International Journal of Education and Practice
2024 Vol. 12, No. 3, pp. 1094-1112
ISSN(e): 2310-3868
ISSN(p): 2311-6897
DOI: 10.18488/61.v12i3.3842

Mastering knowledge construction skills through a context-aware ubiquitous learning model based on the case method and team-based projects

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Article History
Received: 26 July 2023
Revised: 18 March 2024
Accepted: 1 April 2024
Published: 24 July 2024

Keywords
Case method
Context-aware
Ubiquitous learning
Knowledge construction
Team-based project
Online learning.

ABSTRACT

This research aims to prove the effectiveness of a context-aware ubiquitous learning model through the case method and team-based projects in enhancing the knowledge construction skills of students regarding instructional media. In this analysis, a quasi-experimental posttest-only control group design was used, with the subjects comprising 62 students. These students were subsequently split into experimental and control groups of 32 and 30 participants, respectively. An interaction analysis model was also used as the data collection instrument to characterize learning behavior in knowledge construction. This was reflected in a questionnaire, with an independent t-test statistical analysis technique used to analyze the data. The results showed that the context-aware ubiquitous learning model based on the case method and team-based project was effective in improving the knowledge construction skills of students. In managing learning, lecturers were also advised to utilize educational strategies that were more oriented toward the students, such as active techniques including case techniques and team-based projects.

Contribution/Originality: This research offers alternative solutions to address challenges stemming from online learning practices. It achieves this by proposing a context-aware ubiquitous learning model created with a focus on active learning methods, specifically employing the case technique and project-based learning within higher education institutions.

1. INTRODUCTION

The unpreparedness of lecturers and students for online learning, especially during the COVID-19 pandemic, is responsible for the emergence of many issues. According to Irfan, Kusumaningrum, Yulia, and Widodo (2020) the challenges encountered by lecturers in implementing online learning included limitations in presenting materials, such as monotonous and uninteresting components; difficulty in promoting engagement; and establishing interactions among educational personnel. The challenges also made fostering a sense of community difficult (John, 2020). Furthermore, online learning is more stressful than regular face-to-face learning because students are commonly isolated, with inadequate authentic activities hampering concentration (Yusnilita, 2020). From this context, online material is mostly theoretical and does not offer opportunities for students to rehearse and learn effectively, with quality being a major problem (Dhawan, 2020). This explains that comprehensive learning cannot be fully accomplished online (Adnan & Anwar, 2020).

The inability of students to understand a concept is caused by the abstract nature of the subject matter (Sudarma, Prabawa, & Suartama, 2022). This shows that the teaching and learning processes are theoretical and disconnected from the environment, emphasizing reliance on rote memorization. Based on Setyawan and Rahman (2013) many educators emphasize the transfer of knowledge to students in the teaching and learning processes. For students, this type of learning lacks consideration activities, interaction, and the process of knowledge construction. This indicates their ability to learn without comprehension, the capability to merely memorize information without understanding it, and the inability to deeply grasp skills and knowledge (Maba, Widiastuti, Mantra, Suartama, & Sukanadi, 2023).

Educators are now facing students who were born between 1998 and 2012 and are in the Generation Z category (Alabbasi, 2017). They are more technologically literate and creative, accept the differences around them, care about social problems, and enjoy expressing themselves both in cyberspace and in reality. Generation Z have a different way of processing and understanding information, enjoy the concept of teamwork and collaborative activities in learning and are skilled, social, and energetic compared to previous generations (Szymkowiak, Melović, Dabić, Jeganathan, & Kundi, 2021). Understanding the characteristics of students in this category encourages many researchers to design appropriate activities to support their learning process in constructing knowledge (Jeong, Hmelo-Silver, & Jo, 2019).

Therefore, this research aims to prove the effectiveness of a context-aware ubiquitous learning model through the case method and team-based projects in improving the knowledge construction skills of students. This research offers alternative solutions to address challenges stemming from online learning practices. It achieves this by proposing a context-aware ubiquitous learning model created with a focus on active learning methods, specifically employing the case technique and project-based learning within higher education institutions.

2. LITERATURE REVIEW

2.1. Knowledge Construction Skills

Knowledge construction is responsible for demonstrating a valuable learning behavior in realizing the quality of the educational process and achieving objectives (Floren, Ten Cate, Irby, & O'Brien, 2021). It is also defined as a combined and interactive process, where learners develop as well as negotiate their understanding of concepts by linking new knowledge with the existing base (De Wever, Van Keer, Schellens, & Valcke, 2009; Van Aalst, 2009). This process is commonly estimated quantitatively (Lestari, Stalmeijer, Widyandana, & Scherpbier, 2019) or by using qualitative methodologies, such as the implementation of an interaction analysis model to characterize learning behavior (Garrison, Anderson, & Archer, 2001; Gunawardena, Lowe, & Anderson, 1997; Hmelo-Silver, 2003). According to Gunawardena et al. (1997) knowledge structure as a meaningful negotiation process through social interaction emphasizes the public constructivist perspective of learning. This is the observation of five distinct phases of mental concentration, each related to observable and tangible learning behaviors during social interaction. These five phases of knowledge construction depict the entire procedure of meaning negotiation, which occurs when substantial dissonance requiring resolution is observed among students. In this context, the five stages are: 1) exchanging/comparing information, 2) identifying and investigating dissonance or inconsistency among ideas, concepts, or statements, 3) collaborating to negotiate meaning and co-construct knowledge, 4) evaluating and adjusting proposed syntheses or collaborative constructions, and 5) formulating agreement/application statements for newly constructed meaning.

The skills needed in the 21st century typically cover a broad range, including technical proficiency, knowledge, effective communication, collaboration, critical thinking, creativity, and problem solving. This shows that mastering knowledge construction skills requires continuous effort and practice. In this case, students can build a solid foundation for lifelong learning by actively engaging with information, developing critical thinking skills, and synthesizing knowledge. This explains their capability to capitalize on the opportunities presented by the digital era while remaining vigilant in evaluating information for credibility (Niyazova et al., 2023). Collaborating with others (Yunus, Amirullah, Safiah, Ridha, & Suartama, 2022) engaging in reflective practices (Sanjaya, Suartama, & Suastika, 2022) and constantly seeking new knowledge is also very important in preparing students for the navigation of modern world complexities and continuously expanding their intellectual horizons. Nguyen and Diederich (2023) share the understanding that knowledge is socially constructed and suggest the use of online/digital learning environments to optimize the knowledge construction process.

2.2. Context-Aware Ubiquitous Learning

In the era of the Industrial Revolution 4.0 and post-COVID-19 pandemic, many changes are required in education paradigms and practices (Deák, Kumar, Szabó, Nagy, & Szentesi, 2021). This demonstrates that the availability of technology, such as internet networks, various online forum applications, tablets, smartphones, audio, computational software, visuals, graphics, animation, games, as well as other digital devices, is capable of providing new chances to develop meaningful virtual learning methods. In this context, the strategies are expected to be accomplished anytime, anywhere, and in diverse patterns aligning with students learning modalities or preferences. This is because meaningful online learning facilitates the knowledge construction processes of students (Wen, 2022). It also connects new information with knowledge acquired from their experiences. In addition, construction processes are more meaningful than rote memorization (Baharuddin, 2020).

Context-aware ubiquitous learning is an ingenious method considered relevant for maximizing the knowledge construction skills of students. This method emphasizes authentic learning conditions backed by personalized digital technology (Suartama, Triwahyuni, & Suranata, 2022). It also allows learners to learn about real-world objects and activities in the learning process through digital guidance (Hwang, Chu, Shih, Huang, & Tsai, 2010). Furthermore, context awareness supports students in accessing specific learning resources, content, or interactive actions based on their area, time, and personal events. This model supports personal group learning, content, and information management, with education and feedback being provided regarding the period, area, or activities of students. Its environment is also constructed using web-based Learning Management Systems (LMSs) with various methods and functions (Goh, 2010). From this context, LMSs provide the possibility of realizing ubiquitous learning (Suartama, Triwahyuni, Sukardi, & Hastuti, 2020) through new patterns of accessing and sharing information. It is also realized via individual and networked community thinking skills, where students often cooperate to support the growth of new understandings and engage in discussions for innovative explanations (Dochev & Hristov, 2006). In this case, LMSs positively influence students' thinking skills and innovation (Chootongchai & Songkram, 2018; Georgouli, Skalkidis, & Guerreiro, 2008; Govender, 2009; Henderson, 2010).

2.3. Case Method

Several student-centered teaching methods are used to enforce the principles of context-aware ubiquitous learning (Thongkoo, Panjaburee, & Daungcharone, 2019). This method includes case-based (case method) as well as project-oriented (team-based project) learning. The case method is a constructivist method in which real-life issues closely related to the lives of students are offered in the learning process. The case method is a pedagogical approach that aims to accelerate change and knowledge acquisition by bringing real-world affairs and experiences into the teaching space (Sato & Knaus, 2023).

According to Ali et al. (2018) the case method offers students opportunities to engage in the following: (1) analyze the case and its content, (2) expand exploratory understanding through independent research for information, data, and literature, (3) enhance critical thinking skills by solving the presented case, (4) foster improved collaboration by arriving at discussed solutions, and (5) amplify opportunities for feedback via presentations and revisions. Additionally, the cases explained in the learning process address issues related to students' environments, conditions, or future scenarios (Mayer, 2002). By working through the steps of the case method in learning, Schrittesser (2014) summarized the benefits that should be obtained: (1) it can foster a receptive attitude, context awareness, and understanding skills which are important to encourage deep understanding in students, (2) it can develop observation skills and diagnostics for students, and (3) it can bridge the gap between verbalistic learning to meaningful learning.

2.4. Team-Based Projects

A team-based project is a learning process that commonly uses projects/exercises as a moderate. This emphasizes the engagement of students in inquiry, assessment, interpretation, synthesis, and information to make various forms of learning products (Soboleva & Karavaev, 2020). The student-centered model also involves an in-depth analysis of a case, with students collaboratively and constructively delving into learning by applying the research-based method to substantial, real, and relevant issues/queries (Lam, 2012). In addition, the implementation encompasses several components/steps, including (a) formulating learning objectives, (b) comprehending the idea of teaching material, (c) skills activity, (d) creating scheme themes, (e) developing proposals, (f) executing project tasks, and (g) presenting reports (Jalinus, Nabawi, & Mardin, 2017).

The team-based project method has been associated with improved contact as well as critical thinking aptitudes (Bailey, Kiesel, Lobene, & Zou, 2020) and improved algorithmic thinking, collaboration, and problem solving (Wang, 2023). Project-based learning equips students with the skills they need to build meaningful and lasting knowledge (Tingting, Emily, & Miller, 2023) and is important in developing knowledge construction skills. This pedagogical approach engages students in active learning experiences that encourage the development of critical thinking (Sasson, Yehuda, & Malkinson, 2018) problem solving (Stoeva & Stoev, 2022) and creativity (Pan, Lai, & Kuo, 2023).

Based on the perspective of cognitive experts, many patterns are often used to help students construct knowledge more optimally. This includes their engagement in several activities, such as (1) presenting problems, (2) providing opportunities for experimentation, (3) encouraging dialogue and interaction, and (4) forming learning communities (Floren et al., 2021; Wen, 2022).

From these descriptions, a context-aware ubiquitous knowledge method emphasizing the case method and team-based tasks is proposed to guide learning activities in enhancing the knowledge construction skills of students.

2.5. Hypothesis

The following hypothesis was formulated for this research:

H_1: There is a substantial distinction in the knowledge construction skills of learners who learn using the context-aware ubiquitous learning model based on the case strategy and team-based projects and those who learn using the direct e-learning model.

3. METHOD

3.1. Research Design

A quantitative approach is used in this research, which uses a lot of numerical data, and employs statistical methods to analyze the data. In this research, an experimental design was employed to examine the effect of the independent variable on the dependent variable, which indicated that the separated and dependent variables were the learning model and the knowledge construction skills of students, respectively. A quasi-experimental posttest-only control set design by Setyosari (2013) was also implemented to reach the treatment between the experimental and control groups. A quasi-experiment is used because the study does not strictly control other variables that are considered to have an effect on the variable being studied. It is impossible for researchers to place research subjects in a pure laboratory condition that is completely free from the influence of the social environment while being given practical treatment. The experimental group received a specific treatment, namely a context-aware ubiquitous learning model emphasizing the case technique and a team-based project, while the control group did not receive specific therapy and only used the commonly applied traditional direct e-learning model. The design plan is presented in Figure 1.

R_1	X	O_2
R_2		O_4

Figure 1. Research design.

Description:

R_1 = Experimental group

R_2 = Control group

X = Treatment using the context-aware ubiquitous learning model emphasizing the case method and team-based projects

O_2 = Test for the experimental group

O_4 = Test for the control group

3.2. Participants

The participants were students from the Educational Technology and Educational Science departments in the Teacher Training and Education Institute of Persatuan Guru Republik Indonesia (PGRI) Jember, and Universitas Pendidikan Ganesha, Indonesia. In this case, a total of 62 students were split into two classes, namely observed and control groups. The observed class comprised 32 students—15 males and 17 females, and the control group comprised 30 students—13 males and 17 females. All of these participants were also enrolled in the Instructional Media course during the even semester of the 2022/2023 educational year. The determination of the two groups was accomplished through a class random sampling method, supposing that all types were homogeneous after conducting class equivalence tests.

3.3. Procedure

The analysis was conducted directly in designated testing and control classrooms. At this point, the experimental group was treated by implementing a context-aware ubiquitous learning model emphasizing the case method and team-based projects. Meanwhile, learning activities were conducted in the management group using the direct e-learning model. Before implementing the learning model, the knowledge construction skills of the students in each group were simultaneously measured to evaluate the level of their learning construction skills before the commencement of the analysis. Subsequently, learning activities in the experimental and control classrooms were conducted.

The context-aware ubiquitous learning model emphasizing the case method and team-based scheme was implemented in the instructional media course, where the research experts served as facilitators. This demonstrated that the students built their knowledge according to the principles and stages of the applied model. The ubiquitous model in the instructional media course also complied with the designed structured system, as shown in Figure 2.

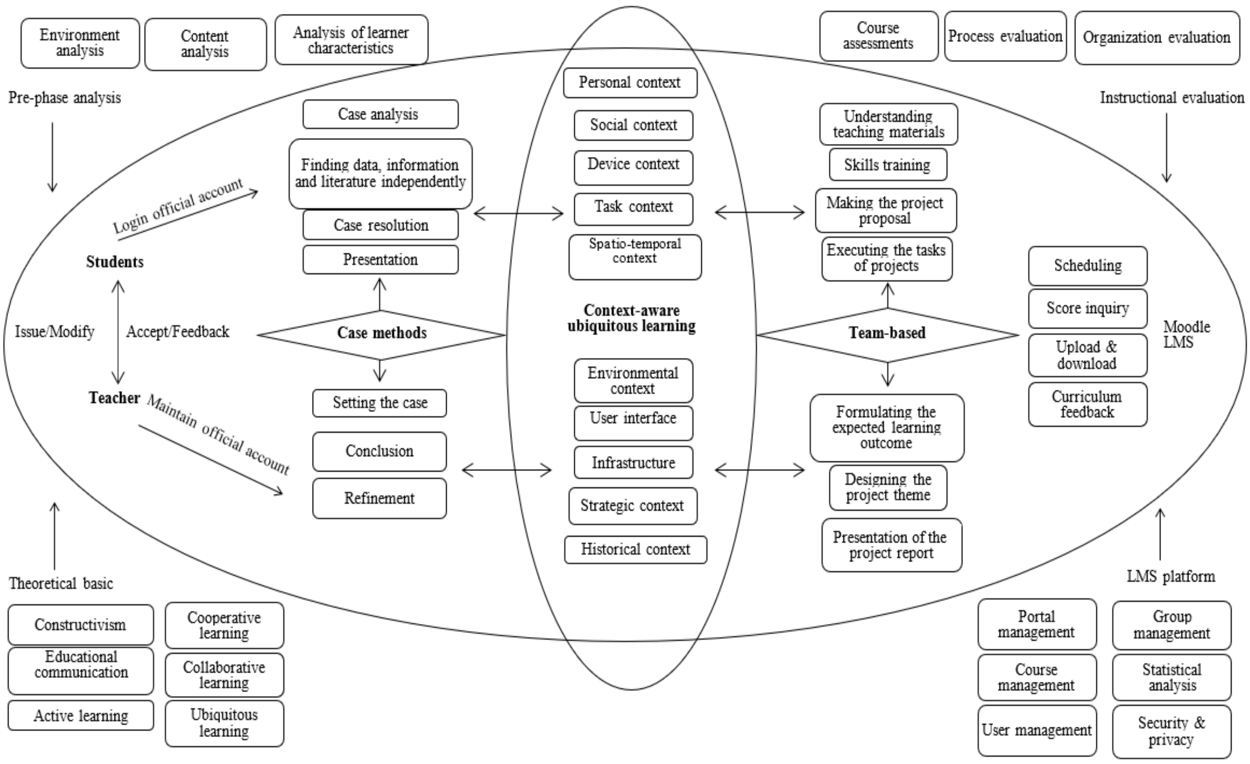

Figure 2. Structure of the context-aware ubiquitous learning model based on the case method and team-based projects.

Based on Figure 2, a context-aware learning environment was created using a web-based LMS with various features and functions. This model facilitated students' access to detailed learning resources, content, and interactive activities regarding personal events. It also supported individual information, content management, and activities emphasizing the situations, environments, and events of students. Furthermore, the ten contexts of the context-aware model encompassed personal, social, task, device, spatiotemporal, infrastructure, environmental, user interface, strategic, and historical principles. These principles were enforced in each stage of the case technique as well as the team-based task-learning technique.

Case-based learning is a complex method closely connected to real problem scenarios appropriate to the subject matter. In this method, the students actively participated in integrating various sources of knowledge in context and attempting to solve cases based on their previous experiences and existing knowledge. The implementation of the method in learning was also characterized by several components/steps, including 1) defining the case, 2) examining the case, 3) independently seeking information, data, and literature, 4) deciding the steps needed to solve the case, 5) drawing conclusions from the discussed answers, 6) presentation, and 7) revision. However, the application of the team-based project method in learning was characterized by the following components/steps: 1) acquiring the anticipated learning outcome, 2) comprehending the idea of the instruction materials, 3) skills training, 4) creating the project theme, 5) designing the proposal, 6) managing the tasks of the project, and 7) presenting the information.

The teaching and learning activities also consisted of the following 15 segments:

1) Course introduction
2) Learning activity 1: The role of instructional media
3) Learning activity 2: Basic concepts of instructional media
4) Learning activity 3: Classification of instructional media
5) Learning activity 4: Characteristics of instructional media types
6) Learning activity 5: Instructional media management
7) Learning activity 6: Instructional media selection

8) Mid-semester examination
9) Learning activity 7: Analysis of instructional media needs
10) Learning activity 8: Instructional media design and production
11) Learning activity 9: Evaluation of instructional media
12) Learning activity 10: Instructional media utilization
13) Practice 1: Production of simple instructional media
14) Practice 2: Production of digital education media
15) Final examination

Based on these descriptions, six segments were designed using the case method, namely learning activities 1, 2, 4, 5, 6, and 10. This was in line with the implementation of the team-based project technique, where the six designed segments included learning activities 3, 7, 8, and 9, as well as practices 1 and 2. To observe the complete instructional media course (accessible through the guest/login feature), u-Learning Class (link) should be accessed. For the control group, learning activities were conducted using the direct e-learning model accessible through e-Learning Undiksha (link). This model allowed students to access the main course as well as enrichment materials and submit responses to the lecturers. In both groups, the implemented topics/materials were similar, concentrating on instructional media. After completing all learning stages, a questionnaire on the knowledge construction skills of students was administered to assess the effectiveness of the applied educational model.

3.4. Instruments

The instrument for measuring the knowledge construction skills of students was developed based on relevant indicators through the analysis of the interchange model for characterizing learning behaviors in the experimental development by Gunawardena et al. (1997). This experimental development comprised the following phases: (a) disseminating or exchanging information, (b) discovering and investigating dissonance or inconsistency among concepts, ideas, or statements, (c) negotiating meaning and co-constructing knowledge, (d) testing and modifying offered synthesis or collaborative construction, and (e) expressing agreement or using newly created meaning. Table 1 shows the grid for measuring the knowledge construction skills of students.

Table 1. Instrument grid for measuring the knowledge construction skills of students.

Knowledge construction phase	Activities/Behaviors
Phase I Transferring/comparing information	1. Sharing experiences or opinions 2. Seeking agreement from one or more other learners 3. Providing reinforcing examples 4. Questioning and answering questions to clarify statement details
Phase II Discovery and exploration of dissonance or inconsistency between ideas, concepts, or statements	1. Recognizing and expressing disagreement 2. Asking and answering queries to clarify sources and the extent of disagreement 3. Presenting arguments or considerations supported by students' experiences, literature, acquired formal data, or relevant opinions to illustrate ideas
Phase III Negotiation of meaning/co-construction of knowledge	1. Negotiating and clarifying meaning and terms 2. Reaching agreement on conflicting concepts 3. Proposing new statements to achieve a compromise and joint construction 4. Integrating or accommodating ideas
Phase IV Testing and modification of proposed synthesis or joint construction	1. Testing the proposed syntheses 2. Analyzing against acquired formal data 3. Testing against contradictory data in the literature
Phase V Statement of agreement/Application of newly constructed meaning	1. Summarizing agreements 2. Applying new knowledge 3. Reviewing the metacognitive comments by students, describing the pattern by which their knowledge or thinking (Cognitive schema) skills had changed due to the interaction in the learning activities

This instrument consisted of 17 statements in a Likert scale questionnaire, with the highest and lowest scores of 5 and 1, respectively. The score for each knowledge construction item was calculated using the following formula: *(actual score:ideal score) x 100%*. Moreover, the instrument underwent expert validation and was pilot tested by 75 students. Table 2 presents the outputs of the corrected item-total correlation calculation for validity in the knowledge construction questionnaire.

Table 2. Validity test of the knowledge construction skills instrument.

Knowledge construction item	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
kc1	59.40	52.162	0.599	0.540	0.827
kc2	59.32	52.356	0.536	0.539	0.829
kc3	58.43	54.653	0.447	0.745	0.835
kc4	59.92	52.129	0.433	0.618	0.834
kc5	60.23	50.367	0.496	0.560	0.831
kc6	58.29	55.778	0.298	0.211	0.840
kc7	59.24	52.428	0.513	0.481	0.830
kc8	58.55	53.413	0.434	0.426	0.834
kc9	59.27	50.793	0.593	0.605	0.826
kc10	59.25	50.003	0.548	0.502	0.827
kc11	58.53	55.360	0.301	0.443	0.840
kc12	58.93	51.820	0.445	0.529	0.834
kc13	58.79	52.630	0.371	0.464	0.838
kc14	58.49	54.632	0.395	0.701	0.836
kc15	58.81	51.803	0.403	0.436	0.837
kc16	59.04	51.742	0.417	0.431	0.836
kc17	59.67	52.252	0.449	0.320	0.833

The instrument validity was determined by examining the corrected item-total correlation column. This displayed a score of 0.227, which is less than the critical value (r-table) and identified invalid items. In Table 2, all items had higher item-total correlation coefficients than the critical value (0.227). This proved that all 17 items were valid, prioritizing the implementation of the tool for data collection. Furthermore, the reliability level was tested using Cronbach's alpha coefficient. In this case, the instrument was considered reliable for implementation when achieving a high reliability level. The interpretation of the coefficient reliability level was also in line with Arikunto (2005), who emphasized the following: (1) 0.80–1.00 = very high, (2) 0.60–0.79 = high, (3) 0.40–0.59 = sufficient, (4) 0.20–0.39 = low, and (5) 0.00–0.19 = very low. Table 3 illustrates the outputs of the reliability calculation for the knowledge construction instrument.

Table 3. Results of the reliability test of the knowledge construction instrument.

Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.842	0.846	17

According to Table 3, the reliability of the knowledge construction skills instrument with 17 valid items had a Cronbach's alpha value of 0.842. This is in line with the interpretation of the coefficient reliability level mentioned by Arikunto (2005) therefore, the reliance of the instrument is categorized as very high and is acceptable for the analysis.

3.5. Data Analysis

The data analysis was conducted using descriptive statistical analysis methods and inferential statistics. A descriptive analysis was carried out to determine the students' levels of construction skills. These values include the mean score, lowest score, highest score, and standard deviation. Inferential statistics are used to test research hypotheses. The data analysis technique at this stage was divided into two parts, namely testing the analysis requirements and testing the research hypothesis. For the analysis requirements test, normality and uniformity of variance analyses were conducted utilizing the Kolmogorov–Smirnov and Levene techniques, respectively. The normality and dissent homogeneity analyses were also used to meet all parametric inferences. Moreover, the testing of the analysis hypotheses was performed using the independent t-test statistical technique with the assistance of SPSS for Windows. All the aforementioned parametric hypotheses were also performed at a sense level of 5%.

4. RESULTS

4.1. Description of Research Data

4.1.1. Knowledge Construction Skills Before Treatment

A total of 62 participants were involved—32 students from the Teacher Training and Education Institute of PGRI Jember (treatment group), which applied a context-aware universal learning model through a case plan and team-based project, and 30 students from Universitas Pendidikan Ganesha (control group), which applied the direct e-learning method. Both groups were provided with similar instruments to assess their level of knowledge construction skills. Table 4 shows the overview of the pre-treatment condition of the research subjects.

Table 4. Knowledge construction skills before treatment.

	Experimental group		Control group	
Knowledge construction skills	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**
	65.03	3.551	66.83	4.800

Based on Table 4, in the empirical category, the mean score and standard deviation of students' knowledge construction skills are 65.03 and 3.551, respectively. Meanwhile, in the control group, the mean and standard deviation are 66.83 and 4.800, respectively. From the overall measurements, no significant difference was observed in knowledge construction skills between the students in both groups. This indicates that knowledge construction skills and the initial abilities of the experimental subjects were not significantly different. These skills were then analyzed based on the responses to the questionnaire using the SPSS program to determine the differences between the groups. Table 5 contains the results of the autonomous sample t-test using SPSS.

Table 5. Independent sample t-test for knowledge construction skills scores before treatment.

Group statistics					
Learning model		**N**	**Mean**	**Std. deviation**	**Std. error mean**
Knowledge construction skills	Context-aware ubiquitous learning	32	65.03	3.551	0.628
	Direct e-learning	30	66.83	4.800	0.876

Independent sample t-test										
		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Upper	Lower
Knowledge construction skills	Equal variances assumed	0.911	0.344	-1.688	60	0.09 7	-1.802	1.068	-3.938	0.334
	Equal variances not assumed			-1.672	53.276	.100	-1.802	1.078	-3.964	0.360

The experimental and control group participants had mean knowledge construction skills scores of 65.03 and 66.83, respectively. This indicates that the Sig. value of Levene's test is 0.344 for skills. In this case, the importance value was greater than 0.05, demonstrating no significant distinction in the score variability of knowledge construction skills between the experimental and control groups. Hence, the separated t-test was conducted based on the assumption of equal variance.

The determination of the differences also required a statistical test using the independent sample t-test. According to Table 2, the t-test outputs for knowledge construction skills scores between the experimental and control groups yielded a significance value of 0.097 ($p > 0.05$, accept H_0). This proves that no significant distinction was found between the skills scores for both groups. In this case, the knowledge construction scores of the students in the experimental and control groups were similar before using the context-aware ubiquitous learning and direct e-learning model.

4.1.2. Knowledge Construction Skills after Treatment

The measurement of knowledge construction skills was conducted using a questionnaire after the treatment of both groups; the results are shown in Table 6.

Table 6. Knowledge construction skills after treatment.

Knowledge construction skills	Experimental group		Control group	
	Mean	**Std. dev.**	**Mean**	**Std. dev.**
	88.19	3.22	83.40	3.51

The average score and standard deviation in the empirical group are 88.19 and 3.22, respectively. Meanwhile, in the control group, the mean and standard deviation are 83.40 and 3.51, respectively. Figure 3 depicts the knowledge construction skills scores of the students in the media learning course, who used the applied educational models (context-aware ubiquitous learning and direct e-learning).

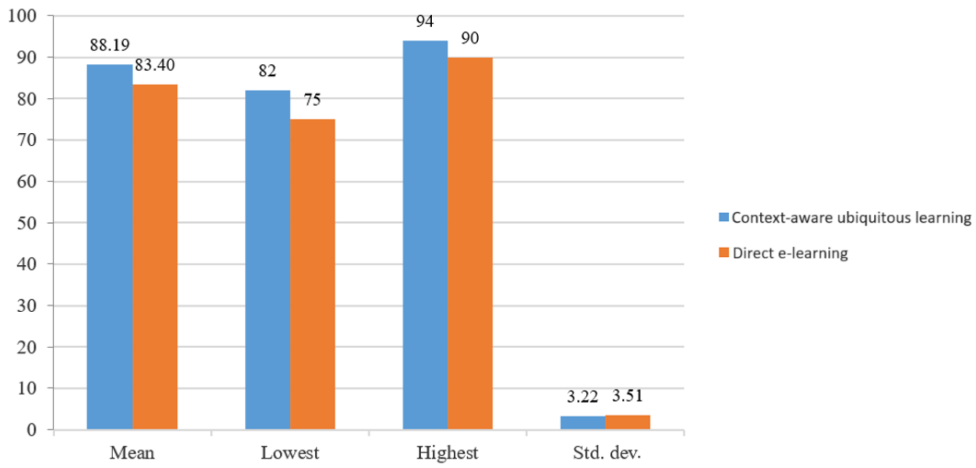

Figure 3. Histogram of the knowledge construction skills of students' learning with context-aware ubiquitous learning and direct e-learning based on the mean, lowest score, highest score, and standard deviation.

Figure 3 shows that the knowledge construction skills of students who studied with the context-aware ubiquitous learning model based on the case method and team-based scheme achieved better scores compared to the knowledge construction skills of students who studied with the direct e-learning model. However, to determine the significance of these differences, statistical testing is needed.

4.2. Analysis Requirement Test

An analysis requirement test was conducted to determine the parametric feasibility before the hypothesis analysis. The analysis requirement test for the difference measurement consisted of normality and homogeneity tests. In this case, the presentation started with the analysis requirement, or assumption test, accompanied by the hypothesis measurement.

4.2.1. Normality Test

The normality test of the data for each treatment group used the Kolmogorov–Smirnov statistical analysis with an importance level of $\alpha = 0.05$. This test aimed to select the normality or symmetry of the score dispersal as the unit of analysis, namely the knowledge construction skills scores of students in the media learning course. From this context, the null hypothesis (H_0) states that the sample emanated from a normally dispersed population. In this case, the decision-making basis indicated that the data distribution was irregular and normal when the effectiveness value or probability was less and more than 0.05, respectively. Table 7 presents the normality test results of the knowledge construction skills data for both groups.

Table 7. Normality test.

Learning model		Kolmogorov–Smirnov(a)			Shapiro–Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
Knowledge construction skills	Context-aware ubiquitous learning	0.133	32	0.160	0.952	32	0.159
	Direct e-learning	0.135	30	0.175	0.971	30	0.560

Note: a. Lilliefors significance correction.

The Kolmogorov–Smirnov normality test exhibited significance values (probabilities) of 0.160 and 0.175 for the knowledge construction skills scores of students from the experimental and control groups, respectively. These values are greater than 0.05 and confirm that the data had a normal allocation. However, the Shapiro–Wilk test produced significance values (probabilities) of 0.159 and 0.560 for the experimental and control groups, respectively. This indicates that the data had a normal distribution due to the scores being greater than 0.05, allowing subsequent testing using the t-test analysis.

4.2.2. Homogeneity Test

The homogeneity test was performed to confine the homogeneous level of the variance values within the sample groups. It was also carried out to analyze the levels of the individual variances of knowledge construction skills scores between the treatment groups. The homogeneity analysis of variance-covariance, namely Levene's test of equality of variances, was employed to detect the presence of heterogeneity, according to Santoso and Tjiptono (2002). The homogeneity of sample dissents was analyzed using Levene's test at a significance level of 0.05. When the importance value is greater than 0.05, H_0 is accepted, indicating that the samples were homogeneous. Table 8 displays the homogeneity analysis results using Levene's test through SPSS.

Table 8. Homogeneity test.

Levene's statistic	df1	df2	Sig.
0.000	1	60	0.993

In Table 8, the significance value for knowledge construction skills data is 0.993, which is greater than the alpha coefficient of 0.05 ($p > 0.05$). This shows that the variance or variance-covariance matrix of the skills data is homogeneous. In this case, the variance was identical for the existing groups (separate variables), namely context-aware ubiquitous learning and direct e-learning model. From the normality and homogeneity analyses, the data obtained was normally dispersed and homogeneous. Therefore, the t-test analysis was conducted due to the fulfillment of the data normality and the variance homogeneity assumptions.

4.3. Hypothesis Test

A hypothesis test was carried out to statistically define the acceptance or rejection level of the proposed hypotheses. This was performed by analyzing the data obtained from measuring the knowledge construction skills of learners in the media learning course. According to H_1, there is a significant difference in the knowledge construction skills between the experimental and control groups. To determine these differences, statistical testing was conducted using a separate sample t-test; Table 9 shows the t-test outputs using SPSS.

Table 9. T-test of knowledge construction skills after the intervention.

Separate sample t-test		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
									Upper	Lower
Knowledge construction skills	Equal variances assumed	0.000	0.993	5.596	60	0.000	4.787	0.856	3.076	6.499
	Equal variances not assumed	-	-	5.580	58.696	0.000	4.787	0.858	3.071	6.504

In Table 9, the outputs of the t-test between the experimental and control groups are shown, with a significance value of 0.000 ($p > 0.05$, H_0 is accepted). This demonstrates that H_0 is rejected and H_1 is accepted. A significant difference was found in the knowledge construction skills scores between both sample groups. The presence of differences also reveals that the implementation of the context-aware ubiquitous learning model affected these skills. Furthermore, the experimental and control groups had average scores of 88.19 and 83.40, respectively (see Table 6). In this context, the moderate score of the experimental group was higher than that of the control group (88.19 > 83.40). This confirms that the context-aware ubiquitous learning model affected the knowledge construction skills of students.

5. DISCUSSION

According to the hypothesis test, a significant difference was observed in knowledge construction skills between the sample groups. Respective mean scores of 88.19 and 83.40 were obtained for the experimental and control groups. In this case, the level of knowledge construction skills of students using the context-aware ubiquitous learning model was higher than those implementing the direct e-learning model. Regarding these differences, knowledge construction skills were influenced by the instructional model regardless of the similar materials, questions, and facilities provided to the students.

Knowledge construction is considered a process of extracting meaning via social interaction, based on a public constructivist view on learning (Gunawardena et al., 1997). It is also considered a collaborative and interactive process, where students develop and negotiate conceptual understanding by combining new knowledge with the living environment (De Wever et al., 2009; Van Aalst, 2009). In this case, five important phases were observed in students' knowledge construction skills, namely 1) sharing/comparing information, 2) determining and exploring dissonance or inconsistencies between ideas, concepts, or statements, 3) negotiating meaning/knowledge co-construction, 4) testing and modifying synthesis or proposed joint construction, and 5) stating the approval/application of newly created meaning (Gunawardena et al., 1997).

Fostering knowledge construction skills required a learning design capable of guiding students through the aforementioned phases. This led to the consideration of a ubiquitous learning environment capable of developing better active and adaptive learning activities in the real world (Suartama et al., 2021). In this case, students were often able to learn with adequate devices and content at the appropriate time and location (Hwang, Tsai, & Yang, 2008). This model encompassed three main resources, namely learning collaborators, contents, and services (Chang & Sheu, 2002; Haruo, Koyoharu, Yasufumi, & Shiho, 2003; Zixue, Shengguo, Kansen, Tongjun, & Aiguo, 2005). Some model characteristics also included the following: (1) context awareness, (2) interactivity, (3) personalization, and (4) flexibility (Chen, Chang, & Wang, 2008; Virtanen, 2018).

A ubiquitous knowledge environment was established using a web-based LMS with various features and functions (Goh, 2010). This environment was constructed by carrying out the following: (1) integrating various instructional delivery methods/models and learning styles, (2) introducing several choices of media/resources and formats of interaction between instructors and students, (3) implementing many features, such as chat, forums, and video conferences. It also provided students with the opportunity to experience the knowledge construction phase, especially in sharing/comparing information. In addition, students were able to share experiences or opinions, express agreement with others, provide supportive examples, and ask and answer questions to clarify statement details.

Context awareness was also achieved by adapting the characteristics of students and their environment through the provision of an authentic learning atmosphere backed by personalized digital technology. This allowed them to follow or research objects and activities in the real world within learning activities guided online (Hwang et al., 2010). It also supported students in accessing specific learning resources, content, or interactive activities related to their area, activities, and personal environment. These conditions were capable of facilitating meaningful learning, a process connecting new information with knowledge acquired from various experiences and environments (Baharuddin, 2020). The learning method also facilitated knowledge construction process skills (Wen, 2022) and provided students with the opportunity to experience relevant phases, especially in the discovery of ideas, concepts, or statements. In addition, the students were able to ask and answer questions to clarify sources and present the arguments or considerations supported by experiences, literature, and formal environmental data.

In the experimental group, the case method aligned with the context-aware ubiquitous model and provided opportunities to conduct the following steps: 1) investigate the case and content, 2) enhance exploratory knowledge by independently seeking information, literature, and data, 3) enhance critical thinking by solving the case, 4) achieve better cooperation by determining collectively discussed answers, and 5) allow opportunities for feedback through exhibits and revisions (Ali et al., 2018). These learning steps were important in the knowledge construction skills of students, especially in the discovery and exploration, meaning negotiation, and testing and modifying synthesis phases. In addition to being the recipients of knowledge through verbal explanations from the lecturer, the students also played active roles in personally discovering the essence of the subject matter. According to Lestari, Rahmawatie, and Wulandari (2023), online case-based learning is capable of initiating the growth of collaborative knowledge construction skills, where students practice interprofessional communication, negotiation, role-sharing, and leadership attributes. This model emphasizes maximum activity as the method of learning by exploring, discovering, connecting, and involving concepts in low-risk surroundings (Ertmer & Koehler, 2014). In this case, students were able to gain several advantages from finishing case-based learning processes. Firstly, the learning model provided opportunities for students to think about problems similar to those encountered in the real world. Secondly, the model established relations between existing problems and the knowledge of students (Koehler, Fiock, Janakiraman, Cheng, & Wang, 2020). Teamwork, critical thinking, and cultural awareness skills were also developed (Yadav, Bozic, Gretter, & Nauman, 2015) with all conducted activities directed toward seeking and determining personal answers to posed questions. This led to the ability to foster self-belief, develop intellectual abilities (Sanjaya et al., 2022) and establish knowledge construction as part of the mental process (Bada & Olusegun, 2015). Therefore, this learning method was effective in creating problem-solving skills and knowledge construction (Koehler, Ertmer, & Newby, 2019; Tawfik & Kolodner, 2016). The results of the research by Daryanes et al. (2023) found that the case method can train students' problem-solving abilities. Facing students with problems can train them to construct their own knowledge as an important part of the concept of lifelong learning.

In the experimental group, the team-based project method was also used in context-aware ubiquitous learning model and several other segments. This method placed students in roles of autonomy, engagement, and greater responsibility in their learning activities (Guo, 2020). This involved several steps, namely 1) defining anticipated learning outcomes, 2) grasping the idea of teaching materials, 3) honing skills through training, 4) conceptualizing a project theme, 5) creating a proposal, 6) completing assignments, and 7) delivering a project report. These steps contributed to enhancing knowledge construction skills, starting from the project selection phase, in a pattern aligning with interests and needs. The planning phase started with existing knowledge, setting, and question formulation enabling students to expand their perceptions and thinking through project-based learning activities (sharing and negotiation phase). The team-based project method also involved skills training for the identification of assumptions and argument evaluation through class meetings, project performance steps, data collection and analysis. This was later accompanied by the evaluation phase and display of the project report (application of new knowledge phase). Based on the team-based project learning stages, students were able to connect their experiences with real-life situations and stimulate critical thought and knowledge construction during the acquisition of new knowledge (Issa & Khataibeh, 2021). Project-based online learning encourages the scientific process, which is the process of obtaining knowledge systematically based on scientific activities and evidence, and this is a significant part of the knowledge construction process (Zen & Ariani, 2022). Moreover, the collaborative team-based project model mediated the students' knowledge construction (Hmelo-Silver, 2003) and aligns with Araújo et al. (2017), who stated that social relations and cooperative work in a ubiquitous learning environment improved academic interpretation. This proves that interactive features enhance combined learning interactions and the knowledge construction process.

6. CONCLUSION

This study analyzed the impact of the context-aware ubiquitous learning model on the knowledge construction skills of students in higher education through the case method and team-based projects. Based on the results, the learning model significantly influenced the scores of knowledge construction skills. This indicates that the model had several advantages over the direct e-learning technique in achieving and improving knowledge construction skills. To manage learning, lecturers should use student-oriented and active strategies, such as case methods as well as team-based projects.

7. RECOMMENDATIONS

Based on the results, the following recommendations are made:

- To involve students in the learning process and improve their knowledge construction skills, lecturers can apply learning models that allow students to learn anytime, anywhere, and in various ways according to their learning modalities/preferences and learning styles as well as using student-centered learning methods. The context-aware ubiquitous learning model is adaptive to the characteristics and environments of students and encourages them to be more active.
- The context-aware ubiquitous learning model should be applied in other higher education institutions that have students with similar characteristics to the subjects who took part in this research.
- For students initially using context-aware learning models based on case methods and team-based projects, lecturers must provide guidance, especially on the implementation practices of the learning management system, regardless of its designation for independent education.

- This model design should be distributed through various activities, such as (1) academic seminars organized by universities, (2) exercise programs for the growth and implementation of learning models, and (3) collaborations with learning centers and educational training institutions. It also needs to be disseminated via several forums to continuously activate and enhance knowledge construction skills.
- Subsequent research should be conducted to implement a context-aware ubiquitous learning model in other courses while targeting different characteristics in distinguished educational levels and pathways.

8. LIMITATIONS

The following limitations were observed:

- The implementation of this model required ICT devices (computers or mobile devices).
- Adequate internet access was needed.
- Specific learning materials/courses were limited.
- The instrument for measuring knowledge construction skills was limited to primary data measurement through questionnaires.
- The testing conducted did not get to the stage of evaluating long-term impacts.

Funding: This research is supported by the Directorate of Research, Technology and Community Service, Directorate General of Higher Education, Research, and Technology, Ministry of Education, Culture, Research and Technology of Indonesia (Grant number: 050/E5/PG.02.00.PL/2023).
Institutional Review Board Statement: The Ethical Committee of the Institute Teacher Training & Education of PGRI Jember, Indonesia has granted approval for this study on 17 March 2023 (Ref. No. 17/PT.106/LPPM/C.J/II/2023).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Conceptualization, methodology, project administration, writing of the original draft, writing review and editing, I.K.S.; data curation, formal analysis, investigation, and supervision, K.S.; resources, software, validation, and visualization, E.T. All authors have read and agreed to the published version of the manuscript.

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