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Improving Learning Experience of High School Gen Z by Designing the Student Worksheet Using Gamification, Augmented Reality, Emotional Design, and Storytelling

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ABSTRACT

The development of digital technology has transformed the learning behaviors of Generation Z, who prefer interactive, visual, and experience-based learning. Conventional models, such as lectures and text-based student worksheets (LKS), are less effective at maintaining motivation and engagement. This study aims to develop and evaluate the effectiveness of a gamified LKS, enriched with storytelling, emotional design, and augmented reality (AR), at SMA Plus Muthahhari Bandung. A Participatory Action Research (PAR) approach was employed, involving teachers, students, and the school principal as active partners throughout each phase. A total of 30 students, consisting of 14 males and 16 females from grades X, XI, and XII, participated in the trial and completed a Likert-scale questionnaire ranging from 1 (strongly disagree) to 5 (strongly agree). The findings indicate that four key dimensions—Engagement and Motivation, Learning Experience, Technical Aspects, and Visual Gamification Elements—achieved mean scores above 4 with high reliability (Cronbach's α ranging from 0.845 to 0.948). The t-test revealed significant gender differences in Learning Experience and Technical Aspects, while the ANOVA test across grade levels showed no significant differences. The AR-based gamified LKS proved effective in enhancing focus, motivation, and the overall learning experience.

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1. INTRODUCTION

The rapid advancement of digital technology has significantly reshaped educational practices and learner behaviour in the twenty-first century. Generation Z, commonly defined as individuals born between 1996 and 2010, represents the first cohort to grow up fully immersed in digital environments (Hernandez-de-Menendez et al., 2020; Rosenberg et al., 2025). Being around mobile devices, multimedia platforms, and interactive content all the time has changed the way they think, talk, and learn (Szymkowiak et al., 2021). Compared to previous generations, Gen Z learners tend to prefer visually rich, interactive, and experience-based learning environments rather than conventional lecture-driven instruction and text-heavy materials (Angelova et al., 2025; Erişen & Bavlı, 2026).

Several studies highlight that Generation Z demonstrates shorter attention spans and a stronger inclination toward multimodal and participatory learning formats (Hegade & Shettar, 2022; Buzzetto-Hollywood & Quinn, 2024; Choudhary & Pandita, 2024). Traditional student worksheets, commonly referred to in Indonesia as Lembar Kerja Siswa (LKS), which primarily rely on written explanations and static exercises, are increasingly perceived as insufficient in maintaining motivation and sustained engagement. As a result, educational institutions are challenged to redesign learning media that not only convey content effectively but also align with the cognitive and behavioral characteristics of digital-native students (Rosenberg et al., 2025).

SMA Plus Muthahhari Bandung (Figure 1), established in 1992 and recognized for its emphasis on character and spiritual education, faces similar challenges. Despite the school's integration of national curriculum standards with foundation-based programs, lecture-based delivery and conventional assignments largely dominate classroom practices. Observations indicate that this approach does not fully resonate with students' learning preferences in the digital era, as many students prefer interactive and technology-enhanced learning experiences that engage them more effectively. The need for innovation becomes more urgent as schools seek to remain pedagogically relevant while maintaining their educational identity.

Figure 1. SMA Plus Muthahhari Bandung.

In response to these challenges, this study explores the redesign of the student worksheet (LKS) by integrating four complementary approaches: gamification, emotional design, storytelling, and augmented reality (AR) (Smiderle et al., 2020). Gamification introduces structured goals, points, and rewards to stimulate motivation and participation (Radu, 2014). Emotional design strengthens learners' affective connection to content, while storytelling provides narrative coherence that supports understanding and memory retention (Mulcki et al., 2023). Augmented reality enhances interactivity by bridging printed materials with immersive digital visualization, allowing learners to engage with content in a more dynamic way and facilitating deeper understanding of complex concepts. The integration of these elements aims to transform the LKS from a

static instructional tool into an engaging and meaningful learning medium.

This study, therefore, seeks to examine how a gamified and AR-integrated student worksheet can enhance the learning experience of Generation Z students at SMA Plus Muthahhari Bandung. By positioning instructional design as a holistic integration of motivational, emotional, visual, and interactive components, the research contributes to ongoing discussions on how learning media can be adapted to meet the demands of contemporary digital-native learners.

2. LITERATURE REVIEW

Technological changes and generational characteristics continually shape educational practices. For Generation Z, learning is no longer limited to text-based materials or one-directional instruction. These learners, accustomed to interactive platforms, visual storytelling, and instant feedback, grew up in a digital ecosystem (Korobkova et al., 2025). This background influences how they focus, process information, and remain engaged. Consequently, instructional media that rely solely on static explanations and repetitive exercises often struggle to maintain sustained attention, leading to decreased engagement and retention of information among learners (Chardonnens, 2025). Effective learning tools for this generation need to create experiences, not merely deliver content (Cilliers, 2021).

Gamification has been extensively examined as a tactic to address this transition (Saxena & Mishra, 2021). Incorporating elements such as points, levels, missions, and rewards can structure learning activities to encourage goal setting and persistence. Rather than positioning students as passive recipients of information, gamified environments invite them to participate actively and track their progress (Conlin & Santana, 2022; Antal-Berbecaru et al., 2024). However, the value of gamification does not lie simply in adding reward mechanisms. The true power of gamification lies in the meaningful integration of these elements into instructional objectives, fostering motivation through purposeful engagement rather than superficial competition.

At the same time, emotional design and storytelling contribute dimensions that extend beyond motivation alone. Emotional design shows how the clarity, beauty, and ease of use of visuals affect how comfortable and connected learners feel to learning materials (Nordin et al., 2021). When students feel visually and emotionally connected to a medium, they are more likely to remain involved and interpret the experience as meaningful (Tomita, 2022). Storytelling further strengthens this connection by introducing narrative flow—through goals, challenges, and resolution—that naturally sustains curiosity (Lin & Chang, 2021). A structured narrative helps students situate abstract concepts within relatable contexts, making the learning process feel coherent rather than fragmented.

Augmented reality (AR) adds another layer to this changing world. By blending printed materials with interactive digital visualization, AR transforms conventional worksheets into exploratory learning environments (Coştu, 2025; Crogman et al., 2025). Students are not only reading or answering questions but also scanning, observing, and interacting with visual simulations. Studies in educational technology indicate that immersive experiences can improve focus and conceptual comprehension, especially for learners who are highly responsive to

visual and spatial representations. When used wisely, AR doesn't take the place of traditional teaching; instead, it makes it more dynamic (AlNajdi, 2022).

Innovative learning media may also influence the perception of educational institutions beyond classroom dynamics (Yanti, 2022). Schools often face evaluation in increasingly competitive educational settings based on their ability to demonstrate relevance, creativity, and adaptability. Well-designed, interactive learning materials signal pedagogical innovation and responsiveness to contemporary needs (Gamaliia et al., 2024). When such practices are communicated through digital platforms or institutional networks, they may strengthen the school's image and attract prospective students and parents (Bungai et al., 2024; Hasanudin et al., 2024). In this sense, the development of effective learning media contributes not only to improved engagement within the classroom but also to institutional sustainability by reinforcing educational identity and public trust.

3. RESEARCH METHODOLOGY

3.1. Research Approach

This study employed a Participatory Action Research (PAR) approach (Cornish et al., 2023), emphasizing active collaboration among researchers, teachers, students, and the school principal at every stage of the process. All participants acted not as passive respondents but as co-designers and evaluators in the development of the gamified Student Worksheet (LKS). This approach was chosen to ensure that the innovation outcomes are relevant to the school environment and can be implemented independently by teachers. The research process was structured into five interrelated phases as follows:

a) Plan

The initial phase began with a survey conducted on August 22, 2025, to identify student characteristics and classroom learning habits. Meetings with the principal and teachers were held to align the program's objectives and expected benefits. Between September 15 and 18, 2025, teachers prepared subject-specific materials to be adapted into creative Student Worksheet (LKS) prototypes, forming the foundation for subsequent design and implementation stages (**Figure 2**).

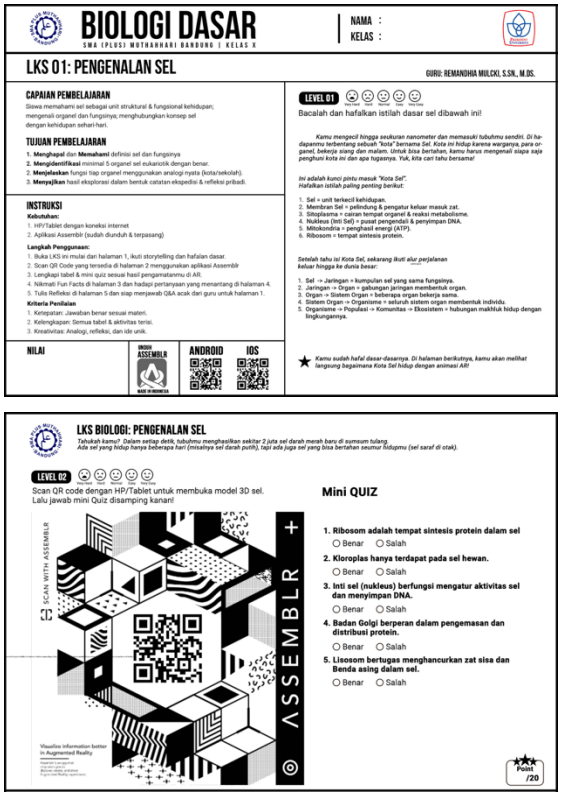


Figure 2. Example of Student Worksheet (LKS) Prototypes.

b) Act

The workshop was conducted on September 19–20, 2025, involving 16 teachers from SMA Plus Muthahhari Bandung (**Figure 3**). The sessions introduced key topics, including Gen Z learning characteristics, gamification strategies, emotional design principles, storytelling techniques, and the

integration of Augmented Reality (AR) using the *Assemblr* application. The training combined presentations with hands-on collaborative practice, allowing participants to directly apply new concepts.

Figure 3. Workshop for Teachers.

Ten teachers actively created LKS designs, which later evolved into eight prototypes across various subjects. The workshop atmosphere was dynamic and cooperative, fostering collaboration between senior and junior teachers, although some technical challenges were encountered due to limited laptop specifications, which hindered the efficiency of the design process and required additional support from the facilitators.

c) Observe

The trial phase was conducted on September 21–22, 2025, across three grade levels—X, XI, and XII—with a total of 30 students, including 14 males and 16 females. The participants consisted of 9 students from Grade X, 12 from Grade XI, and 9 from Grade XII.

Figure 4. Trial Phase in the Classroom.

Each session lasted 80 minutes and integrated both conventional and interactive activities, such as scanning QR codes, completing point- and level-based missions, and engaging with storytelling-based learning narratives. Teachers and the school principal acted as observers, documenting students' participation, interactions, and responses throughout the learning process (**Figure 4**).

d) Reflect

After the trial, all the students filled out a five-point Likert scale questionnaire (1 = strongly disagree, 5 = strongly agree) to reflect on what they had learned. The data were used to evaluate the effectiveness of the LKS in terms of engagement, motivation, learning experience, and technical quality. Qualitative data were analysed to capture classroom dynamics and students' emotional responses, while quantitative data gave quantifiable insights into user perceptions of media effectiveness.

Findings revealed strong enthusiasm from both students and teachers, accompanied by feedback regarding the clarity of instructions and time allocation. These insights guided improvements in the visual layout, activity sequence, and emotional design of the LKS (Learning Knowledge System) before the next implementation cycle. The PAR framework fostered a reciprocal learning process between teachers and researchers (Xin & Brion-Meisels, 2024). Through iterative cycles of action, observation, and reflection, this study not only produced an innovative learning medium but also enhanced teachers' capacity to independently design and evaluate technology-based worksheets.

e) Data Analysis

Quantitative analysis was performed to assess students' responses subsequent

to the classroom implementation of the gamified LKS. Data from 30 students were analyzed descriptively to identify overall response tendencies across four dimensions: Engagement and Motivation, Learning Experience, Technical Aspects, and Visual Gamification Elements. Mean scores and standard deviations were calculated to provide an overview of students' perceptions.

Table 1. Questionnaire Structure and Measured Dimensions

Dimension	Question
Engagement and Motivation	I was able to maintain focus during the learning session.
	The tasks in the LKS increased my motivation to complete the activities.
	The learning activities encouraged me to stay actively involved.
Learning Experience	The learning session felt enjoyable.
	The time passed quickly during the activity.
	The learning experience felt meaningful.
	Overall, I accepted and appreciated this learning approach.
Technical Aspects	The LKS was easy to use.
	The LKS had an attractive appearance.
	The activity flow was clear and easy to follow.
Visual Gamification Elements	The points, levels, and reward system increased my enthusiasm.
	The storytelling elements helped me understand the material better.
	The emotional and visual design made the learning more engaging.

The questionnaire consisted of 13 items distributed across the four dimensions, as presented in **Table 1**. All items were measured using a five-point Likert scale (1 = strongly disagree, 5 = strongly agree).

To assess the instrument's internal structure, Principal Component Analysis (PCA) and Factor Analysis (FA) with varimax rotation were performed. Factors with eigenvalues above 1.0 were retained, and factor loadings exceeding 0.70 were considered acceptable. Internal consistency was evaluated using Cronbach's alpha.

Inferential analysis was subsequently applied to explore perceptual differences across demographic groups. An Independent Samples t-test was conducted to compare male and female students, while a One-Way ANOVA was used to examine differences across grade levels (X, XI, and XII). A significance level of 0.05 was adopted for all statistical tests.

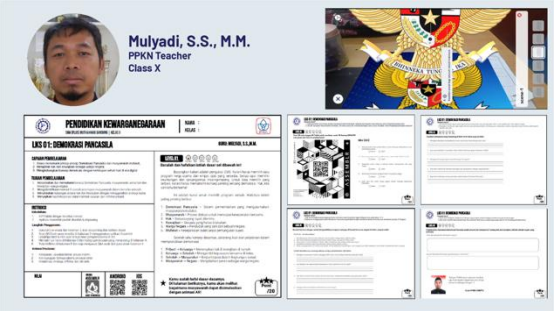
4. RESULTS AND DISCUSSION

The program produced eight Student Worksheets (LKS) developed through a design approach that combined gamification, storytelling, emotional design, and augmented reality (AR) using the Assemblr application. The products were created through a two-day workshop attended by 16 teachers from SMA Plus Muthahhari Bandung, with 10 teachers directly involved in the prototype development process (**Figure 5**).

Figure 5. Teachers' Workshop.

The eight LKS covered a range of subjects, including Biology, Civics (PPKN), Indonesian History, Sociology, Indonesian

Language, Economics, French Language, and Geography (**Figure 6**). The classroom trials were conducted across three grade levels—X, XI, and XII—with a total of 30 students participating as research respondents.



(a)

(b)

Figure 6. Output of Student Worksheets (LKS) from the Teacher Workshop: (a) PPKN Teacher, (b) Indonesian History Teacher.

4.1. Analysis of Student Responses to Gamified Worksheets

As shown in **Table 2**, the analysis revealed that all indicators across the four main dimensions achieved mean scores above 4, indicating a strong positive response from the students of SMA Plus Muthahhari Bandung toward the implementation of gamified Student Worksheets (LKS). Additionally, all items demonstrated loading factors above 0.7, confirming that each statement was strongly correlated with its respective construct and exhibited sound construct validity.

Table 2. Mean Scores and Factor Loadings Across Four Learning Dimensions.

Dimension	Scale	Mean	Loading Factor
Engagement & Motivation	Focus during Learning	4.14	0.949
	Task Motivation	4.21	0.932
	Learning Activity	4.11	0.976
Learning Experience	Perception of Time	4.11	0.744
	Enjoyment	4.32	0.901
	Meaningfulness	4.07	0.817
	Overall Acceptance	4.07	0.889
Technical Aspects	Ease of Use	4.18	0.941
	Visual Appearance	4.36	0.806
	Activity Flow	4.29	0.906
Visual Gamification Elements	Gamification Elements (Points, Levels, Rewards)	4.39	0.845
	Storytelling	4.11	0.892
	Emotional Design	4.29	0.908

In the Engagement and Motivation dimension, three indicators demonstrated consistently high mean values: Learning Focus (4.14), Task Motivation (4.21), and Learning Activity (4.11). All exhibited loading factors above 0.93, confirming their strong interrelationship in shaping students' intrinsic motivation. Learning Activity showed the highest loading (0.976), suggesting that active involvement in LKS activities was the most influential factor in fostering learning motivation.

The Learning Experience dimension reflected a balanced integration of cognitive and affective aspects. The highest mean appeared in Enjoyment (4.32; 0.901), followed by General Acceptance (4.07; 0.889), Meaningfulness (4.07; 0.817), and Learning Time (4.11; 0.744). These results indicate that students perceived the gamified LKS as enjoyable, engaging, and meaningful. The lower loading for Learning Time suggests variation in perceptions of session duration—some students experienced time passing quickly, while others needed more time to adapt to the gamified learning format.

For the Technical Aspect dimension, all indicators showed strong internal consistency, with mean scores above 4.18 and factor loadings exceeding 0.80. Ease of Use (4.18; 0.941) had the strongest correlation with the construct, followed by Activity Flow (4.29; 0.906) and Visual Appearance (4.36; 0.806). These findings show that students perceived the worksheets as user-friendly, visually appealing, and clearly structured. Technical clarity and accessibility played a central role in supporting engagement and comprehension.

The Visual Gamification Elements dimension also received highly positive responses. The Gamification Element achieved the highest mean (4.39; 0.845), followed by Emotional Design (4.29; 0.908) and Storytelling (4.11; 0.892). This suggests that features such as points, levels, and rewards were not merely decorative but contributed directly to motivation to learn. Storytelling and emotional design enhanced personal engagement, making the learning experience more interactive and meaningful.

Overall, the four dimensions demonstrated strong interconnections. Engagement and motivation emerged from positive learning experiences reinforced by clear technical structures and compelling visual design. These findings emphasize that the success of gamified learning relies not only on instructional content but also on how learning media are designed to stimulate interaction, emotion, and understanding.

4.2. Factor and Reliability Analysis of Gamified Learning Dimensions

The quantitative data collected was analyzed using Principal Component Analysis (PCA) and Factor Analysis (FA). The FA was derived from PCA through varimax rotation to identify latent dimensions that represented the underlying constructs of the measurable variables. The PCA results yielded principal component scores (eigenvectors), which were examined using the stopping rule theory. Only factors with eigenvalues greater than 1.0 were retained, as these indicated meaningful latent dimensions that contributed significantly to the explained variance. Each latent variable was then named according to the conceptual meaning of its observed indicators, resulting in four main dimensions: Engagement and Motivation, Learning Experience, Technical Aspects, and Visual Gamification Elements. This analytical process ensured that the measurement structure was statistically valid, interpretable, and aligned with the theoretical constructs of gamified learning design.

As shown in **Table 3**, all dimensions had eigenvalues greater than 1, ranging from 2.336 to 2.843, confirming that each factor was dominant. The explained variance was also high, ranging from 71.07% to 90.67%, indicating that one factor was sufficient to represent each construct without additional components. Descriptively, the mean values across dimensions ranged from 4.14 to 4.27, with

relatively low standard deviations (0.92–1.11), suggesting that students consistently rated the gamified worksheets positively.

Table 3. Factor Analysis of Gamified Learning Dimensions.

Statistic	Engagement & Motivation	Learning Experience	Technical Aspects	ıification
Mean	4.15	4.14	4.27	4.26
Standard Deviation	1.11	0.98	0.96	0.92
Cronbach's α	0.948	0.845	0.863	0.854
Eigenvalue / Variance	2.72	2.843	2.357	2.336
Percentage of Variance	90.67	71.07	78.57	77.85
Cumulative Percentage	90.67	71.07	78.57	77.85

Among the four dimensions, Engagement and Motivation emerged as the most influential. High reliability and explained variance indicate that students' emotional connection and intrinsic motivation were central to their learning experience. They not only enjoyed the activities but also felt challenged and motivated to complete the tasks.

The Learning Experience dimension demonstrated coherence between cognitive and affective elements. Indicators such as enjoyment, meaningfulness, and time perception were strongly interrelated, and the inclusion of General Acceptance reinforced this construct. Students perceived the activities as enjoyable, relevant, and emotionally engaging, which enhanced their overall satisfaction with the learning process.

The Technical Aspects dimension also showed strong reliability, emphasizing the importance of clarity, usability, and visual appeal. Students found the worksheets easy to understand, visually attractive, and well-structured. These technical qualities supported comprehension and allowed students to focus on learning rather than on navigating the media.

Finally, the Visual Gamification Elements dimension highlighted how interactive components such as points, rewards, storytelling, and emotional design helped sustain engagement. These elements transformed the worksheets from static materials into dynamic learning experiences, making students more involved and emotionally connected.

The analysis showed that gamified worksheets that combined emotional and visual design helped students stay focused, motivated, and learn in a way that was meaningful. The four dimensions were interdependent and worked well together to make a cohesive learning space. This stable and reliable construct demonstrates that the LKS model is both pedagogically effective and adaptable for future research or broader classroom applications.

4.3. Male and Female Students' Perceptions of Gamified Worksheets

The t-test results, as shown in **Table 4**, showed significant differences between male and female students in two dimensions: Learning Experience ($p = 0.015$) and Technical Aspects ($p = 0.044$). Conversely, no significant differences were found in Engagement and Motivation ($p = 0.107$) or Visual Gamification Elements ($p = 0.079$).

Table 4. Independent Samples t-Test by Gender

Dimension	t-statistic	p-value	Interpretation
Engagement & Motivation	-1.698	0.107	Not significant
Learning Experience	-2.687	0.015	Significant
Technical Aspects	-2.18	0.044	Significant
Visual Gamification Elements	-1.854	0.079	Not significant

The difference in the Learning Experience dimension indicates that female students had a more positive perception of learning through gamified worksheets. They found the learning process more enjoyable, meaningful, and personally engaging. This aligns with the tendency of female learners to respond more strongly to affective elements in learning, such as storytelling, emotional design, and self-reflection. In contrast, male students tended to view the effectiveness of the media more from its functional or competitive aspects, often prioritizing efficiency and performance over emotional engagement. This difference in orientation made the emotional dimension of the "learning experience" more prominent among female students.

The Technical Aspects dimension also revealed a clear difference. Female students rated the visual appearance, clarity of flow, and ease of use of the media higher than their male counterparts. This suggests that they are more sensitive to the quality of interface design and the aesthetic aspects of learning media. A well-structured visual layout and clear navigation tend to enhance comfort and perceived ease of learning, particularly for users who pay attention to visual details and the order of information.

In contrast, the absence of significant differences in Engagement and Motivation, as well as in Visual Gamification Elements, suggests that competitive and interactive components—such as points, levels, and rewards—produced relatively balanced motivational effects across genders. Both male and female students showed similar levels of engagement in learning activities. This indicates that the gamification mechanism works universally, stimulating both cognitive and emotional engagement without strong gender bias.

Overall, the findings reveal that perceptual differences are more evident in emotional and aesthetic aspects rather than in motivation or participation. The gamified media appears to maintain a balanced appeal for both genders, although affective and visual experiences tend to resonate more strongly with female students.

4.4. Comparison of Students' Perceptions Across Grade Levels

The ANOVA test results, as shown in **Table 5**, indicated no significant differences across grade levels (10, 11, and 12) in the four analyzed dimensions: Engagement and Motivation ($p = 0.363$), Learning Experience ($p = 0.546$), Technical Aspects ($p = 0.366$), and Visual Gamification Elements ($p = 0.781$).

Table 5. One-Way ANOVA by Grade Level

Dimension	F-statistic	p-value	Interpretation
Engagement & Motivation	1.056	0.363	Not significant
Learning Experience	0.621	0.546	Not significant
Technical Aspects	1.048	0.366	Not significant
Visual Gamification Elements	0.25	0.781	Not significant

These findings suggest that students across grade levels perceived the gamified student worksheets (LKS) in a relatively consistent manner. Grade 10 students, who were still adjusting to high school routines, Grade 11 students, who were in a phase of conceptual strengthening, and Grade 12 students, who had more mature learning experiences, all demonstrated similar levels of engagement and acceptance.

The absence of significant differences across grades indicates that the effectiveness of the gamified worksheets

does not depend on students' academic maturity. The design successfully created an equal learning experience across age groups. The technical clarity, visual appeal, and gamified structure appeared inclusive and accessible, allowing all students to navigate and enjoy the learning process without major challenges.

From a pedagogical perspective, these results reinforce the adaptability of gamification-based learning across different grade levels. Motivational mechanisms such as rewards, storytelling, and visual interaction effectively engage learners with varying cognitive abilities. In essence, the media design maintained a balance between challenge and comfort (optimal flow), ensuring that the learning experience remained engaging and equitable among all grades.

In practice, the ANOVA findings indicate that gamified worksheets can be implemented consistently across different levels of secondary education without substantial modifications to content or structure. This adaptability supports the creation of a cohesive and continuous learning ecosystem, both technically and affectively, throughout the school's academic program.

4.5. Discussion

The findings indicate that the gamified Student Worksheet (LKS), which integrates storytelling, emotional design, and augmented reality (AR), had a positive impact on students' learning experience at SMA Plus Muthahhari Bandung. The four key dimensions—Engagement and Motivation, Learning Experience, Technical Aspects, and Visual Gamification Elements—each had a mean score above 4 and demonstrated high reliability, confirming the effectiveness of the media in enhancing student engagement and comprehension.

The Engagement and Motivation dimension showed the strongest influence, suggesting that gamified activities successfully stimulated students' focus and intrinsic drive to complete learning tasks. The Learning Experience dimension indicated that students perceived the process as enjoyable and meaningful, with narrative and visual elements helping build emotional connections to the material. The Technical Aspects dimension also received strong ratings, indicating that the worksheets were user-friendly, well-structured, and supported independent and efficient learning.

The Visual Gamification Elements dimension further enhanced engagement through points, levels, rewards, and emotionally driven design, creating a sense of accomplishment. The t-test results revealed that female students rated the technical and experiential aspects more highly, while the ANOVA test found no significant differences across grade levels. Collectively, these results indicate that the gamified LKS model is inclusive, adaptable across different student groups, and effective in creating an interactive and meaningful learning experience for Generation Z learners.

5. CONCLUSION

This study confirms that the gamified Student Worksheet (LKS), enhanced through storytelling, emotional design, and augmented reality (AR), effectively improves the learning experience of Generation Z students at SMA Plus Muthahhari Bandung. As digital natives, Gen Z learners prefer interactive, visually appealing, and experience-based learning environments. The four main dimensions—Engagement and Motivation, Learning Experience, Technical Aspects, and Visual Gamification Elements—showed strong internal consistency,

reinforcing that effective learning design must combine meaningful content with visual and emotional engagement.

The results highlight that active participation is at the core of successful gamified learning. Game elements and storytelling pique interest and drive intrinsic motivation, while clear technical and visual elements make learning easier and more comfortable. Although female students demonstrated higher sensitivity toward experiential and aesthetic aspects, the overall impact of the gamified LKS remained consistent across grade levels, showing its inclusivity and adaptability.

In conclusion, the gamified LKS with AR integration exemplifies an adaptive and inclusive pedagogical strategy that corresponds with the cognitive and behavioral traits of Generation Z. This model not only enhances motivation and focus but also builds emotional connection and sustained engagement in learning. These findings provide a framework for future educational innovations to develop interactive, reflective, and student-centered learning experiences in the digital era.

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