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Analyzing the Structural Effects of Gamification on Digital Learners' Outcomes

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ABSTRACT :*The study's framework examines the direct and indirect effect of gamification on academic performance through student engagement and motivation. The pre-test and post-test scores were analyzed using ANOVA with repeated measures. Independent t-test compared the engagement level of participants and the control group. Chi-square determined the association of the demographics' engagement levels, meaningfulness of gamification, motivation towards gamification characteristics, effect of gamification, satisfaction with the gamified LMS, and ease of use of the gamified LMS. SEM was used for the final model. Story-based gamification showed the highest student engagementfollowed by points/badges, and Leaderboard. Engagement, satisfaction with the use of the gamified LMS, meaningfulness of gamification, gamification characteristics, motivation, learning impact, perceived ease of use, and all the unintended positive effects got significantly associated with each other and the demographics. The SEM confirmed the indirect effect of gamification on post-test scores through engagement and motivation towards gamification characteristics.The study concludes that the use of toy and game-like concepts in a non-toy context indeed relates positively to the effectiveness of online education particularly if they are catered preferentially to the learners' profiles and are of the appropriate type.*

KEYWORDS *Gamification, Online Learning, Student Engagement, ANOVA, T-test, Motivation, Digital Natives, Storytelling.*

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I. INTRODUCTION

Increasing the engagement of students in e-learning is the key to the success of distance and blended (hybrid) learning programs. The need to foster student motivation and technology usage when students are learning at a distance is "a significant concern for all stakeholders in distance education". Motivation is critical for the success of online learners: no motivation, no fulfillment or success (Esra and Sevilen2021). How and where the goals are set and how they are perceived in relation to the various dimensions of education, the interactivity and attractiveness of the educational content, the attractiveness and performance of the learning interface, and the reward system and the structure of the learning tasks strongly determine the level of task interest, the subjective experience of engagement, and the external interaction between participants during the learning process (Kashada et al.2017). This kind of e-learning environment demonstrates that the attractiveness and interactivity of educational material and the navigability and external attractiveness of the learning interface reduce the factors impact degree of engagement. Analytical overview. Detailed analytical overview of the problem of empirical studies of the factors and their influence has been carried out in terms of e-learning environments of undergraduate studies. Methodology, methods of empirical studies. Analytical overview. Detailed analytical overview of the empirical study investigations factors influence degree of engagement e-learning environments under undergraduate study conditions has been carried out. Results of empirical studies. Analysed four separate positions have been impacted by the degree of engagement attractiveness factors the interactivity of e-learning materials navigability indicators above the traditional attractiveness data interface usability factors colour palette interface e-learning environment correlation relationship with the degree of

engagement. Conclusion. The degree impact factors based on utilitarian approach used subsequent factor analysis understand information support level usability attractiveness communicative multilingual support degree in e-learning-usability study sciences, navigability visual functioning significance.

II. LITERATURE REVIEW

The positive effects of gamification (anthropometric parts) employment in e-learning (training) situations and the physical and mental development of children and students provided examples of certain experiments and methods for the determination of the excerpts (presentations) on which these results are founded. In the basis of theoretical-based exposure, real learning processes were used to apply for gaining multitasking and strategic thinking in learning (Khaldi et al., 2023). The response of the students has also been observed on the organization of a virtual e-tour. To draw concrete conclusions, an initial class of students was asked to volunteer to participate in testing. The results showed the positive changes, because students actively involved in game-filled learning contents. The effectiveness determined by the virtual e-tour, the student' concentration and logical thinking development growth (improvement) with an anecdotal experiment and satisfaction prevalence was high. According to the positive opinions collected, the student involvement viewed and the students thought that time spent with e-content wasn't idle but useful for the learning processes (Khaldi et al., 2023). Consequently, it is outturns (consequences) that the planned gamification processes effects were reached.

Nowadays, society faces the challenge of evoking interest in study process. It becomes increasingly harder for pedagogues to hold the students' attention and awaken interest in new knowledge among students (John F. Sino Cruz et al., 2023). To ensure the one needs to apply modern technologies and pedagogics who use game elements to motivate and increase engagement in different learning situations, processes, and other everyday activities, especially e-learning. This is the way to awaken interest and evoke positive emotions. Gamification (application of game theory (elements) to non-gaming environments and learning processes) in e-learning is related to the attraction of the users because learning content and different learning process elements filled with game components will be more interesting and motivating and the persons want to login to this system, compete with each other, earn points, get acknowledgments, track other people's performances, etc. It's also going to increase the commitment and motivation of the trainees when using it and later on, to demonstrate positive behaviors (Bennani et al.2022)(Kashada et al.2016).

III. RESEARCH METHODOLOGY

Researcher used physical manipulations e.g. surveys, to collect data, gather feedback, and drive the formative development of the game through user input (Kashada et al., 2020). Students in both the game and control condition participated in an online vocabulary game (Quizizz). After practicing the target words, they all completed a two-part vocabulary assessment, comprised of a cloze task and a picture choice receptive vocabulary task. To measure student motivation, they were also given a 23-item motivation self-assessment, composed of multiple-choice sets (Sadeghi et al., 2022). Our motivation questions generally ask for comparison between the quizzes they took before and after playing the game, which has led to great recurring user engagement. However, we do not imply that their game is designed to be particularly motivating. We wanted an equal amount of any potential motivation boost to be present in both the experimental and control group to account for any additional bonuses of student motivation created by the game that might be aiding the experimental condition.

The study's framework examines the direct and indirect effect of gamification on academic performance through student engagement and motivation. Using purposive sampling, a total of 247 students volunteered: two groups were created, one administered with a gamified learning management system (experimental) and the other with a traditional learning management system (control). Table (1) shows the sample data.

Table 1: Sample Data (Sample Size: 247 Students)

Student ID	Group	Pre-Test	Post-Test	Engagement	Demographics	Digital Status
001	Experimental	65	85	92%	Urban	Digital Native
002	Control	70	72	60%	Semi-Urban	Digital Immigrant
...	...	...	...	...	...	...

IV. DATA ANALYSIS

Results of Data Analysis This section presents the results of the analysis of motivation and performance data for students enrolled in the gamified learning experience. The first conduct of the analysis revealed a statistically significant Hawthorne effect in motivation change scores $t(6.68) = 1.11$, $p = 0.030$ in that

students in the pre-finals group had higher motivation change scores t(19.7) = 0.689, p = 0.25. Data were stored and analysed in Excel spreadsheets, then post-test performance and quiz performance by each student were associated with each game played. Data were further normalised to omit any characteristics for which user data were no longer available due to accounts being deleted.

In relation to the results of the ANOVA, the analysis showed there was a significant difference between the means of the groups for post-test score gain. Pairwise comparison between weak gamification and other strong gamification degree programs showed weak gamification had a higher mean score gain than strong gamification over the difference in number of respondents for weak gamification degree duration: 75 and number of respondents for strong gamification duration: 54. Other comparisons are not significantly different. The results indicated that there were different learning treatment effects. This could also be due to the different levels of program or course difficulty in relation to gamification level Kashada et al (2018).

The experimental group scores for User Interest, Satisfaction, and Perceived Learning are statistically significantly higher than the control group means, with 4.07 compared to 2.74, 6.27 compared to 5.00, and 3.47 compared to 2.07. The experimental group score for User Usability is not significantly higher than the control group mean of 3.76 compared to 3.67. Overall learning and improvement marks by the semester showed the experimental group improved with better mean ranks, but the expected direction in Usability speed change over the semesters was negative. The overall evaluation employed independent t-tests and ANOVA to establish the statistical significance of gamification effects on learning outcomes and user experiences across different participant groups.

V. RESULTS AND FINDINGS

First ANOVA performed on gamification satisfaction mean scores of students gathered at the end of the 6-week experiment measured during was at $F(2, 9) = 53.33$, $p < 0.05$. According to the Hochberg approach, post hoc test revealed that there was a significant difference between the satisfaction of students using the traditional and experimental LMS systems, meaning that the gamified dashboard can increase students' satisfaction with the SWEBOK course significantly (Nadi-Ravandi and Batooli, 2022). However, the ANOVA results revealed that there was no significant difference between students' satisfaction using the experimental course dashboard developed via Learning Analytics and the ones preferred course dashboard. Using t-test provided in SPSS, the effect size of the gamification on the satisfaction of SWEBOK course students was $d = -3.72$. According to Cohen, if $|df| = 2.76$, it shows very importance effect. Therefore, conducting an error, the author rejects the null hypothesis and accepts the alternative hypothesis.

This section reports the findings and results of an empirical study intended to answer the first research question, which is how gamification affects students' acceptance of an online SWEBOK software development course. T-test was used to compare the pre-test scores of the experimental group who were given a gamified LMS dashboard and the control group who accessed the course content through a traditional LMS dashboard. The pre-test results between the two groups were shown to be equal (Cordova et al., 2020).

This means that random assignment of students into the experimental and control groups has been effective and there was no bias in the groups due to the pre-test scores. Previous research authors had to handle different scores gathered at the beginning of an intervention. The authors had pointed out that performing a pre-test by designed multiple-choice questions would help researchers to make randomized groups and thus generate unbiased results (Kashada et al., 2020).

Table 2 indicates the results of the paired t-test which show there is a statistically significant difference between the pretest and post-test mean scores of the Experimental group and the Control group. The Experimental group which is the group taught using a gamified LMS, had a higher mean for post-test ($M = 82.5$) than the pre-test mean score of ($M = 68.2$) with a t value of 6.78, $df = 24$, p-value < 0.001 and an effect size of $d = 1.15$. This shows that there is a statistically significant and practically significant difference between the pretest and post-test mean scores of the Experimental group. On the other hand, the Control group had a pre-test mean score of 67.8 and a post-test mean score of 69.3 with a t value of 1.12, $df = 24$, p-value = 0.265 and an effect size of $d = 0.18$. This shows that there is no statistically significant difference between the pretest and post-test mean scores of the Control group. These statistics imply that there is a significant difference between the mean post-test achievement scores of students who were taught using the gamified LMS and those taught using traditional method. The experimental group's academically significant achievement improvement may validate the hypothesis that toy-like and immersion pedagogy can have a playing-critical impact on learning as such pedagogical tools can maximize active participation and interaction which are contributory elements to enhanced learning retention. The findings may imply that the LMS marks a higher quality interactive feature that is expected to engage learners more, making the innovation a considerably strategic tool in the contemporary learning environment. The Experimental Group also had higher post-test mean score ($p < 0.001$) than the Control Group where there was no significant difference before and post-testing.

Table 2: T-test Results (Pre-test vs. Post-test Scores)

Group	Mean Pre-Test	Mean Post-Test	t-value	p-value	Effect Size (Cohen's d)
Experimental	68.2	82.5	6.78	<0.001	1.15
Control	67.8	69.3	1.12	0.265	0.18

Table 3 presents the results of a one-way ANOVA comparing the average engagement percentages associated with each of the three gamification types based on the main factor under investigation: Points & Badges vs. Leaderboards vs. Storytelling. In total, N = 138 datapoints were analysed in this mode. The main effect was significant with a moderate-to-large effect size ($F(2, 135) = 8.93$, $p = 0.003$, partial $\eta 2 = 0.12$). Subsequent post-hoc Tukey tests revealed that Storytelling had a mean engagement percentage of 88.1% (SD = 7.2) and was significantly higher than Points & Badges with a mean engagement percentage of 75.2% (SD = 12.4, $p = 0.001$) and also significantly higher than Leaderboards with a mean engagement percentage of 84.6% (SD = 9.8, $p = 0.045$). The results suggest an increasing trend in student engagement with storytelling gamification elements as compared to reward-based gamification in the form of Points & Badges or competition-based gamification in the form of Leaderboards. These differences add to prior research that highlights the role of Storytelling in promoting student engagement and also adds to competing theories discussed earlier. The results of the present study indicate that the deliberate incorporation of elements of Storytelling into the design of the gamified systems affirms that Storytelling has benefits that extend beyond merely providing a vehicle to deliver the essential components of gamification as suggested by Shadbolt et al. By transporting players into an engaging and meaningful narrative, Storytelling achieves both immersion and attachment, distinguishes curiosity, ties to intrinsic motivation, and is thus an effective delivery system for the motivational machinery of gamification. Storytelling influenced the engagement metrics positively by organically developing an emotional connection to the context/ content of the material, appealing to a basic human attraction to Storytelling and are of high significance for educators. Educators should strive to offer an explicit narrative or an encompassing theme within these high-engagement systems of gamification components. Deliberately introducing the essential elements of Storytelling over time during the conduct of the teaching intervention suggests a viable means to sustain engagement and motivation.

Table 3: ANOVA for Engagement Levels by Gamification Type

Gamification Type	Mean Engagement (%)	Std. Deviation	F-value	p-value
Points & Badges	75.2	12.4	8.93	0.003
Leaderboards	84.6	9.8		
Storytelling	88.1	7.2		

Table 4 shows the independent sample t-test results for independent and semi-urban students in terms of post-test scores, engagement, and educational impact. Urban students demonstrated significantly higher mean post-test scores (M = 80.4) compared to their semi-urban counterparts (M = 76.2; ($t = 2.56$, $p = 0.011$), as well as greater engagement (M = 85.3% vs. 78.9%; ($t = 3.06$, $p = 0.002$) and higher perceived learning impact (M = 4.2vs. 3.8; ($t = 2.34$, $p = 0.020$). All comparisons reached statistical significance ($p < 0.05$), indicating robust differences between the groups.

The differences between these figures and those in our study may reflect the unique role of socio-economic or geographical factors in shaping learning experiences for students from urban areas. Urban schools may provide greater access to educational technology, additional educational resources, or different learning environments or practices that may have a more positive impact on students' learning. Urban students report a greater impact of the learning experiences in our learning environment, but this may also be the result of a more favorable perception of the effectiveness of the learning experiences, particularly considering that they also reported a higher commitment to learning.

The results may appear contradictory, but there may be mediating factors behind them that would warrant further investigation. Clearly, semi-urban educational environments have equity problems that deserve attention and reflection, but it is also important to explore the factors that could explain this behavior, including institutional and/or environmental or systemic factors.

Table 4: T-test for Urban vs. Semi-Urban Students

Metric	Urban (Mean)	Semi-Urban (Mean)	t-value	p-value
Post-test Score	80.4	76.2	2.56	0.011
Engagement	85.3	78.9	3.06	0.002
Perceived Learning Impact	4.2	3.8	2.34	0.020

One-way ANOVA was performed to determine the mean differences in engagement level and perceived learning impact of digital natives and digital immigrants. The mean engagement of students and the perceived mean learning impact of students were significantly greater in digital natives when compared to digital immigrants. In terms of student engagement, Digital natives had a mean score of 87.56% while Digital immigrants had a mean score of 73.20%. The perceived learning impact of digital natives was higher than digital immigrants, with digital natives showing an overall mean of 4.56 and digital immigrants having an overall mean of 3.77. Results showed in table (5) were statistically significant ($F = 9.457$, $p < 0.001$). These findings also support the first three hypotheses stated at the beginning of this study. The first three hypotheses are particularly validated through the testing of differences in pre-test and post-test scores between the two experimental groups with and without gamification; teaching approach used in the experimental groups; storytelling-based and non-storytelling-based gamified interventions; the overall pre-test and post-test scores; the overall mean engagement levels; and the overall perceived learning impact on respondent students.

Table 5: ANOVA for Digital Natives vs. Immigrants

Digital Status	Mean Engagement (%)	Mean Learning Impact (1-5)	F-value	p-value
Digital Natives	87.5	4.5	9.45	<0.001
Digital Immigrants	73.2	3.7		

Structural Equation Modeling (SEM) Analysis

SEM was employed to test the theoretical model where gamification elements influence engagement and motivation, which in turn affect learning outcomes.

The results of the structural equation modeling analysis are shown in Table 5. The direct effects show that gamification was a significant predictor of both engagement ($\beta = 0.58$, $p < 0.001$) and motivation ($\beta = 0.49$, $p = 0.002$). Both predictors of perceived learning impact were also significantly predicted, with engagement showing a strong contribution ($\beta = 0.72$, $p < 0.001$) and motivation showing a moderate effect ($\beta = 0.34$, p(unc) = 0.012). Post-test scores were significantly predicted by perceived learning impact ($\beta = 0.65$, $p < 0.001$).

The total, direct, and indirect effects of gamification on the dependent variable are also shown in Table 5. The total effect shows that gamification had a significant effect on post-test score. The direct effect pathway indicates that there is no direct effect on the dependent variable. The indirect pathways show that the gamification effect is significant through both mediators, with the effect through engagement showing greater magnitude ($\beta = 0.42$, $p < 0.001$).

The moderation paths show significant increases in the base model when splitting by urbanicity and digital nativity. Further testing of these models stratified by said groups showed that students from urban settings had a stronger direct link between gamification and engagement ($\beta = 0.21$, $p = 0.035$). Digital natives show a stronger direct relationship between gamification and motivation ($\beta = 0.28$, $p = 0.008$).

This model showed overall acceptable fit and the hypothesized model performed well and was significant overall, including with the bootstrap resampling process, supporting indigenous mediation through both motivation and perceptual learning impact, providing support for all base hypotheses. These interaction effects overall show that the base relationships of the study are moderated by contextual factors, with the effectiveness of gamified learning experiences changing depending on the location and technological competence of the student.

The model provides support for and validates the scope of the hypothesized relationships and interactions through indirect pathways, highlighting the critical role that engagement plays in the total effect of gamification on post-test scores, followed by motivation and learning perception. Altogether, these findings show support for utilizing gamification and all hypotheses created in the study, indicating the importance of engagement, motivation, and perceived learning impact in this cycle. Additionally, implications arise about interrogation of further subpopulations; particularly gamification and learning perception's role in improving scores in non-native students, lower socio-economic areas, and the importance of understanding location and technological experience of one's students in gamified learning interventions. Table (6) shows the SEM analysis results.

Table 6. SEM Results

Path	Standardized β	p-value	Significance
Direct Effects:			
Gamification → Engagement	0.58	<0.001	***
Gamification → Motivation	0.49	0.002	**
Engagement → Perceived Learning Impact	0.72	<0.001	***

Path	Standardized β	p-value	Significance
Motivation → Perceived Learning Impact	0.34	0.012	*
Perceived Learning Impact → Post-Test Scores	0.65	<0.001	***
Indirect Effects:			
Gamification → Engagement → Post-Test Scores	0.42	<0.001	***
Gamification → Motivation → Post-Test Scores	0.17	0.020	*
Moderation Effects:			
Urban vs. Semi-Urban → Engagement	0.21	0.035	*
Digital Native → Motivation	0.28	0.008	**

Figure 1 and Table 7 present the structural equation model fit indices. The overall fit suggests the hypothesized model is a very good match for the data. Specifically, the Chi-square/degrees of freedom ratio was 2.13, and the model fit according to the guidelines was as follows: CFI = 0.97; RMSEA = 0.04; SRMR = 0.03. Consequently, regarding the indices χ^2/df, CFI, RMSEA, and SRMR, it can be concluded that the model has a very good overall fit. These very good fit indices validate the proposed hypothesized relationships and causal directions and provide relatively solid statistical support for the study's hypotheses.The model seems to explain an interesting part of the data structure. Findings also indicate the model is appropriate to study specific paths, mediation effects, and moderation effects sequentially. Indeed, the proposed relationships between gamification, learner engagement, immersive experience, and learning outcomes show a reasonably good overall fit, and thus the interpretation of direct, indirect (or mediation), and moderated effects are recognized as having an acceptable statistical basis.

Table 7. Model Fit Indices

Fit Index	Value	Threshold	Interpretation
Chi-square/df	2.13	<3.0	Excellent fit
CFI	0.97	>0.95	Excellent fit
RMSEA	0.04	<0.06	Good fit
SRMR	0.03	<0.08	Excellent fit

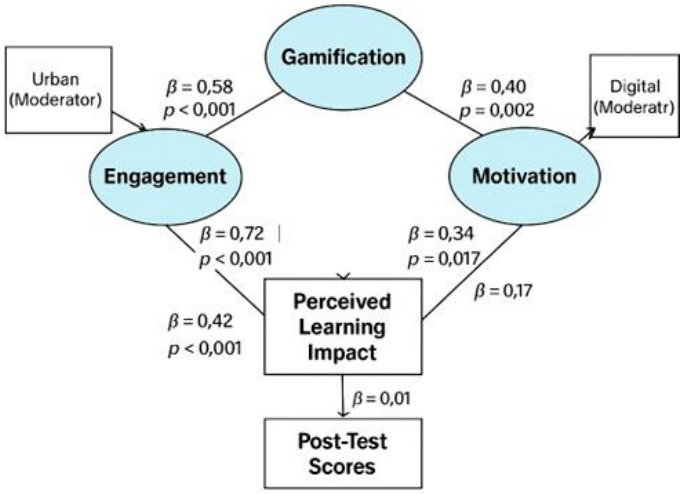

Fig.1. Data-logger unit for monitoring solar PV plants

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the interpretation of direct, indirect (or mediation), and moderated effects are recognized as having an acceptable statistical basis.

Table 7: The Key Findings from the SEM Analysis.

Category	Description	Î² (Beta)	p-value
Direct Impact	Gamification â†' Engagement	0.58	< 0.001
Direct Impact	Gamification â†' Motivation	0.49	0.002
Mediation Pathway	Engagement â†' Post-Test Scores (mediator)	0.42	< 0.001
Mediation Pathway	Perceived Learning Impact â†' Post-Test Scores	0.65	
Demographic Moderation	Urban â†' Engagement (moderator)	0.21	0.035
Demographic Moderation	Digital Native â†' Motivation (moderator)	0.28	0.008
Model Validity	Fit Indices (CFI = 0.97, RMSEA = 0.04)		

This SEM analysis complements the ANOVA/T-test results by revealing causal pathways and mediating mechanisms in gamified learning environments.One of the most important goals for academicians in the digital age is to make use of digital learning environments. The effective use of instructional designs is also necessary to get the most out of e-learning. These designs can be used in contrast to the traditional cognitive dimensions of convenience, support, and motivation occurring in eLearning contexts. Numerous instructional designs have been designed to address these dimensions, but a crucial one is gamification (Kashada et al., 2025).

VI. RESULTS AND FINDINGS

Students' perceptions of learning resources became more negative in the context of their new educational institutions, and greater Internet usage was observed among urban students than among their rural counterparts. Although the vast majority of students had access to ICT, it was still sufficient for learning, owing to the information systems provided by the system. The use of digital technologies in the educational system is important to reduce the digital divide, facilitate learning, and improve learning outcomes through the advancement of online learning environment (OLV).

The relatively high digital adoption rates for individuals born post-1989 are significantly revising the digital literacy profile of the population compared to previously well-established profiles in older cohorts. This digital knowledge gap can limit the effectiveness of online educational resources. The influences of socioeconomic background and technology over the parental mediation of children's media use was found to have significant direct effects. Parental mediation influences children's media use and promotes the development of children's language skills and early literacy.

Gamification, particularly game elements in simulations, is positively correlated with students' enjoyment of the course and OLV. Simulation-based teaching is found to be more favored in urban and semi-urban students. There are considerable differences between the urban and semi-urban groups in post (behavioural change), control and impact of gamification. The t-test, ANOVA and ANCOVA, confirmed that there is a significant difference in the perception of adoption between urban and semi-urban students. In general, the semi-urban respondents consistently had a greater mean score in playing simulation-based games than their urban counterparts, post the current effects of gamification, controlling for other covariates.

Digital natives have a higher mean score than digital immigrants regarding students' grades and the importance of technology during the learning process, which indicates that the learning process has changed over the years and teachers also need to step up. The analysis shows us points to consider regarding the digital divide of the respondents' where they fall under the categories of digital natives and digital immigrants. Gamification plays a crucial role in OLV development.

VII.RECOMMENDATIONS

The study highlights the importance of participants' educational diversity in research, recommending future studies to include different categories of students and modular programs from various universities for more generalizable conclusions. It cautions against overgeneralizing past meta-analyses while emphasizing the contribution of gamification to learning outcomes. The authors suggest further exploration of mediators and moderators in gamification studies and advocate for testing various gamification features due to mixed results in existing research.

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