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Virtual Learning Ecosystems and Their Influence on Collaborative Knowledge Construction

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ABSTRACT

This study examines virtual learning ecosystems and their influence on collaborative knowledge construction in technology-enhanced education. The study aimed to analyze how digital platform quality, interaction intensity, and learner engagement affect students' collaborative knowledge construction. A quantitative survey was conducted with 180 undergraduate students who had participated in virtual learning for at least one semester. Data were collected through a structured questionnaire and analyzed using descriptive statistics and multiple regression. The findings showed that virtual learning ecosystems positively influenced collaborative knowledge construction. Interaction intensity and learner engagement were the strongest contributing factors. Students with accessible platforms, structured resources, and active peer communication showed better idea negotiation, shared problem-solving, and collective meaning-making. This study highlights the importance of designing effective virtual learning ecosystems to support collaborative digital learning.

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INTRODUCTION

The development of educational technology has driven major changes in the way learners access information, interact, and build knowledge. Learning is no longer limited to physical classrooms, but is evolving into a virtual ecosystem that integrates digital platforms, online learning resources, discussion forums, video conferencing, and learning management systems. In this ecosystem, technology not only functions as an aid, but also as a pedagogical space that shapes students' learning experiences, communication patterns, and academic engagement. The digital transformation of education requires institutions to ensure that technology is used in a directional, inclusive, and aligned manner with learning goals. OECD (2025) emphasizes that digital technology can support engagement, collaboration, and independent learning if applied through proper pedagogical alignment. McCarthy et al. (2023) also emphasized that the digital transformation of education requires systemic leadership, teacher capacity, infrastructure, and a culture of innovation so that technological changes truly impact the quality of learning.

In the context of higher education, virtual learning ecosystems act as social-cognitive spaces that allow students to discuss, share ideas, solve problems, and generate mutual understanding. The virtual ecosystem provides opportunities for students to interact synchronously and asynchronously, so that the learning process can take place more flexibly. However, this flexibility needs to be balanced with a learning design that is able to maintain the depth of student interaction and involvement. Matee et al. (2023) found that virtual collaborative learning in higher education provides opportunities for broader academic interaction, but still faces challenges on technology readiness, student participation, and the quality of institutional support. Du and Ibrahim (2025) add that the use of social media in collaborative learning can expand the space for knowledge sharing, but its effectiveness is highly dependent on activity design, communication rules, and clear academic goals.

Previous studies have shown that online collaborative learning can improve learning outcomes if supported by quality interactions. Meaningful digital interaction is characterized not only by the intensity of communication, but also by the ability of students to build arguments, give feedback, clarify ideas, and draw conclusions together. Qafzezi et al. (2024) explain that productive feedback and targeted online interaction can strengthen a supportive learning atmosphere and encourage student success in higher education. Shanzey (2025) also shows that online collaborative learning through digital platforms contributes to the improvement of students' communication skills, especially when learning is designed to encourage active participation and group cooperation. Thus, the quality of interaction is an important dimension in assessing the success of the virtual learning ecosystem.

The research gap is also seen in the study of collaborative task design in the digital environment. Much virtual learning still focuses on the distribution of materials and the collection of assignments, while the process of negotiating ideas, group reflection, and building shared knowledge has not always been central to learning activities. Janah (2024) found that the use of social media in collaborative learning can support online knowledge sharing and student academic performance if directed through clear and structured activities. Sergeeva et al. (2025) through meta-analysis also showed that mobile-supported collaborative learning has a positive effect, although it still requires a strong pedagogical design so that collaboration does not stop at the use of devices. These findings suggest that research on virtual learning ecosystems needs to pay attention to the integration between platforms, activities, learning regulations, and interaction support.

In the Indonesian context, the development of digital learning still faces challenges in the form of access gaps, variations in lecturer readiness, and differences in students' ability to utilize technology for collaborative learning. This challenge is increasingly complex because higher education needs to balance the demands of learning flexibility with the need to maintain academic quality. Butarbutar et al. (2023) show that online collaborative learning provides space for flexible learning practices through group projects, digital interactions, and peer feedback. Aulia et al. (2024) also emphasized that online collaborative learning is a complex process that requires careful planning, design, implementation, and evaluation so that social, pedagogical, and technological aspects can support each other. Therefore, the development of a virtual ecosystem needs to be directed at learning that is not only accessible, but also able to form productive academic interactions.

Based on this description, this study aims to analyze the influence of virtual learning ecosystems on collaborative knowledge construction in technology-based learning. The research focus is directed at the relationship between the quality of the virtual learning environment, the intensity of interaction, learner engagement, and the formation of shared knowledge. Theoretically, this research contributes to the development of educational technology studies, especially in explaining the relationship between digital ecosystems and collaborative knowledge construction. Practically, this research can be a reference for lecturers, platform developers, and educational institutions in designing virtual learning that is more interactive, participatory, and oriented towards meaningful collaboration. Aldalalah (2025) shows that interactive digital content based on TPACK can improve students' cognitive achievements and skills. Fonseca (2024) added that collaborative learning ecosystems can strengthen communities of practice through social relationships, exchange of experiences, and joint knowledge production in the digital space.

LITERATURE REVIEW

Virtual Learning Ecosystems in Educational Technology

Virtual learning ecosystems are digital learning environments that integrate platforms, learning resources, social interactions, pedagogical activities, and technological support in one interconnected learning system. In educational technology, the virtual ecosystem not only functions as a space for delivering materials, but also as a system that forms the pattern of communication, participation, and knowledge production of students. This ecosystem is increasingly important as modern learning demands flexibility, accessibility, and cross-spatial collaboration. Rojas and Chiappe (2024) explain that the education digital ecosystem needs to be understood as a complex network that connects technology, users, data, and learning processes. Meanwhile, Zou et al. (2025) emphasized that 21st-century digital learning is evolving through the integration of artificial intelligence, virtual learning, learning analytics, and adaptive learning design.

Collaboration as the Basis for Knowledge Construction

Collaborative knowledge construction is rooted in the view of social constructivism which places interaction as the main process in knowledge formation. In virtual learning, students build understanding through discussion, negotiation of meaning, exchange of arguments, joint problem-solving, and group reflection. Oyarzun and Martin (2023) show that online learner collaboration supports the development of knowledge and skills through technology design, facilitation, and targeted social interaction. In line with that, Lin (2022) emphasized that the quality of interaction is an important indicator in assessing collaborative knowledge construction because not all digital communication produces meaningful academic understanding.

Quality of Interaction in Virtual Learning

The quality of interaction is the main factor that determines the success of the virtual learning ecosystem. Quality interaction is not only seen from the frequency of communication, but also from the depth of the discussion, the relevance of the contribution, the clarity of argumentation, and the ability of students to build ideas gradually. Bach et al. (2024) found that the quality of digital interaction in collaborative learning is related to student learning outcomes and satisfaction. In another context, Alsayer (2023) shows that students' experiences in an online international collaborative environment are influenced by synchronous and asynchronous forms of communication, readiness to participate, and the ability to manage differences of views in discussions.

Activity Design and Collaborative Learning Structure

The design of learning activities determines whether the virtual ecosystem is able to encourage students to collaborate actively or just complete individual assignments. A good collaborative activity should have a clear purpose, division of roles, stages of work, discussion space, and an end product that demands mutual contribution. Reyes (2025) emphasized that the design of collaborative activities in higher education needs to consider the learning context, pedagogical strategies, supporting technologies, and forms of evaluation. In addition, Marnola et al. (2025) show that the project-based collaborative online learning

model based on asynchronous discussion forums can help direct lecturers as facilitators and students as active learners in the process of compiling common knowledge.

Student Engagement in the Virtual Ecosystem

Learner engagement is an important component in virtual learning ecosystems because involvement determines the intensity of students in accessing materials, discussing, responding to friends' ideas, and completing group assignments. Engagement is not only behavioral, but also includes cognitive, emotional, and social aspects. Hu et al. (2025) explain that engagement in online learning is influenced by motivation, digital literacy, emotions, self-regulation, task characteristics, digital platforms, collaboration, and interaction. Deng et al. (2025) also show that the effectiveness of online learning is related to the ability of educators to understand the factors that affect student engagement, especially in a learning environment that demands independence and active participation.

The Role of Lecturer Facilitation in Knowledge Construction

In virtual learning, lecturers play the role of facilitators who direct discussions, provide feedback, prepare assignments, and maintain the quality of academic interactions. Without clear facilitation, online forums can turn into superficial conversations that do not result in knowledge construction. Hackett et al. (2024) emphasized that collaborative online international learning requires collaboration between lecturers across institutions, joint assignment design, and facilitation that is able to connect students in cross-cultural learning experiences. Meanwhile, Theelen and Dirkx (2025) explained that the success of blended education is greatly influenced by lecturers' understanding of learning design principles, the use of online learning environments, and the ability to integrate technology with pedagogy.

Self-Regulation and Technology Support in Collaborative Learning

Collaborative knowledge construction in a virtual ecosystem requires the ability to self-regulate, group regulation, and adequate technological support. Students need to manage time, manage contributions, monitor understanding, and adjust learning strategies during the collaboration process. Younas et al. (2025) show that technology-enabled blended learning can strengthen students' knowledge construction and academic motivation. In addition, Wu et al. (2024) found that the use of ChatGPT-based Intelligent Learning Aid can support the advancement of self-regulation and knowledge construction in blended learning through fast and contextual information assistance.

Knowledge Work Competencies in Higher Education

Virtual learning ecosystems also play a role in shaping the knowledge work competencies needed by students in higher education. This competency includes the ability to understand information, create knowledge, use digital tools, collaborate, and manage academic work processes independently and collectively. Muukkonen et al. (2022) explained that knowledge work competence includes students' ability to understand and create knowledge, orchestrate collaboration, and carry out self-regulation and mutual regulation. Tuononen et al. (2025) also emphasized that the development of generic skills in

higher education is closely related to the way lecturers understand, teach, and evaluate the competencies needed by students in academic and professional contexts.

Sintesis Literature Review

Based on the literature review, virtual learning ecosystems can be understood as a digital environment that combines technology, pedagogy, social interaction, student involvement, lecturer facilitation, and learning regulatory support. This ecosystem has an important influence on collaborative knowledge construction because knowledge is not formed individually, but through social processes that involve discussion, negotiation, argumentation, and the elaboration of common meaning. Purbasari et al. (2025) show that the social collaborative e-learning model can improve the cognitive, behavioral, and emotional adaptability of students in higher education. Quintero et al. (2024) added that the flow experience in computer-supported collaborative learning needs to be considered because the flow of activities, technology support, and collaborative experiences affect the quality of group learning.

METHODOLOGY

This study uses a quantitative approach with a correlational descriptive design to examine the influence of virtual learning ecosystems on collaborative knowledge construction in students. The quantitative approach was chosen because the focus of the study is to measure the relationships between statistically analyzeable variables and generate generalizations of the population studied (Liu et al., 2023). The correlational descriptive design is in accordance with the research objectives that want to determine the influence of the quality of the virtual learning ecosystem, the intensity of interaction, and student involvement on the process of building common knowledge.

The research population consists of all undergraduate students at public and private universities who have participated in online learning for at least one semester. The sampling technique uses purposive sampling, which is to select respondents who have active experience in the virtual ecosystem and participate in collaborative learning activities, so that the data obtained is relevant to the research focus (Tee et al., 2022). The sample size was set at 180 students, in accordance with the recommendations of quantitative methods for correlation and regression analysis, taking into account the diversity of faculty backgrounds and semester levels to obtain adequate representation.

Data collection was carried out through a structured questionnaire, which was developed from previous research instruments on virtual learning ecosystems and collaborative knowledge construction (Chong et al., 2023; Yusoff et al., 2024). The questionnaire consists of four sections: quality of digital platforms, intensity of interaction, student engagement, and collaborative knowledge construction. The validity of the content was tested by three experts in the fields of educational technology and pedagogy, while the reliability of the instrument was tested using Cronbach's alpha test, with a value of ≥0.70 considered adequate for quantitative analysis.

The research procedure was carried out in stages. The initial stage is licensing and socialization to lecturers and students, followed by the distribution of questionnaires online through the university's official platform. The second stage is data collection for two weeks, with periodic reminders to increase response rates. The third stage is verification, data cleaning, and checking the completeness of the response before the analysis is carried out. All procedures are carried out with due regard to research ethics, including informant consent, anonymity, and data confidentiality (Rahman et al., 2022).

Data analysis was carried out using descriptive statistics to describe respondent characteristics and research variables, as well as multiple regression analysis to test the influence of virtual learning ecosystem quality, interaction intensity, and student involvement on collaborative knowledge construction. The analysis was carried out with SPSS software version 29 and SmartPLS 4 to strengthen the validity of the findings with the PLS-SEM approach, in accordance with the latest practice in quantitative research in the field of higher education (Gao et al., 2024; Wu & Lin, 2023). The results of the analysis were used to draw conclusions about the causal relationship between variables and practical implications for the development of the digital learning ecosystem.

With this methodology, research can systematically identify key factors in virtual learning ecosystems that support collaborative knowledge construction, as well as generate findings that can be published in reputable journals and used as a basis for developing digital learning strategies in universities.

RESEARCH RESULT

Respondent Characteristics

The research involved 180 students from various faculties, with 57% from science & technology, 43% from humanities & social. The average age is 20.8 years. Most of the respondents (102 people) were women and 78 were men. This distribution is quite representative for the analysis of relationships between variables.

Table 1. Respondent Characteristics

Features	Frequency	Percentage (%)
Faculty of Science & Technology	103	57
Faculty of Humanities & Social Sciences	77	43
Women	102	57
Male	78	43
Average Age	–	20,8

Quality of Virtual Ecosystems

Students assessed that the digital platform was easy to use, intuitive navigation, and communication features supported collaborative learning. The average score of ecosystem quality is 4.12. The highest items were related to accessibility (4.18) and material availability (4.15). The lowest item on AI integration for automated feedback (3.95).

Table 2. Average Virtual Ecosystem Quality Score

Quality Aspect	Average	Standard Deviation
Accessibility	4,18	0,50
Material Availability	4,15	0,52
Forum & Chat Features	4,10	0,55
AI & Automated Feedback	3,95	0,60

Intensity of Interaction

The average interaction intensity was 3.98. Students are active in forums, peer feedback, and project discussions. The distribution chart shows 60% high, 30% medium, 10% low. The highest analysis item related to the exchange of ideas (4.05), the lowest coordination of group tasks (3.88).

Table 3. Distribution of Student Interaction Intensity

Interaction Levels	Frequency	Percentage (%)
Height	108	60
Medium	54	30
Low	18	10

Student Engagement

Engagement includes behavioral, cognitive, and emotional. The average score is 4.05. The highest cognitive items (4.10) reflected students' focus on problem solving, while emotional engagement was relatively lower (3.98).

Table 4. Average Student Engagement Score

Aspects of Engagement	Average	Standard Deviation
Behavior	4,03	0,57
Cognitive	4,10	0,52
Emotional	3,98	0,60

Collaborative Knowledge Construction

The average collaborative knowledge construction score was 3.95. Top items: argumentation & evaluation (3.97), negotiation of ideas (3.92), drafting common understanding (3.96). Variations between groups show differences in the quality of contributions.

Tabel 5. Rata-rata Skor Collaborative Knowledge Construction

Collaboration Aspects	Average	Standard Deviation
Negotiation of Ideas	3,92	0,61
Argumentation & Evaluation	3,97	0,59
Preparation of Mutual Understanding	3,96	0,62

Analysis of Correlation and Variable Relationships

Multiple regression analysis shows a positive and significant influence:

a. Quality of virtual ecosystem → CKC: $\beta = 0.41$, $p < 0.01$
b. Intensity of interaction → CKC: $\beta = 0.38$, $p < 0.01$
c. Student engagement → CKC: $\beta = 0.35$, $p < 0.01$

Table 6. Multiple Regression Results

Independent Variables	b	t	p
Quality of Virtual Ecosystems	0,41	6,72	<0.01
Intensity of Interaction	0,38	6,02	<0.01
Student Engagement	0,35	5,58	<0.01

These results show that the quality of the virtual ecosystem is the strongest predictor of collaborative knowledge construction, followed by the intensity of student interaction and engagement.

Comparison with Previous Research

When compared to the research of Qafzezi et al. (2024), the results of this study show a higher correlation between the quality of the platform and CKC, likely due to the use of collaborative project forums with the integration of complete learning resources. Meanwhile, cognitive engagement was more dominant than emotional engagement, consistent with Shanzey's (2025) findings, but the interaction intensity value was slightly higher, indicating stronger student active participation in this research model.

DISCUSSION

Quality of Virtual Ecosystem and Collaborative Knowledge Construction

The results showed that the quality of the virtual ecosystem had the strongest influence on the construction of students' collaborative knowledge ($\beta = 0.41$, $p < 0.01$). These findings are in line with the Community of Inquiry (CoI) theory which emphasizes the importance of aspects of teaching presence, cognitive presence, and social presence in online learning (Garrison et al., 2021). The good quality of the platform supports interaction, information management, and facilitation of collaborative activities, so that students are able to build mutual understanding. These results also support the findings of Anderson et al. (2022) which show that a structured and responsive online learning environment increases student engagement and their ability to solve problems collectively.

The significance of these findings suggests that educational institutions need to focus on designing an integrated ecosystem, including intuitive navigation, integration of learning resources, and interactive features that facilitate discussion. Consequently, technology investment is not enough to provide a platform, but must be accompanied by a pedagogical strategy to maximize knowledge construction.

Intensity of Student Interaction and Participation

The analysis showed that the intensity of the interaction had a significant positive effect on CKC ($\beta = 0.38$, $p < 0.01$). This factor is in line with the concept of social constructivism by Vygotsky (1978), which states that knowledge is built through social interaction and collaboration. Research data shows that students who actively discuss, give feedback, and respond to friends' contributions are better able to build collective understanding.

However, differences were found in some groups of students who had low participation, even though access to the platform was quite good. This indicates that motivational factors, digital readiness, and self-efficacy also influence the results of knowledge construction, as found by Lee and Lee (2023) in an e-learning study. Therefore, increased interaction needs to be balanced with training on the use of the platform, intrinsic motivation, and lecturer facilitation guidance.

Learner Engagement

The average student engagement score of 4.05 indicates that the cognitive aspect is more dominant than the emotional and behavioral aspects. These findings are in line with the theory of multidimensional engagement (Fredricks et al., 2004; revised by Wang et al., 2023) that distinguishes cognitive, emotional, and behavioral engagement as determinants of learning success. Students tend to focus more on problem solving, argument evaluation, and reflection, which support the construction of knowledge.

A consequence of these findings is that online learning needs to be designed to balance cognitive and emotional engagement, for example through gamification, online ice-breaking, and social interaction strategies that trigger emotional motivation. Factors that support the initial hypothesis are interactive platforms and project-based collaborative tasks. Opposite factors arise from

groups of students who are less emotionally active, which lowers the quality of their knowledge construction.

Integration of Results with Previous Research

Overall, this study supports previous findings on the importance of platform quality, interaction, and student engagement (Chong et al., 2023; Liu et al., 2023). The difference is that this study emphasizes the simultaneous effect of the three variables on CKC in the context of blended learning in Indonesia, while the previous study emphasizes more on a single variable or a global context. This adds to the understanding that the success of virtual learning ecosystems is influenced by synergy between variables, not individual factors alone.

Research Constraints and Weaknesses

The main obstacle of this study is the dependence on self-reports from students through questionnaires, which can cause social bias. In addition, the use of purposive sampling limits the generalization of findings to the entire student population. Variations in disciplinary backgrounds and learning experiences are also factors that affect outcomes unevenly. Follow-up research recommendations are to conduct mixed-methods, combining digital observations, platform activity log analysis, and in-depth interviews to obtain stronger triangulation data (Nguyen et al., 2024; Sari & Wijayanti, 2025).

Theoretical and Practical Contributions

Theoretically, this study reaffirms the principles of social constructivism and Community of Inquiry, as well as strengthens empirical evidence on the influence of digital ecosystems on collaborative knowledge construction in higher education. Practically, this research provides a basis for lecturers and institutions to design interactive, collaborative, and project-based learning platforms and activities, improving the quality of interactions, engagement, and learning outcomes. These results are also relevant for the development of technology-based curricula that are adaptive and support 21st century skills (Kaur et al., 2022).

The Role of Digital Learning Design on the Effectiveness of Virtual Learning Ecosystems

The results show that the success of virtual learning ecosystems is not only influenced by the quality of technology, but also by how the environment is designed to support an active and collaborative learning process. Full-featured digital platforms do not always produce knowledge construction if they are not supported by learning designs that encourage exploration, communication, and reflection. These findings show that the pedagogical aspect has an equally important position as the technological aspect in virtual learning.

Rapanta et al. (2021) explain that an effective online learning design requires a shift from a material delivery approach to an activity-based approach that involves social interaction, collaboration, and meaning construction. This shows that lecturers not only act as providers of information, but also as designers of learning experiences. In addition, Martin et al. (2022) emphasized that a quality online learning design needs to consider activity structures, communication strategies, assessments, and learning support so that students are able to actively participate in the digital environment.

Based on this perspective, the results of this study strengthen the understanding that virtual learning ecosystems must be developed through the integration of technology and pedagogy. A virtual learning environment that has a clear activity structure allows students to understand learning objectives, manage group contributions, and generate mutual understanding. Therefore, the success of collaborative knowledge construction relies heavily on alignment between technology design and instructional strategies.

Social Dynamics in Collaborative Knowledge Construction

The findings of the study show that student interaction is one of the main factors that affect the success of collaborative knowledge construction. Interaction in virtual learning is not only related to the amount of communication, but also the quality of the exchange of ideas that takes place during the learning process. Students who actively comment, question ideas, and conduct group reflections show a higher level of knowledge construction.

Damşa and Jornet (2021) state that collaborative learning is a social process that involves the formation of a shared object of knowledge through collective communication, coordination, and development of ideas. In a virtual context, this process requires a digital space that allows students to build social relationships while conducting academic activities. Meanwhile, Tan et al. (2023) found that the quality of online discussions is greatly influenced by students' ability to make arguments, provide logical reasons, and connect new information with previous understanding.

Thus, the results of this study show that technology is only a facilitator, while the construction of knowledge occurs through student social activities. This has the implication that virtual learning needs to provide activities that require students to not only be digitally present, but also intellectually active.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that virtual learning ecosystems positively influence collaborative knowledge construction in higher education. Key factors include platform quality, interaction intensity, and learner engagement, which enable students to exchange ideas, evaluate arguments, and build shared understanding. Technology alone is insufficient; effective pedagogical design and facilitation are essential.

It is recommended that institutions design interactive, inclusive ecosystems with structured tasks, discussion forums, peer feedback, and reflective activities. Enhancing digital literacy and infrastructure supports active participation. Future research should use mixed methods combining surveys, interviews, and learning analytics to deepen understanding of collaborative knowledge processes and compare different platforms and models.

ADVANCED RESEARCH

This study is limited by self-reported data, a sample of 180 undergraduates, and a quantitative design that cannot fully capture collaborative dynamics. Future research should adopt mixed-methods combining surveys, interviews, learning analytics, and observations, and explore different platforms, disciplines, and instructional models to optimize virtual learning ecosystems for collaborative knowledge construction.

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