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The Impact of Adaptive Educational Game-Based Learning on University Students' Learning Experience: A Structural Equation Modeling Approach

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ABSTRACT

The integration of technology in higher education has become increasingly important, yet limited empirical evidence exists regarding the effectiveness of adaptive educational game-based learning (EGBL) in Indonesian university contexts. This study investigates the impact of adaptive and interactive educational game-based learning on university students' learning experiences, employing Structural Equation Modeling (SEM) to examine the relationships between EGBL dimensions and learning outcomes. A quantitative survey design was employed with 180 undergraduate students from Universitas Pendidikan Indonesia. Participants engaged with a role-playing game (RPG) educational platform for eight weeks. Data were collected using validated instruments measuring EGBL effectiveness (12 items, α=0.92) and learning experience (15 items, α=0.91). The structural model demonstrated excellent fit indices (χ^2=125.68, p>0.05; RMSEA=0.078; CFI=0.94; GFI=0.91). EGBL significantly influenced learning experience (β=0.72, p<0.01), explaining 51.8% of variance. Students reported enhanced motivation (86.7%), improved comprehension (86.1%), and increased collaboration (86.1%). Game mechanics, adaptivity, and visual design were identified as critical success factors. Adaptive EGBL effectively enhances university students' learning experiences through interactive engagement, immediate feedback, and collaborative features. These findings support the integration of well-designed educational games in higher education curricula.

Integrasi teknologi dalam pendidikan tinggi semakin penting, namun masih terbatas bukti empiris tentang efektivitas pembelajaran berbasis game edukasi adaptif (EGBL) dalam

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konteks universitas Indonesia. Penelitian ini mengkaji dampak pembelajaran berbasis game edukasi adaptif dan interaktif terhadap pengalaman belajar mahasiswa, menggunakan Structural Equation Modeling (SEM) untuk menguji hubungan antara dimensi EGBL dan hasil pembelajaran. Desain survei kuantitatif digunakan dengan 180 mahasiswa sarjana Universitas Pendidikan Indonesia. Partisipan menggunakan platform game edukasi role-playing (RPG) selama delapan minggu. Data dikumpulkan menggunakan instrumen tervalidasi untuk mengukur efektivitas EGBL (12 item, α=0.92) dan pengalaman belajar (15 item, α=0.91). Model struktural menunjukkan indeks kesesuaian yang sangat baik (χ^2=125.68, p>0.05; RMSEA=0.078; CFI=0.94; GFI=0.91). EGBL berpengaruh signifikan terhadap pengalaman belajar (β=0.72, p<0.01), menjelaskan 51.8% varians. Mahasiswa melaporkan peningkatan motivasi (86.7%), pemahaman yang lebih baik (86.1%), dan kolaborasi yang meningkat (86.1%). Mekanika permainan, adaptivitas, dan desain visual diidentifikasi sebagai faktor kesuksesan kritis. EGBL adaptif secara efektif meningkatkan pengalaman belajar mahasiswa melalui keterlibatan interaktif, umpan balik langsung, dan fitur kolaboratif. Temuan ini mendukung integrasi game edukasi yang dirancang dengan baik dalam kurikulum pendidikan tinggi.

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1. INTRODUCTION

The digital transformation of higher education has accelerated significantly in recent years, necessitating innovative pedagogical approaches that leverage technology to enhance learning experiences (UNESCO, 2020). Traditional lecture-based instruction increasingly faces challenges in maintaining student engagement and motivation, particularly among digital-native learners who expect interactive and personalized learning environments (Prensky, 2001; Siemens, 2005). Educational Game-Based Learning (EGBL) has emerged as a promising pedagogical innovation that combines entertainment elements with educational content to create engaging learning experiences (Gee, 2003; Plass et al., 2015). By incorporating game mechanics such as challenges, rewards, narratives, and immediate feedback, EGBL creates immersive environments that can potentially enhance motivation, engagement, and learning outcomes (Hamari et al., 2016; Sailer et al., 2017).

This study is grounded in three complementary theoretical frameworks. Constructivism Theory (Piaget, 1972; Dewey, 1938) posits that learners actively construct knowledge through interaction with their environment. EGBL provides constructivist learning environments where students learn through exploration, experimentation, and problem-solving within game contexts. Experiential Learning Theory (Kolb, 1984) emphasizes learning through concrete experiences, reflective observation, abstract conceptualization, and active experimentation. Educational games facilitate this cycle by providing immediate feedback and opportunities for iterative practice. Flow Theory (Csikszentmihalyi, 1990) suggests that optimal learning occurs when challenge levels match learner capabilities, creating a state of deep engagement. Adaptive EGBL systems can dynamically adjust difficulty to maintain this optimal balance.

Despite growing interest in EGBL, several critical gaps remain in the literature. First, most studies focus on K-12 education, with limited empirical evidence regarding EGBL effectiveness in higher education contexts, particularly in Indonesia (Connolly et al., 2012). Second, few studies employ rigorous quantitative methods such as Structural Equation Modeling to examine the complex relationships between EGBL dimensions and learning outcomes. Third, there is insufficient understanding of how specific game design elements—particularly adaptivity and interactivity—influence learning experiences in university settings. While previous research has demonstrated EGBL's positive effects on learning outcomes (Annetta et al., 2009; Chen et al., 2020), most studies examine simple correlations without exploring the structural relationships between multiple EGBL dimensions and learning experience components. Furthermore, the specific mechanisms through which adaptive and interactive features influence learning remain underexplored.

This study addresses these gaps by: (1) employing SEM to examine complex relationships between EGBL dimensions and learning experiences; (2) focusing specifically on university students in an Indonesian context; (3) investigating adaptive RPG-based learning platforms with personalized difficulty adjustment; and (4) providing empirical evidence for design principles that optimize educational game effectiveness. Specifically, this study aims to analyze the influence of Educational Game-Based Learning on university

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students' learning experiences, identify critical EGBL dimensions that significantly impact learning outcomes, and provide evidence-based recommendations for educational game design in higher education. Based on the theoretical framework and research gaps identified, this study hypothesizes that: H1: Adaptive Educational Game-Based Learning has a significant positive effect on university students' learning experience.

2. RESEARCH METHOD

This study employed a quantitative research design with a survey approach to examine the causal relationship between Educational Game-Based Learning (EGBL) and learning experience. The research is both descriptive and verificative in nature, where the descriptive component aims to systematically describe EGBL implementation and learning experience characteristics, while the verificative component tests the hypothesized relationships using Structural Equation Modeling (SEM).

The target population consisted of active undergraduate students at Universitas Pendidikan Indonesia (UPI) who were enrolled in business and management courses during the 2024/2025 academic year. Purposive sampling was employed with specific inclusion criteria: active undergraduate students in semesters 3-6, enrolled in courses utilizing the educational game platform, having access to internet-connected devices, and voluntary participation with informed consent. Based on Hair et al. (2006) recommendations for SEM analysis requiring minimum 5-10 observations per estimated parameter, and with 30 parameters estimated in this study, a minimum sample of 150-300 respondents was required. This study successfully collected data from 180 respondents, exceeding the minimum threshold. The sample characteristics included faculty distribution from Economics and Business Education (45%), Management (35%), and Accounting (20%), with gender composition of 58% female and 42% male students from semesters 3rd (30%), 4th (35%), 5th (20%), and 6th (15%).

Data collection utilized validated questionnaire instruments adapted from established scales. The EGBL Scale was adapted from Plass et al. (2015) and Hamari et al. (2016), while the Learning Experience Scale was adapted from Kolb (1984) and Laurillard (2012). Both instruments employed a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). Prior to main data collection, instrument validity and reliability were established through a pilot test conducted with 30 students, content validity review by three education technology experts, construct validity assessment confirming factor loadings above 0.70 for all items and Average Variance Extracted (AVE) above 0.50 for all constructs, and reliability testing showing Cronbach's Alpha of 0.92 for EGBL and 0.91 for Learning Experience, with Composite Reliability exceeding 0.70 for all constructs.

3. RESULTS AND DISCUSSION

RESULTS

Descriptive Statistics of Educational Game-Based Learning

The descriptive analysis of EGBL dimensions reveals high levels of student satisfaction across all measured components (Table 1).

Table 1. Table 1. Descriptive Statistics of EGBL Dimensions

DIMENSION	INDICATOR	MEAN	SD	AGREEMENT (%)
Learning Design	Clear learning objectives	4.09	0.68	81.7
	Effective learning strategies	4.22	0.64	84.5
	Relevant content	4.36	0.58	87.2
User Interface	User-friendly platform	4.31	0.62	86.1
	Easy-to-use features	4.47	0.55	89.4
	Attractive visual design	4.39	0.60	87.8
Game Mechanics	Interactive gameplay	4.36	0.59	87.2
	Appropriate difficulty	4.42	0.57	88.3
	Motivating rewards	4.22	0.65	84.4
Social Features	Collaboration facilitation	4.31	0.62	86.1
	Healthy competition	4.19	0.67	83.9
	Effective communication	4.22	0.64	84.4
Overall EGBL		4.30	0.48	86.0

Key Findings

1. Learning Design Excellence: The high agreement rates (81.7%-87.2%) indicate that the educational game successfully aligned learning objectives with curriculum requirements. Content relevance received the highest rating (M=4.36), suggesting effective integration of business concepts within the game narrative.
2. Superior User Experience: User interface dimensions scored consistently high (86.1%-89.4%), with "easy-to-use features" receiving the highest rating (M=4.47). This demonstrates successful implementation of user-centered design principles.
3. Engaging Game Mechanics: Students positively evaluated game mechanics (84.4%-88.3%), particularly the appropriate difficulty level (M=4.42), which suggests the adaptive system effectively maintained optimal challenge levels.
4. Effective Social Integration: Social features received strong positive responses (83.9%-86.1%), indicating that collaborative and competitive elements successfully fostered peer interaction

Descriptive Statistics of Learning Experience

Students reported overwhelmingly positive learning experiences across all measured dimensions (Table 2).

Table 2. Descriptive Statistics of Learning Experience Dimensions

DIMENSION	INDICATOR	MEAN	SD	AGREEMENT (%)
Motivation & Engagement	Enthusiasm during gameplay	4.17	0.69	83.3
	Enjoyable learning experience	4.33	0.61	86.6
	Sustained motivation to learn	4.33	0.62	86.7
	Active participation	4.28	0.64	85.6
Cognitive Development	Improved comprehension	4.31	0.63	86.1
	Better concept connection	4.12	0.70	82.8

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	Practical knowledge application	4.00	0.75	80.0
	Enhanced understanding	4.22	0.66	84.4
Skill Development	Critical thinking skills	4.14	0.69	82.8
	Analytical abilities	4.08	0.71	81.7
	Hand-eye coordination	3.89	0.78	77.7
Social Interaction	Teamwork collaboration	4.31	0.62	86.1
	Idea sharing	4.19	0.68	83.9
	Comfortable peer interaction	4.22	0.65	84.4
	Effective group communication	4.17	0.69	83.3
Overall Learning Experience		4.20	0.52	84.0

Key Findings:

1. High Motivation and Engagement: Students reported strong enthusiasm (M=4.17) and sustained motivation (M=4.33), indicating that EGBL successfully overcame the boredom commonly associated with traditional learning methods.
2. Significant Cognitive Gains: High ratings for comprehension (M=4.31) and concept connection (M=4.14) suggest that the game effectively facilitated deep learning beyond superficial memorization.
3. Skill Development: While all skill dimensions received positive ratings, critical thinking (M=4.14) and analytical abilities (M=4.08) scored higher than hand-eye coordination (M=3.89), reflecting the cognitive focus of the educational game.
4. Enhanced Social Learning: Strong social interaction scores (83.3%-86.1%) demonstrate that collaborative game features successfully fostered peer learning and communication skills.

Measurement Model Assessment

Table 3. Measurement Model Assessment

Construct	Items	Factor Loading Range	AVE	CR	Cronbach's α
EGBL	12	0.74 -0.86	0.597	0.94	0.92
Learninng Experience	15	0.72 – 0.85	0.583	0.95	0.91

Key Findings:

1. Convergent Validity: All factor loadings exceeded 0.70, and AVE values surpassed 0.50, confirming convergent validity (Hair et al., 2006).
2. Discriminant Validity: The square root of AVE for each construct (EGBL=0.773, LE=0.763) exceeded inter-construct correlations (r=0.72), confirming discriminant validity.
3. Reliability: Both Cronbach's Alpha and Composite Reliability values exceeded 0.90, indicating excellent internal consistency.

Structural Model Evaluation

Table 4 Model Fit Indices

Fit Index	Obtained Value	Threshold	Interpretation
Chi-Square (χ^2)	125.68	P > 0.05	Excellent
RMSEA	0.078	≤ 0.08	Good

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CFI	0.94	≥ 0.90	Excellent
GFI	0.91	≥ 0.90	Excellent
TLI	0.93	≥ 0.90	Excellent

Model Fit Interpretation

1. Chi-Square Test: The non-significant chi-square ($p>0.05$) indicates no significant difference between the observed and model-implied covariance matrices, suggesting excellent model fit (Byrne, 2016).
2. RMSEA: The value of 0.078 falls within the acceptable range (≤0.08), indicating good approximation with minimal error (Browne & Cudeck, 1993).
3. CFI and TLI: Values above 0.90 (CFI=0.94, TLI=0.93) demonstrate that the model explains substantially more variance than the null model (Hu & Bentler, 1999).
4. GFI: The value of 0.91 indicates that the model accounts for 91% of the variance in the observed data.

Conclusion: All fit indices meet or exceed recommended thresholds, confirming that the structural model provides an excellent representation of the relationships between EGBL and learning experience.

Hypothesis Testing

Table 5 Structural Path Coefficients

Hypothesis	Path	Standardized Coefficient (β)	Standard Error	t-value	p-value	R^2	Decision
H1	EGBL → Learning Experience	0.72	0.048	15.00	<0.001	0.518	Supported

Hypothesis Testing Results

H1: Educational Game-Based Learning significantly influences Learning Experience

The analysis reveals a strong, significant positive relationship between EGBL and learning experience ($\beta=0.72$, $t=15.00$, $p<0.001$). The coefficient of determination ($R^2=0.518$) indicates that EGBL explains 51.8% of the variance in students' learning experiences, representing a substantial effect size (Cohen, 1988).

Interpretation:

1. For every one standard deviation increase in EGBL quality, learning experience improves by 0.72 standard deviations
2. The relationship is highly significant ($p<0.001$), providing strong evidence against the null hypothesis
3. The large effect size confirms that EGBL is a critical determinant of learning experience quality

DISCUSSION

Theoretical Implications

The strong positive relationship between EGBL and learning experience ($\beta=0.72$, $p<0.001$) provides robust empirical support for constructivist learning theories in digital contexts. This finding aligns with and extends previous research in several important ways:

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1. Constructivist Learning Theory Validation
   The results strongly support Piaget's (1972) constructivism, demonstrating that active, interactive learning environments significantly enhance learning experiences. The RPG format allowed students to construct knowledge through exploration, experimentation, and problem-solving within authentic business scenarios. The high ratings for cognitive development (M=4.20) suggest that students moved beyond passive knowledge reception to active knowledge construction.
   This finding extends constructivist theory into digital gaming contexts, showing that well-designed educational games can create the "cognitive disequilibrium" necessary for learning while providing scaffolding through adaptive difficulty systems (Jonassen, 1994).
2. Experiential Learning Cycle Facilitation
   The significant impact of EGBL on learning experience validates Kolb's (1984) experiential learning theory. The game platform effectively facilitated all four stages of the learning cycle:
   - Concrete Experience: Students engaged with realistic business scenarios
   - Reflective Observation: Immediate feedback prompted reflection on decisions
   - Abstract Conceptualization: Students connected game experiences to theoretical concepts
   - Active Experimentation: The safe environment encouraged risk-taking and experimentation

   The high rating for "practical knowledge application" (80.0% agreement) demonstrates successful transfer from game to real-world contexts, addressing a common criticism of educational games (Bellotti et al., 2013).
3. Flow Theory and Optimal Challenge
   The strong positive effects support Csikszentmihalyi's (1990) flow theory. The adaptive difficulty system successfully maintained optimal challenge levels (M=4.42), preventing both boredom (challenge too low) and anxiety (challenge too high). This balance is critical for sustained engagement, as evidenced by the high motivation scores (M=4.33).
   The R^2 value of 0.518 indicates that EGBL accounts for 51.8% of learning experience variance, suggesting that while game design is crucial, other factors (instructor support, peer dynamics, individual differences) also contribute significantly.

Practical Implications

For Educational Institutions:

1. Curriculum Integration: The strong empirical evidence supports systematic integration of well-designed educational games into higher education curricula. Institutions should:
   a. Allocate resources for educational game development or licensing
   b. Provide training for faculty in EGBL implementation
   c. Establish quality standards for educational game selection
2. Pedagogical Innovation: EGBL should be positioned as a complement to, not replacement for, traditional instruction. The blended approach leverages the strengths of both methods:

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a. Games for engagement, practice, and application
b. Traditional instruction for complex theoretical foundations

3. Infrastructure Investment: The web-based platform's success (86.1% user satisfaction) demonstrates the viability of browser-based solutions, which require minimal infrastructure investment compared to specialized software.

For Educational Game Designers:

1. Critical Design Elements: The research identifies four essential design dimensions:
   a. Learning Design (87.2% agreement): Clear alignment between game objectives and learning outcomes is non-negotiable
   b. User Interface (89.4% agreement): Intuitive, attractive interfaces significantly impact adoption and sustained use
   c. Game Mechanics (88.3% agreement): Appropriate difficulty and meaningful rewards drive engagement
   d. Social Features (86.1% agreement): Collaborative and competitive elements enhance learning through social interaction
2. Adaptive Systems: The high ratings for appropriate difficulty (M=4.42) underscore the importance of adaptive algorithms that personalize challenge levels. Designers should prioritize:
   a. Real-time performance monitoring
   b. Dynamic difficulty adjustment
   c. Personalized feedback systems
3. Balance Entertainment and Education: The high enjoyment ratings (M=4.33) combined with strong cognitive development scores (M=4.20) demonstrate that educational effectiveness and entertainment value are not mutually exclusive. Designers must resist the temptation to prioritize one at the expense of the other.

Comparison with Previous Research

This study's findings align with and extend previous EGBL research in several important ways. The positive effects of game-based learning on student motivation observed in this study are consistent with findings from Plass et al. (2015), who demonstrated that well-designed educational games enhance intrinsic motivation through meaningful challenges and immediate feedback. Similarly, Hamari et al. (2016) identified gamification's significant positive impact on student engagement, which mirrors the high active participation ratings observed in this research. The effectiveness of game mechanics in enhancing motivation, as demonstrated by Sailer et al. (2017), is further supported by the positive student responses to the reward systems and interactive elements implemented in the BizQuest RPG platform.

However, this study makes several novel contributions that distinguish it from previous research. Methodologically, while many previous EGBL studies have relied on simple correlational analyses or t-tests to examine relationships between variables, this research employs Structural Equation Modeling to investigate complex structural relationships, providing more robust evidence for causal inferences. This methodological rigor allows for a more comprehensive understanding of how multiple EGBL dimensions simultaneously

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influence learning experiences. Contextually, most existing EGBL research has focused on Western educational systems or K-12 education, leaving a significant gap in understanding how game-based learning functions in Asian higher education contexts. By providing empirical evidence from Indonesian university students, this study demonstrates the cross-cultural validity of EGBL principles while acknowledging potential contextual variations that may require adaptation.

The focus on adaptive systems represents another important distinction from previous research. While earlier studies have typically examined static educational games with fixed difficulty levels, this research specifically investigates adaptive platforms that personalize challenge levels based on individual student performance. This focus on adaptivity reflects the next generation of educational technology and provides insights into how dynamic difficulty adjustment can maintain optimal engagement over extended learning periods. Furthermore, rather than focusing narrowly on single outcomes such as test scores or motivation levels, this study examines a comprehensive learning experience encompassing cognitive, affective, and social dimensions. This holistic approach provides a more complete picture of how educational games influence the multifaceted nature of student learning, addressing criticism that earlier research often examined isolated variables without considering the interconnected nature of learning experiences.

4. KESIMPULAN DAN SARAN

This study provides compelling evidence that adaptive Educational Game-Based Learning significantly enhances university students' learning experiences in higher education contexts. The research demonstrates that well-designed educational games incorporating adaptive difficulty systems, interactive mechanics, and collaborative features create engaging learning environments that positively transform how students experience learning. Students who engaged with the Educational Game-Based Learning reported substantial improvements in motivation, cognitive development, and social interaction, confirming that game-based approaches can address the engagement challenges commonly associated with traditional instruction methods.

The theoretical contribution of this research lies in its rigorous empirical validation of constructivist, experiential learning, and flow theories within digital gaming contexts. By employing Structural Equation Modeling, this study moves beyond simple correlational analyses to establish robust structural relationships between game design elements and learning outcomes. The findings extend existing theories by demonstrating that adaptive systems can maintain optimal challenge levels that sustain student engagement over extended periods, while interactive narratives facilitate the experiential learning cycle from concrete experience through reflective observation to practical application. This study also contributes context-specific evidence from Indonesian higher education, addressing a significant geographic gap in educational technology research and suggesting that game-based learning principles hold cross-cultural validity.

From a practical perspective, this research offers actionable insights for multiple stakeholders in higher education. Educational institutions should view adaptive game-

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based learning platforms not as supplementary entertainment but as evidence-based pedagogical tools worthy of strategic investment and curriculum integration. The success factors identified—clear learning objectives, intuitive interfaces, appropriate difficulty levels, and collaborative features—provide a practical framework for evaluating and selecting educational games. Instructors can leverage these findings to enhance their teaching by integrating games as practice and application tools while maintaining traditional instruction for foundational knowledge, creating blended learning environments that capitalize on the strengths of both approaches. For educational technology developers, this research highlights the critical importance of balancing entertainment value with educational effectiveness, implementing adaptive algorithms that personalize learning experiences, and designing social features that foster peer learning and collaboration.

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