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Enhancing Junior High School Students' Motivation in Physics Learning through Kahoot! Based Gamification: An ARCS Model Approach

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Abstract – *Motivation plays a pivotal role in shaping students' engagement and achievement, particularly in subjects such as physics that are often perceived as difficult and abstract. Numerous studies have shown that low motivation among junior high school students contributes to poor performance and limited participation. This highlights the urgency of innovative instructional approaches that can foster interest and persistence. Gamification has emerged as a promising solution, with platforms such as Kahoot! providing interactive features designed to increase student engagement through competition, feedback, and collaboration. The objective of this study was to examine the effectiveness of Kahoot!-based gamification in enhancing students' learning motivation in physics, measured comprehensively using Keller's ARCS model (Attention, Relevance, Confidence, and Satisfaction). A quasi-experimental design with a one-group pretest–posttest approach was employed, involving 175 eighth-grade students from six junior high schools in East Nusa Tenggara, Indonesia. Data were collected through a validated ARCS-based motivation questionnaire and analyzed using descriptive statistics, the Wilcoxon Signed-Rank Test, effect size calculation, and normalized gain (N-Gain). The findings revealed a significant increase in students' motivation, with overall scores rising from 3.15 to 4.10, a large effect size (r = 0.85), and a medium N-Gain (0.51). The greatest improvement occurred in attention, while satisfaction increased the least. These results confirm that Kahoot! effectively improves multiple dimensions of motivation and demonstrates its value as an innovative tool for fostering interactive, student-centered learning in physics. The novelty of this study lies in applying the ARCS framework to analyze gamification outcomes in junior high school physics. The contribution of this study lies in demonstrating that gamification, particularly through Kahoot!, can effectively enhance multiple dimensions of learning motivation in physics. Furthermore, the findings enrich the body of knowledge on gamification in science education and present valuable implications for improving physics learning in Indonesia and comparable educational contexts.*

Keywords: *ARCS model; gamification; Kahoot!; physics education; motivation*

I. INTRODUCTION

The success of the teaching and learning process in schools cannot be attributed solely to students' cognitive abilities but is also significantly determined by their motivation to learn. Motivation functions as a driving force that sustains students' persistence, enthusiasm, and active participation in classroom activities, ultimately influencing the achievement of desired learning outcomes. This issue becomes particularly critical in science education, and physics in particular, since students often regard physics as one of the most challenging subjects due to its complex formulas, abstract principles, and frequent reliance on mathematical reasoning (Nurlina, 2020). Negative perceptions toward physics can act as psychological barriers, reducing student engagement and limiting achievement, especially at the junior high school level, where foundational concepts are introduced (Rini et al., 2024; Setiaji et al., 2024).

Theories of learning motivation, such as Self-Determination Theory (SDT), emphasize the importance of fostering intrinsic motivation as a way of enabling learners to engage in deep, self-regulated learning (Deci & Ryan, 2000). Empirical research has consistently shown that learning motivation exerts a significant influence on academic achievement across various contexts (Aldalur & Perez, 2023; Bouchrika et al., 2021). However, student motivation in junior high school physics remains comparatively low. This problem has been attributed to both limited student participation and the monotonous delivery of physics lessons, which fail to stimulate curiosity or connect abstract principles to students' everyday experiences (Wangchuk et al., 2023; Kiraga, 2023; Navos et al., 2024). Indeed, research indicates that physics curricula in many developing educational contexts are often regarded as uninteresting and overly theoretical. This situation demands innovative pedagogical approaches that can make physics more engaging, meaningful, and enjoyable for students.

One potential solution lies in integrating technological advancements in education, particularly digital learning platforms, which can transform the classroom into a more interactive and participatory environment (Iju et al., 2025). The last decade has witnessed rapid growth in the adoption of gamification, defined as the use of game elements such as points, leaderboards, challenges, and rewards in non-game contexts to enhance motivation, engagement, and learning outcomes (Kalogiannakis et al., 2021; Nurtanto et al., 2021). Gamification in education seeks to harness students' familiarity with and attraction to games to create a dynamic, competitive, and engaging learning environment. Empirical studies have demonstrated that gamification can significantly enhance learning motivation, encourage active participation, and improve conceptual understanding in science education (Bunyamin et al., 2020; Asniza et al., 2021).

Kahoot! is one of the most widely used gamification platforms in educational settings worldwide. The platform enables teachers to create interactive quizzes and surveys that students can access via smartphones or computers, allowing for real-time participation and instant feedback. Kahoot! has been found to foster engagement, collaboration, and enthusiasm in classrooms while simultaneously enhancing cognitive performance (Ghawail & Yahia, 2022; Iman et al., 2021). By embedding physics concepts into a game-like environment, Kahoot! can provide students with immediate reinforcement, encourage healthy competition, and reduce anxiety related to failure, thereby creating a supportive environment for learning difficult content (Humairah et al., 2025).

Despite the broad adoption of Kahoot! and other gamified platforms in education, several challenges and research gaps remain. Existing studies have primarily focused on qualitative outcomes such as student perceptions or general engagement (Di Blasi et al., 2022; Petrusly et al., 2024). While these investigations provide valuable insights into the popularity of Kahoot!, many lack systematic measurement of learning motivation using validated frameworks. For example, Bahri and Nurhidayah (2024) reported an increase in elementary students' motivation after using Kahoot!, but the study did not employ a comprehensive model for evaluating different motivational dimensions. Similarly, research conducted at the higher education level has concentrated mainly on perceptions of usefulness rather than direct motivational outcomes (Petrusly et al., 2024). Consequently, little is known about how Kahoot! specifically affects the multiple components of motivation in junior high school physics learning.

Another limitation observed in previous research is the lack of systematic measurement tools to capture the nuanced impact of gamification on learning motivation. The ARCS model—comprising attention, relevance, confidence, and satisfaction—provides a robust framework for such measurement (Keller, 2010). The ARCS model emphasizes that motivational design in learning should not only attract learners' attention but also ensure relevance to their goals, build confidence in their abilities, and foster satisfaction with learning experiences. Previous research utilizing ARCS has demonstrated its reliability for assessing motivational changes in technology-enhanced learning environments (Andari, 2020; Sakdah et al., 2021). However, very few studies have applied the ARCS model to investigate gamification in junior high school physics, despite its potential to reveal which motivational dimensions are most influenced by gamified tools such as Kahoot!.

Recent meta-analyses support the effectiveness of gamification in science learning. Patar et al. (2024) reported that gamification significantly improves fundamental physics learning outcomes, with instant feedback and healthy competition being critical features for success. In addition, Wang and Tahir (2020) identified that features such as anonymous nickname generation reduce fear of failure, thereby promoting student confidence. Freitas et al. (2020) found that game-based question formats, such as puzzles and multiple-choice questions, can enhance higher-order thinking by encouraging exploration and problem-solving. These findings collectively highlight that Kahoot!'s diverse features may influence different aspects of motivation, making it an ideal platform for systematically measuring the ARCS dimensions.

The specific use of Kahoot! in physics classrooms has yielded encouraging results in various educational contexts. For instance, Hidayat et al. (2023) demonstrated that junior high school students who used Kahoot! not only showed higher motivation but also exhibited improved comprehension of physics concepts compared to students in traditional classrooms. Similarly, Santoso and Widiyanti (2022) observed that Kahoot! enhanced student satisfaction and confidence in science learning through instant feedback and interactive features. Yet, despite these positive outcomes, most studies have been limited to either general science subjects or contexts outside junior high schools in Indonesia. Furthermore, only a handful have applied rigorous quasi-experimental designs to establish causal relationships between gamification and motivation, particularly in physics education.

Given these limitations, a clear research gap exists in examining the systematic effect of gamification on learning motivation in junior high school physics using a validated model. Most prior investigations have either targeted younger learners at the elementary level (Bahri & Nurhidayah, 2024), older learners at the university level (Petrusly et al., 2024), or addressed motivation in general terms without dissecting the specific motivational dimensions involved. Moreover, studies focusing on Indonesian contexts remain scarce, despite the pressing need for innovative teaching approaches to overcome widespread perceptions of physics as a difficult subject (Navos et al., 2024). Therefore, research that applies Kahoot! in junior high school physics classrooms while systematically measuring motivation through the ARCS model would make a significant contribution to the literature.

The present study aims to address this gap by examining the effectiveness of interactive gamification through Kahoot! in improving junior high school students' motivation to learn physics. Specifically, this study employs a quasi-experimental design with pretest and posttest measures to capture changes in motivation across the four ARCS components. The novelty of this research lies in its integration of a widely accessible gamification tool with a validated motivational framework in the context of junior high school physics. This context has been underexplored in previous research. By doing so, this study not only offers empirical evidence regarding the motivational impact of Kahoot! but also contributes to the theoretical understanding of how different gamification features align with specific dimensions of learning motivation. Ultimately, the findings are expected to provide practical insights for teachers and policymakers in designing interactive, student-centered physics learning strategies that respond to the needs and learning styles of the digital generation.

II. METHODS

This study employed a quasi-experimental approach, utilizing a one-group pretest–posttest design. This design was considered appropriate because it enables the measurement of changes in learning motivation before and after the intervention in the same group of participants, even in the absence of a control group. The design is commonly employed in classroom-based intervention research where random assignment is not feasible, but rigorous evaluation of change is still required (Fraenkel et al., 2019). Table 1 presents the research design in schematic form, illustrating the temporal sequence of pretest, treatment, and posttest phases.

Table 1. Research design of the one-group pretest–posttest

Group	Pretest (X_1)	Treatment (T)	Posttest (X_2)
Grade VIII	Physics motivation	Learn with Kahoot!	Physics motivation

The study was conducted in six junior high schools located in Ngada Regency, East Nusa Tenggara Province, Indonesia. The participants were 175 students drawn from eighth-grade physics classes during the 2023/2024 academic year. A purposive sampling technique was employed, guided by several inclusion criteria: (a) students were actively enrolled in the selected schools, (b) students attended classes regularly, (c) permission was obtained from both school authorities and parents, and (d) students agreed to participate throughout the entire intervention process. Such purposive sampling ensured that the sample was both contextually relevant and practically manageable for implementing the gamification intervention (Creswell & Creswell, 2018).

The research instrument used to measure students' motivation in learning physics was a motivation questionnaire developed according to Keller's ARCS model. The ARCS model has been widely validated in educational settings to assess the motivational impact of instructional design and technological interventions (Keller, 2010). The questionnaire consisted of 30 statements distributed across the four dimensions of the ARCS framework. Responses were recorded on a five-point Likert scale ranging from strongly disagree to strongly agree. Examples of items included: "the way the teacher presented the material captured my attention (attention)"; "the material presented was relevant to my daily life (relevance); "I am confident I can master the lesson (confidence)", and "I feel satisfied with my learning outcomes (satisfaction)".

The validity of the questionnaire was established through expert judgment by three specialists in physics education and educational psychology. Content validity indices were calculated, yielding Item-Content Validity Index (I-CVI) values ranging from 0.83 to 1.00, and a Scale-Content Validity Index (S-CVI/Ave) of 0.94. These values exceeded the recommended thresholds for instrument validity in educational research (Polit & Beck, 2006). Reliability testing using Cronbach's alpha yielded a coefficient of 0.87, confirming the instrument's high internal consistency and reliability (Field, 2018). Table 2 provides a summary of the instrument's validity and reliability indices.

Table 2. Validity and reliability of the ARCS-based motivation questionnaire

ARCS components	Focus questions	Example statement
Caution	Do learning methods attract students' attention?	"I'm interested in how to learn physics using Kahoot!"
Relevance	Is the material appropriate to the learning needs of students?	"The physics material taught through Kahoot! according to my needs."
Confidence	Do students feel capable and confident in learning?	"I'm sure I can understand physics material with the help of Kahoot!"
Satisfaction	Are students satisfied with the learning process and outcomes?	"I feel happy and satisfied learning physics using Kahoot!"

The intervention procedure consisted of several stages. The preparation phase included obtaining research permissions, conducting preliminary socialization with school administrators and teachers, and training physics teachers in the use of Kahoot!. The implementation phase began with the administration of the pretest questionnaire to capture students' baseline motivation. The treatment was then delivered across four consecutive classroom meetings, each lasting approximately 90 minutes. During these sessions, physics content was taught using conventional methods in combination with gamified activities. At the end of each lesson, students engaged with Kahoot! quizzes designed as interactive, game-based assessments aligned with the curricular content. Each quiz contained between 10 and 15 multiple-choice items with embedded images or diagrams where appropriate, aiming to maintain student engagement and stimulate competition. The use of Kahoot! allowed for immediate feedback, real-time leaderboards, and interactive participation, features that have been shown to enhance students' attention and motivation (Wang & Tahir, 2020; Iman et al., 2021). The posttest questionnaire was administered after the completion of the four sessions to measure changes in students' motivation. In addition to questionnaire data, observational field notes and teacher reflections were collected to provide supporting qualitative insights into student engagement and classroom dynamics.

Data analysis was performed in several stages. First, descriptive statistics including means, standard deviations, and percentages were calculated to provide an overview of students' motivation levels before and after the intervention. Second, data normality was tested using the Shapiro–Wilk test, which is appropriate for small to medium sample sizes (Razali & Wah, 2011).

The results indicated that the data were not normally distributed ($p < 0.05$). Accordingly, non-parametric tests were employed. Specifically, the Wilcoxon Signed-Rank Test was used to examine differences between pretest and posttest scores. The Wilcoxon test is suitable for paired data when normality assumptions are violated and has been widely applied in educational research for evaluating intervention effects (Pallant, 2020).

To better understand the magnitude of the improvement in students' motivation, the effect size was calculated to determine the strength of the observed changes. The interpretation followed Cohen's (1988) guidelines, which classify effect sizes as small, medium, or large. In addition, the normalized gain (N-Gain) was used to measure how much students' motivation improved relative to the maximum possible gain, categorized as high, medium, or low (Hake's, 1999). All data analyses were performed using SPSS version 31 to ensure accurate and reliable results.

III. RESULTS AND DISCUSSION

The results of this study are presented in three stages: (a) descriptive statistics of students' learning motivation before and after the intervention, (b) inferential statistical analysis using the Wilcoxon Signed-Rank Test, and (c) effectiveness analysis based on N-Gain. To complement these results, a graphical comparison of the ARCS motivational components is provided.

The descriptive analysis revealed that students' motivation scores increased after the implementation of Kahoot! as a gamified learning tool. The data presented in Table 3 show the mean and standard deviation of pretest and posttest scores for each ARCS dimension and for overall motivation.

Table 3. Descriptive statistics of learning motivation scores

Statistics	Pretest	Posttest
Quantity	175	175
Mean	3.15	4.10
Standard deviation	0.45	0.40
Minimum score	2.00	3.20
Maximum score	3.90	4.80

Table 3 presents the descriptive statistics of students' learning motivation scores before and after the implementation of Kahoot!-based gamification. The results indicate a clear improvement in motivational outcomes. The mean score increased substantially from 3.15 in the pretest to 4.10 in the posttest, reflecting an average gain of 0.95 points on a five-point scale. This improvement was accompanied by a slight reduction in score variability, as shown by the decrease in the standard deviation from 0.45 to 0.40, suggesting that students' motivation levels became more homogenous after the intervention.

Furthermore, the minimum score rose from 2.00 at pretest to 3.20 at posttest, while the maximum score increased from 3.90 to 4.80. These changes indicate that not only did the average level of motivation improve, but also that the lowest-performing students experienced meaningful gains, thereby narrowing the motivational gap across the class. The descriptive results thus provide strong preliminary evidence that Kahoot!-based gamification positively influenced students' motivation in learning physics.

Prior to testing differences between pretest and posttest scores, normality was examined using the Shapiro–Wilk test, which indicated that the data were not normally distributed ($p < 0.05$). Consequently, the Wilcoxon Signed-Rank Test was applied. The results, shown in Table 4, demonstrate that the differences between pretest and posttest scores were statistically significant.

Table 4. Results of the Wilcoxon signed-rank test for motivation scores

Test statistics	**Value**
Z	-11.25
Sig. (2-tailed)	0.000

The Wilcoxon Signed-Rank Test produced a Z-value of –11.25 with $p < 0.05$, confirming that the posttest motivation scores were significantly higher than the pretest scores. The effect size, calculated as $r = Z/\sqrt{N}$, was 0.85, which falls within the category of a significant effect (Cohen, 1988). This suggests that the intervention had a significant impact on students' motivation to learn physics.

To further evaluate the effectiveness of the intervention, N-Gain analysis was conducted. Table 5 presents the results of the N-Gain calculations, which provide insight into the relative improvement in motivation.

Table 5. N-gain analysis of students' motivation scores

Dimension	**N-Gain**	**Category**
Attention	0.55	Medium
Relevance	0.52	Medium
Confidence	0.51	Medium
Satisfaction	0.34	Medium
Overall	0.51	Medium

As indicated in Table 5, the overall N-Gain was 0.51, which falls within the medium category of effectiveness. This suggests that Kahoot!-based gamification produced a moderate but meaningful improvement in students' motivation to learn physics. The highest N-Gain was recorded in the attention dimension (0.55), consistent with the descriptive findings, while satisfaction recorded the lowest N-Gain (0.34), though it still fell within the medium category. The comparative improvements across the ARCS components are illustrated in Figure 1.

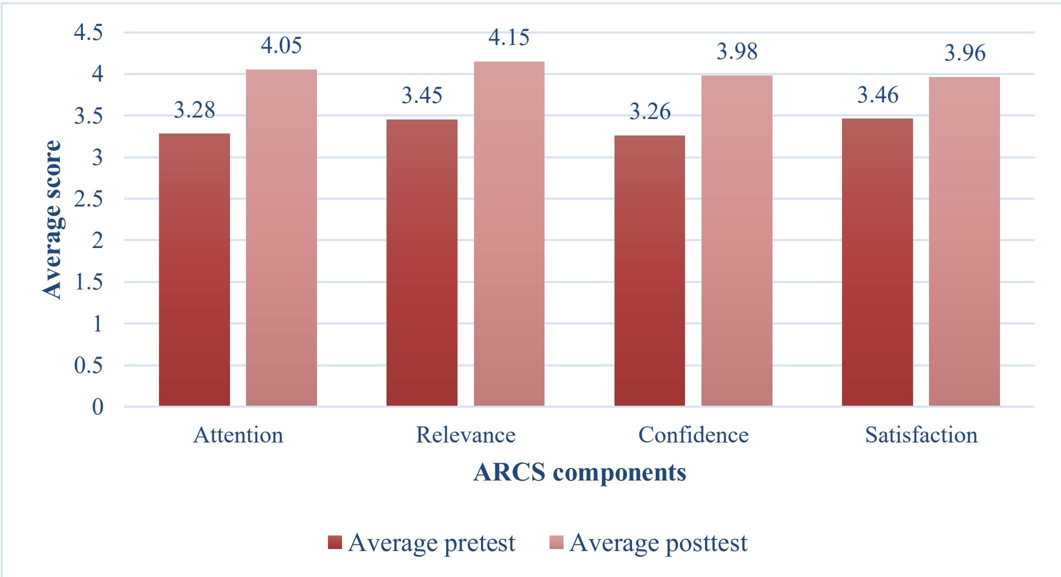

Figure 1. Comparison of pretest and posttest scores in the ARCS motivation dimensions

The results of this study confirm that Kahoot!-based gamification significantly improved students' motivation to learn physics at the junior high school level, as demonstrated by the increase in mean motivation scores (from 3.15 to 4.10), the Wilcoxon signed-rank test ($Z = -11.25$, $p < 0.001$), a very large effect size ($r = 0.85$), and an overall medium N-Gain (0.51). Improvements were observed across all ARCS components, with the largest increase in attention (34.84%) and the smallest in satisfaction (19.75%). These findings reinforce the claim that gamification, when integrated thoughtfully into instructional design, provides measurable motivational benefits for students in science education contexts.

From a theoretical standpoint, the findings are consistent with SDT, which argues that intrinsic motivation arises when learners experience autonomy, competence, and relatedness (Daryanes & Ririen, 2020; Deci & Ryan, 2000). Kahoot! fosters autonomy by allowing students to make choices in an enjoyable and playful format, enhances competence by providing immediate feedback and opportunities to succeed, and promotes relatedness by embedding competition and collaboration with peers. Previous studies have similarly documented that gamification can create an autonomy-supportive learning environment that motivates students to persist in cognitively demanding tasks (Aldalur & Pérez, 2023; Wangchuk et al., 2023). Within the context of physics learning, where students often perceive the subject as abstract and difficult (Rini et al., 2024; Setiaji et al., 2024), gamified tools help to reduce psychological barriers and promote sustained engagement.

The dimension-specific improvements provide further insight into how gamification influences motivation. Attention recorded the highest gain, which aligns with the literature emphasizing that interactive features, such as points, leaderboards, and time pressure, are powerful in capturing and sustaining learners' focus (Rahmawati, 2023; Asniza et al., 2021). These mechanics are particularly suited for junior high school learners, who tend to respond positively to novelty and competition. The increase in attention in this study mirrors findings from Baguio et al. (2021), who reported that game-based strategies led to observable increases in attentiveness and classroom participation. Moreover, meta-analytic reviews of gamification in education (Dichev & Dicheva, 2017; Wang & Tahir, 2020) consistently highlight that the most immediate and robust effects of gamification are observed in learners' attentional engagement, lending strong external validity to our results.

The improvement in relevance reflects students' perception that the learning process was more meaningful and connected to their goals. Kahoot! supports relevance by presenting abstract concepts through visually engaging and contextually framed quizzes, making connections between physics content and students' lived experiences. This finding is consistent with those of Andari (2020) and Sakdah et al. (2021), who emphasized that learners' motivation is enhanced when instructional activities demonstrate personal significance and practical application. In the present study, the integration of curriculum-aligned questions into the Kahoot! platform likely reinforced the relevance of the material, as reflected in the posttest gains. These results also align with Santoso and Widiyanti (2022), who found that gamified learning fosters students' perception of usefulness, thereby elevating their motivation.

Confidence also increased significantly, demonstrating that gamification can enhance students' self-efficacy in physics. This finding supports Keller's (2010) assertion that confidence grows when learners receive clear, immediate feedback and repeated opportunities to practice without excessive penalty. Kahoot!'s anonymity features (nicknames, team play) reduce performance anxiety, encouraging active participation even among students with lower prior achievement. Wang and Tahir (2020) similarly reported that anonymity and supportive competition reduce fear of failure, thus strengthening self-efficacy. The present study confirms these mechanisms, suggesting that gamified learning can counteract physics anxiety and cultivate greater confidence among adolescent learners.

The comparatively smaller increase in satisfaction, while still positive, suggests that gamification's immediate appeal may not automatically translate into enduring fulfillment with the learning process. In the ARCS model, satisfaction is influenced not only by enjoyment but also by a sense of mastery and recognition of achievement (Keller, 2010). While Kahoot! provides short-term gratification through instant feedback and rewards, longer-term satisfaction may require alignment with broader curricular goals, reinforcement through summative achievement, or structured opportunities for reflection. Similar observations have been reported by Patar et al. (2024), who noted that while gamification enhanced short-term engagement, satisfaction levels were contingent upon how learning outcomes were consolidated. Hidayat et al. (2023) also found that gamified physics lessons improved engagement and comprehension, but students' satisfaction increased further only when feedback was explicitly linked to their overall learning progression. Thus, while Kahoot! is highly effective in energizing students and boosting attention.

Triangulation with qualitative data collected from teachers supports the quantitative findings. Teachers observed heightened enthusiasm during the gamified sessions, with students eagerly anticipating quizzes and even passive learners becoming actively involved. Puzzle-type and open-ended Kahoot! items encouraged deeper thinking, while real-time leaderboards sustained energy in the classroom. These observations corroborate the numerical increases in Attention, Relevance, and Confidence, demonstrating how Kahoot! reshaped the classroom into a more interactive and student-centered environment. Similar classroom-level transformations have been documented by Humairah et al. (2025), further validating the robustness of gamification effects.

Methodologically, the large effect size ($r = 0.85$) is particularly noteworthy, suggesting that the improvements in motivation were not only statistically significant but also substantial in magnitude. This result aligns with previous meta-analyses (Wang & Tahir, 2020; Di Blasi et al., 2022) that have shown gamification to exert moderate-to-large effects on motivation and engagement. The medium N-Gain (0.51) situates the intervention's effectiveness within the typical range reported for gamified science learning interventions (Meltzer, 2002). Together, these indicators suggest that Kahoot!-based gamification is both a reliable and effective approach to elevating student motivation in physics education.

Importantly, this study extends the literature in several ways. First, applying the ARCS model offers a dimension-specific analysis of how gamification influences motivation, which few previous studies have systematically addressed in the context of junior high school physics (Fazriyah et al., 2020; Sindi et al., 2023). Second, it situates findings within the Indonesian context, where research on gamification in physics education remains limited despite widespread acknowledgment of motivational challenges in science learning (Navos et al., 2024). Third, the combination of quantitative and qualitative evidence enriches the interpretation, demonstrating not only statistical significance but also observable classroom dynamics.

Nevertheless, limitations must be acknowledged. The use of a one-group pretest–posttest design limits causal inference, as other factors, such as maturation or extraneous events, could have influenced the results. The study's sampling frame—six schools within one regency—and its short duration (four meetings) limit generalizability and raise questions about the sustainability of motivational gains. These limitations mirror those identified in prior gamification research (Di Blasi et al., 2022; Petrusly et al., 2024). Future studies should address these constraints by employing control groups, expanding the geographical scope of samples, and conducting longitudinal assessments to explore long-term impacts on both motivation and achievement.

In practical terms, the findings provide actionable insights for educators. Kahoot! is accessible, easy to integrate, and capable of stimulating students' attention, confidence, and relevance perception in physics classrooms. However, to maximize satisfaction and ensure durable motivational gains, teachers may need to complement gamified quizzes with reflective discussions, mastery-oriented feedback, and explicit connections to curricular objectives. This aligns with Keller's (2010) guidance that motivation is optimized when instructional strategies address all ARCS components holistically.

IV. CONCLUSION AND SUGGESTION

This study demonstrated that integrating Kahoot! as an interactive gamification platform significantly enhanced junior high school students' motivation to learn physics. The quantitative results revealed substantial improvements across all four components of the ARCS model, with the largest gain observed in attention and smaller yet positive gains in Relevance, Confidence, and Satisfaction. Statistical analysis using the Wilcoxon signed-rank test confirmed that these differences were significant, with a very large effect size ($r = 0.85$) and a medium overall effectiveness (N-Gain = 0.51). Complemented by teacher observations, the findings provide strong empirical evidence that gamified learning strategies can transform physics classrooms into more engaging, interactive, and student-centered environments.

Despite its promising results, the study has certain limitations. The one-group pretest–posttest design restricts causal inference, and the relatively short intervention period and localized sampling limit the generalizability and long-term conclusions. Future research should address these limitations by employing control groups, extending the duration of interventions, and conducting longitudinal studies across a more diverse range of educational contexts. Nevertheless, the study contributes to the growing body of literature on gamification by offering dimension-specific evidence of motivational gains in physics education. By applying the ARCS model, this research highlights not only that Kahoot! effectively raises student motivation but also clarifies which aspects of motivation are most strongly affected. These insights can guide educators and curriculum designers in leveraging gamification to address motivational challenges in physics learning, thereby fostering more effective and sustainable educational practices.

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