., 2024). In asynchronous environments, where the absence of immediate feedback can hinder learning, scaffolding becomes even more critical to maintain continuity in cognitive processes. Previous research has emphasized that poorly designed asynchronous learning often leads to student disorientation and disengagement (Moorhouse & Wong, 2022; Varkey et al., 2023). The present study provides empirical evidence that digital scaffolding embedded within LMS-based modules can mitigate these issues. This suggests that the effectiveness of asynchronous learning is not determined solely by learner autonomy but by how that autonomy is structured within a coherent pedagogical design.

In addition to engagement, the study demonstrates that discovery learning significantly enhances students' knowledge construction. The higher quality of digital artifacts produced by the experimental group indicates that students were able to engage in deeper cognitive processing, including analysis, synthesis, and argumentation. This finding aligns with constructivist theory, which views learning as an active process of meaning-making through interaction with information and prior knowledge (Cakir, 2022; Saleem et al., 2021). The structured inquiry process in discovery learning encourages students to move beyond surface-level understanding toward more complex knowledge structures. This is consistent with recent studies showing that discovery-oriented learning promotes higher-order thinking and problem-solving skills (Ena et al., 2024; Lethulur et al., 2025). Compared to conventional expository approaches that often emphasize information transmission, the discovery learning model fosters a more generative form of learning. Therefore, the findings reinforce the theoretical claim that knowledge construction is optimized when learners actively engage in inquiry-based activities.

Furthermore, the findings highlight that the improvement in knowledge construction is closely related to the nature of the learning tasks. When tasks are designed as a sequence of discovery activities culminating in knowledge products, students are encouraged to elaborate, verify, and generalize information. This supports the argument that meaningful learning in asynchronous environments depends on the quality of task design rather than the technological medium itself (Berestok, 2021; Dama, 2024). Previous studies have criticized online learning for promoting content reproduction rather than knowledge creation (Duran, 2020). The present study challenges this assumption by demonstrating that asynchronous learning can facilitate deep learning when tasks require students to integrate multiple sources and construct arguments. This finding extends the literature by showing that knowledge construction in online learning is not inherently limited but can be enhanced through appropriate pedagogical strategies. Consequently, this research contributes to redefining the potential of asynchronous learning as a space for intellectual development rather than mere content delivery.

From a broader perspective, the study also underscores the importance of instructional design in determining the effectiveness of asynchronous learning environments. The integration of discovery learning within an LMS context transforms the platform from a content repository into an interactive learning environment that supports inquiry and knowledge construction. This aligns with the concept of cognitive presence in online learning, which emphasizes the importance of structured inquiry processes in fostering meaningful learning experiences (Sadaf et al., 2021). Previous research has shown that many LMS implementations fail to achieve this due to a lack of pedagogical alignment (Ho, 2024; Mansour, 2024). The present findings provide empirical support for the argument that instructional design, rather than technology alone, is the key determinant of learning quality. This insight has practical implications for educators, suggesting that the effectiveness of digital learning environments depends on how learning activities are structured and sequenced.

Despite these contributions, the findings must be interpreted within the context of certain limitations. The study was conducted within a single institutional setting with a relatively homogeneous sample, which may limit the generalizability of the results to other educational contexts. Additionally, the focus on asynchronous learning did not include comparisons with synchronous or blended modalities, which may yield different patterns of engagement and knowledge construction (Alhazbi & Hasan, 2021; Eggers et al., 2021). Another limitation relates to the measurement of learning outcomes, which relied primarily on observable artifacts and engagement indicators, potentially overlooking deeper metacognitive processes. These limitations suggest that the observed effects may be influenced by contextual and methodological factors. Therefore, while the findings provide strong evidence of effectiveness, further research is needed to validate and extend these results across diverse settings and methodological approaches.

In conclusion, this study contributes to the growing body of literature on asynchronous learning by demonstrating that discovery learning can effectively enhance both engagement and knowledge construction. The findings extend existing theories by showing that inquiry-based learning is not only applicable but also highly effective in asynchronous contexts, provided that it is supported by structured scaffolding and meaningful task design. This research offers a conceptual contribution by integrating engagement and knowledge construction within a unified analytical framework, highlighting their interdependence in determining learning quality. Practically, the study provides actionable insights for educators in designing asynchronous learning environments that promote deep, reflective, and student-centered learning. Ultimately, the findings position discovery learning as a viable strategy for transforming asynchronous education into a more meaningful and cognitively engaging experience.

CONCLUSION

This study concludes that the implementation of discovery learning in asynchronous online environments has a positive and statistically significant effect on students' learning engagement and knowledge construction. Students exposed to discovery-based modules demonstrated higher levels of active participation, sustained persistence, and deeper cognitive engagement compared to those in conventional expository settings, which was further reflected in the superior quality of their learning artifacts, characterized by stronger analytical depth, systematic organization, and meaningful integration of concepts with real-world contexts. These findings confirm that asynchronous learning can move beyond procedural task completion toward reflective and meaningful learning when it is supported by inquiry-oriented instructional design. Theoretically, this study extends constructivist perspectives by demonstrating that knowledge is more effectively constructed through processes of exploration, interpretation, and synthesis rather than passive information reception, particularly in environments that demand high learner autonomy. Practically, the results emphasize the importance of designing asynchronous learning that incorporates contextual problem triggers, structured inquiry phases, and adaptive digital scaffolding, enabling educators to facilitate deeper engagement and more robust knowledge construction, thereby transforming online learning into a cognitively rich and student-centered experience.

AUTHOR CONTRIBUTIONS STATEMENT

Novianto Puji Raharjo conceived and designed the research, led the implementation of the Participatory Action Research activities in the field, conducted data collection, and prepared the initial draft of the manuscript. Mohammad Rofiuddin contributed to the development of the research methodology, assisted in data analysis and interpretation, and provided critical revisions to improve the clarity and academic quality of the manuscript.

REFERENCES

Alanazi, A. A., Osman, K., & Halim, L. (2024). Effect of scaffolding strategies and guided discovery on higher-order thinking skills in physics education. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(9), em2496. https://doi.org/10.29333/ejmste/14980

Alanazi, A. A., Osman, K., & Halim, L. (2025). Development of technology-enhanced higher order thinking learning module based on scaffolding and guided discovery approaches. In *2024 Yearbook Emerging Technologies in Learning* (pp. 485-509). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-80388-8_26

AlGerafi, M. A. M., Zhou, Y., Oubibi, M., & Wijaya, T. T. (2023). Unlocking the Potential: A Comprehensive Evaluation of Augmented Reality and Virtual Reality in Education. *Electronics*, *12*(18). https://doi.org/10.3390/electronics12183953

Alhazbi, S., & Hasan, M. A. (2021). The Role of Self-Regulation in Remote Emergency Learning: Comparing Synchronous and Asynchronous Online Learning. *Sustainability*, *13*(19). https://doi.org/10.3390/su131911070

Arghode, V., Brieger, E., & Wang, J. (2018). Engaging instructional design and instructor role in online learning environment. *European Journal of Training and Development*, *42*(7–8), 366–380. https://doi.org/10.1108/EJTD-12-2017-0110

Barkley, E. F., & Major, C. H. (2020). *Student Engagement Techniques: A Handbook for College Faculty*. John Wiley & Sons.

Bean, J. C., & Melzer, D. (2021). *Engaging Ideas: The Professor's Guide to Integrating Writing, Critical Thinking, and Active Learning in the Classroom*. John Wiley & Sons.

Brau, B. (2016). *Constructivism*. https://pressbooks.pub/ipthandbook/chapter/constructivism/

Cain, M., Sheehan, H., & Taouk, S. (2024). "It doesn't feel like we've had the chance to really connect". The crucial need for social presence in fully asynchronous teacher education. *Teaching and Teacher Education*, *152*, 104789. https://doi.org/10.1016/j.tate.2024.104789

Cakir, M. (2022). Constructivist approaches to learning in science and their implications for science pedagogy: A literature review. *International Journal of Environmental and Science Education*.

Chen, B., Chang, Y.-H., Ouyang, F., & Zhou, W. (2018). Fostering student engagement in online discussion through social learning analytics. *The Internet and Higher Education*, *37*, 21–30. https://doi.org/10.1016/j.iheduc.2017.12.002

Cheung, S. K. S., Kwok, L. F., Phusavat, K., & Yang, H. H. (2021). Shaping the future learning environments with smart elements: Challenges and opportunities. *International Journal of Educational Technology in Higher Education*, *18*(1), 16. https://doi.org/10.1186/s41239-021-00254-1

Chusni, M. M., Saputro, S., Suranto, & Rahardjo, S. B. (2020). The potential of discovery learning models to empower students' critical thinking skills. *Journal of Physics: Conference Series*, *1464*(1), 012036. https://doi.org/10.1088/1742-6596/1464/1/012036

Collıns, K., Groff, S., Mathena, C., & Kupczynskı, L. (2019). Asynchronous Video and the Development of Instructor Social Presence and Student Engagement. *Turkish Online Journal of Distance Education*, *20*(1), 53–70. https://doi.org/10.17718/tojde.522378

Conrad, D., & Openo, J. (2018). *Assessment Strategies for Online Learning: Engagement and Authenticity*. Athabasca University Press. https://doi.org/10.15215/aupress/9781771992329.01

Czerkawski, B. C., & Lyman, E. W. (2016). An Instructional Design Framework for Fostering Student Engagement in Online Learning Environments. *TechTrends*, *60*(6), 532–539. https://doi.org/10.1007/s11528-016-0110-z

de-Marcos, L., Garcia-Lopez, E., & Garcia-Cabot, A. (2016). On the effectiveness of game-like and social approaches in learning: Comparing educational gaming, gamification & social networking. *Computers & Education*, *95*, 99–113. https://doi.org/10.1016/j.compedu.2015.12.008

Eggers, J. H., Oostdam, R., & Voogt, J. (2021). Self-regulation strategies in blended learning environments in higher education: A systematic review. *Australasian Journal of Educational Technology*, *37*(6), 175–192. https://doi.org/10.14742/ajet.6453

El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*, *18*(1), 53. https://doi.org/10.1186/s41239-021-00289-4

Ena, T. A. B., Tangi, H. C., & Lawung, Y. D. (2024). Analysis of Learning Outcomes of Buffer Solution Materials through the Discovery Learning Approach in Vocational High Schools. *Journal of Social Studies Arts and Humanities (JSSAH)*, *4*(3), 098. https://doi.org/10.33751/jssah.v4i3.12835

Fabriz, S., Mendzheritskaya, J., & Stehle, S. (2021). Impact of Synchronous and Asynchronous Settings of Online Teaching and Learning in Higher Education on Students' Learning Experience During COVID-19. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.733554

Galikyan, I., & Admiraal, W. (2019). Students' engagement in asynchronous online discussion: The relationship between cognitive presence, learner prominence, and academic performance. *The Internet and Higher Education*, *43*, 100692. https://doi.org/10.1016/j.iheduc.2019.100692

Hew, K. F. (2016). Promoting engagement in online courses: What strategies can we learn from three highly rated MOOCS. *British Journal of Educational Technology*, *47*(2), 320–341. https://doi.org/10.1111/bjet.12235

Hilton, J. (2016). Open educational resources and college textbook choices: A review of research on efficacy and perceptions. *Educational Technology Research and Development*, *64*(4), 573–590. https://doi.org/10.1007/s11423-016-9434-9

Ho, Y. (2024). Enhance adult students' online knowledge construction: Exploring effective instructional designs and addressing barriers. *Journal of Computer Assisted Learning*, *40*(4), 1675–1689. https://doi.org/10.1111/jcal.12983

Kahn, P., Everington, L., Kelm, K., Reid, I., & Watkins, F. (2017). Understanding student engagement in online learning environments: The role of reflexivity. *Educational Technology Research and Development*, *65*(1), 203–218. https://doi.org/10.1007/s11423-016-9484-z

Lan, M., & Hew, K. F. (2020). Examining learning engagement in MOOCs: A self-determination theoretical perspective using mixed method. *International Journal of Educational Technology in Higher Education*, *17*(1), 7. https://doi.org/10.1186/s41239-020-0179-5

Lee, L. (2021). Exploring Self-Regulated Learning Through Flipped Instruction with Digital Technologies: An Intermediate Spanish Course. In *Language Education in Digital Spaces: Perspectives on Autonomy and Interaction* (pp. 39–59). Springer, Cham. https://doi.org/10.1007/978-3-030-74958-3_3

Lethulur, N. D., Juandi, D., & Dahlan, J. A. (2025). The Effectiveness of Discovery, Inquiry, Problem, and Project-Based Learning in Mathematics Education: A Systematic Literature Review. *Jurnal Pendidikan MIPA*, *26*(1), 268–279. https://doi.org/10.23960/jpmipa.v26i1.pp268-279

Li, K. C., & Wong, B. T. (2025). Agile-Blended Learning: An Innovative Technology-Mediated Approach to Distance Education. *SN Computer Science*, *6*(2), 127. https://doi.org/10.1007/s42979-024-03646-y

Mansour, N. (2024). Students' and facilitators' experiences with synchronous and asynchronous online dialogic discussions and e-facilitation in understanding the Nature of Science. *Education and Information Technologies*, *29*(12), 15965–15997. https://doi.org/10.1007/s10639-024-12473-w

Marougkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023). Virtual Reality in Education: A Review of Learning Theories, Approaches and Methodologies for the Last Decade. *Electronics*, *12*(13). https://doi.org/10.3390/electronics12132832

Martin, F., & Borup, J. (2022). Online learner engagement: Conceptual definitions, research themes, and supportive practices. *Educational Psychologist*, *57*(3), 162–177. https://doi.org/10.1080/00461520.2022.2089147

Mcguire, M. (2026). Reclaiming pedagogy in virtual learning environments: Educator and student perspectives. *Teaching in Higher Education*, *0*(0), 1–21. https://doi.org/10.1080/13562517.2026.2614964

Moorhouse, B. L., & Wong, K. M. (2022). Blending asynchronous and synchronous digital technologies and instructional approaches to facilitate remote learning. *Journal of Computers in Education*, *9*(1), 51–70. https://doi.org/10.1007/s40692-021-00195-8

Nadjamuddin, L., Rore, I., Mahmud, J., Zaky, M., Tadeko, N., & Nirmala, B. (2026). Effectiveness of Hybrid Discovery Learning in Enhancing Students' Comprehension and Critical Thinking Skills. *International Journal of Interactive Mobile Technologies*, *20*(1). https://doi.org/10.3991/ijim.v20i01.57485

Nikolopoulou, K. (2023). Self-Regulated and Mobile-Mediated Learning in Blended Tertiary Education Environments: Student Insights from a Pilot Study. *Sustainability*, *15*(16). https://doi.org/10.3390/su151612284

Nückles, M., Roelle, J., Glogger-Frey, I., Waldeyer, J., & Renkl, A. (2020). The Self-Regulation-View in Writing-to-Learn: Using Journal Writing to Optimize Cognitive Load in Self-Regulated Learning. *Educational Psychology Review*, *32*(4), 1089–1126. https://doi.org/10.1007/s10648-020-09541-1

Okoye, K., Rodriguez-Tort, J. A., Escamilla, J., & Hosseini, S. (2021). Technology-mediated teaching and learning process: A conceptual study of educators' response amidst the Covid-19 pandemic. *Education and Information Technologies*, *26*(6), 7225–7257. https://doi.org/10.1007/s10639-021-10527-x

Osborne, D. M., Byrne, J. H., Massey, D. L., & Johnston, A. N. B. (2018). Use of online asynchronous discussion boards to engage students, enhance critical thinking, and foster staff-student/student-student collaboration: A mixed method study. *Nurse Education Today*, *70*, 40–46. https://doi.org/10.1016/j.nedt.2018.08.014

Ouyang, F., & Chang, Y.-H. (2019). The relationships between social participatory roles and cognitive engagement levels in online discussions. *British Journal of Educational Technology*, *50*(3), 1396–1414. https://doi.org/10.1111/bjet.12647

Ozdem-Yilmaz, Y., & Bilican, K. (2025). Discovery Learning—Jerome Bruner. In B. Akpan & T. J. Kennedy (Eds.), *Science Education in Theory and Practice: An Introductory Guide to Learning Theory* (pp. 173–187). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-81351-1_11

Rienties, B., Lewis, T., McFarlane, R., Nguyen, Q., & Toetenel, L. (2018). Analytics in online and offline language learning environments: The role of learning design to understand student online engagement. *Computer Assisted Language Learning*, *31*(3), 273–293. https://doi.org/10.1080/09588221.2017.1401548

Simamora, R. E., Saragih, S., & Hasratuddin. (2019). Improving Students' Mathematical Problem Solving Ability and Self-Efficacy through Guided Discovery Learning in Local Culture Context. *International Electronic Journal of Mathematics Education*, *14*(1), 61–72. https://doi.org/10.12973/iejme/3966

Siregar, T. (2025). *The Effectiveness of the Discovery Learning Model in Enhancing Students' Mathematical Problem-Solving Skills* (No. 2025101549). Preprints. https://doi.org/10.20944/preprints202510.1549.v1

Soydan Oktay, Ö., & Yüzer, T. V. (2024). The analysis of interactive scenario design principles supporting critical and creative thinking in asynchronous learning environments. *Interactive Learning Environments*, *32*(8), 4183–4204. https://doi.org/10.1080/10494820.2023.2195443

Van Laer, S., & Elen, J. (2017). In search of attributes that support self-regulation in blended learning environments. *Education and Information Technologies*, *22*(4), 1395–1454. https://doi.org/10.1007/s10639-016-9505-x

Varkey, T. C., Varkey, J. A., Ding, J. B., Varkey, P. K., Zeitler, C., Nguyen, A. M., Merhavy, Z. I., & Thomas, C. R. (2022). Asynchronous learning: A general review of best practices for the 21st century. *Journal of Research in Innovative Teaching & Learning*, *16*(1), 4–16. https://doi.org/10.1108/JRIT-06-2022-0036

Vlachopoulos, D., & Makri, A. (2019). Online communication and interaction in distance higher education: A framework study of good practice. *International Review of Education*, *65*(4), 605–632. https://doi.org/10.1007/s11159-019-09792-3

Wong, Z. Y., & Liem, G. A. D. (2022). Student Engagement: Current State of the Construct, Conceptual Refinement, and Future Research Directions. *Educational Psychology Review*, *34*(1), 107–138. https://doi.org/10.1007/s10648-021-09628-3

Zajda, J. (2021). Constructivist Learning Theory and Creating Effective Learning Environments. In J. Zajda (Ed.), *Globalisation and Education Reforms: Creating Effective Learning Environments* (pp. 35–50). Springer International Publishing. https://doi.org/10.1007/978-3-030-71575-5_3

Zydney, J. M., Warner, Z., & Angelone, L. (2020). Learning through experience: Using design based research to redesign protocols for blended synchronous learning environments. *Computers & Education*, *143*, 103678. https://doi.org/10.1016/j.compedu.2019.103678