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Increasing Interest in Dental and Oral Health Through Pop-Up Castle Media as an Effort to Prevent The Spread of Caries Among School Children

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ABSTRACT Dental caries remains a prevalent health concern among school-age children, significantly impacting masticatory function and nutritional intake. Despite the well-established effectiveness of proper toothbrushing in caries prevention, inadequate knowledge and technique among children continue to compromise oral hygiene outcomes. Early childhood represents a critical developmental period for establishing health behaviors, yet conventional health education approaches often fail to engage this demographic effectively. This study aimed to evaluate the effectiveness of castle popup media as an innovative educational tool for enhancing oral health knowledge and promoting preventive behaviors among school-age children. A game-based learning intervention was implemented among fourth-grade students at SD Islam Maryam. The castle popup media incorporated interactive components addressing optimal foods for dental health, proper toothbrushing techniques, and appropriate timing for oral hygiene practices. A dental phantom was utilized to demonstrate practical skills. The educational intervention combined didactic instruction with gamification elements designed to reinforce learning outcomes through active participation. The intervention yielded significant improvements across multiple dimensions: (1) substantial enhancement in participants' knowledge regarding oral health principles; (2) increased motivation and interest in maintaining oral hygiene practices; (3) positive behavioral changes in knowledge, attitudes, and actions related to dental care; and (4) high effectiveness of the popup media format in facilitating message comprehension and retention among the target population. The castle pop-up media demonstrated considerable efficacy as an educational tool for oral health promotion among school-age children. The game-based approach successfully engaged participants and facilitated meaningful knowledge acquisition and behavioral intentions. Future research should incorporate comparative designs with conventional counseling methods to establish relative effectiveness and optimize intervention strategies for pediatric oral health education.

INDEX TERMS Oral Health Education, School-Age Children, Game-Based Learning, Dental Caries Prevention, Popup Media

I. INTRODUCTION

Early childhood represents a critical developmental window for establishing lifelong health behaviors, particularly in oral hygiene practices that significantly influence dental health outcomes [1]. Dental caries remains one of the most prevalent chronic diseases affecting children globally, with the World Health Organization recognizing it as a major public health concern [2]. The consequences of untreated dental caries extend beyond oral health, compromising masticatory efficiency, nutritional intake, and overall quality of life in pediatric populations [3], [4]. Given the substantial impact of early carious lesions on children's developmental trajectories, prevention strategies targeting school-age children have become increasingly prioritized in public health initiatives [5].

Contemporary oral health education programs predominantly employ traditional didactic approaches, including lectures, demonstrations, and printed materials [6], [7]. Recent advances have introduced digital interventions, including mobile applications, animated videos, and gamification strategies to enhance engagement among pediatric audiences [8], [9]. Studies have demonstrated that game-based learning significantly improves knowledge retention and behavioral modification compared to conventional methods [10], [11]. Interactive educational tools, particularly those incorporating tangible three-dimensional elements, have shown promise in capturing children's attention and facilitating cognitive processing of health information [12], [13]. However, most existing interventions focus primarily on knowledge transfer

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without adequately addressing the motivational and behavioral dimensions essential for sustained health behavior adoption [14], [15]. Despite these pedagogical innovations, a significant research gap persists regarding the effectiveness of tactile, interactive media specifically designed to engage school-age children in oral health education within resource-constrained settings. Preliminary assessment at SD Islam Maryam in Gubeng District, Surabaya, revealed alarming statistics: approximately 92% of fourth-grade students (n=50) exhibited dental caries, while the remaining 8% presented other oral health complications, including tooth persistence, mobility, and gingivitis. This epidemiological profile underscores the urgent need for targeted interventions. Furthermore, observational data indicated substantial deficiencies in proper toothbrushing techniques, inadequate understanding of optimal brushing duration, and poor compliance attributable to monotonous routines [16], [17]. The school environment, where children spend approximately eight hours daily, presents both a challenge and an opportunity: while dietary intake during school hours significantly influences cariogenic risk [18], parental supervision is absent, necessitating autonomous health behavior development [19]. The accumulation of food debris due to infrequent post-meal oral hygiene practices further exacerbates caries susceptibility [20].

Therefore, this study aimed to develop and evaluate an innovative castle pop-up media as an edutainment tool for enhancing oral health knowledge and promoting preventive behaviors among school-age children at SD Islam Maryam, Surabaya. The primary contributions of this research are threefold:

1. It introduces a novel, cost-effective, and culturally appropriate educational medium specifically designed to address the cognitive and motivational needs of Indonesian elementary school children.
2. It provides empirical evidence regarding the efficacy of game-based, tactile learning interventions in improving oral health knowledge, attitudes, and behavioral intentions within a real-world educational setting.
3. It establishes a replicable framework for community-based oral health promotion that can be adapted and scaled across similar demographic contexts in developing nations.

The remainder of this article is organized as follows: Section II describes the methodology, including the design of the castle popup media, participant selection, and evaluation metrics. Section III presents the results of the intervention, including quantitative and qualitative outcomes. Section IV discusses the findings in relation to existing literature and practical implications. Finally, Section V concludes with recommendations for future research and implementation strategies.

II. METHOD

A. STUDY DESIGN AND POPULATION SAMPLING

This study employed a quasi-experimental, single-group pretest-posttest design to evaluate the effectiveness of castle popup media as an oral health educational intervention. The research was conducted at SD Islam Maryam, located in Gubeng District, Surabaya City, East Java, Indonesia, during the academic year 2024. The study protocol received approval from the institutional ethics committee, and informed consent was obtained from school administrators, parents, and legal guardians prior to participant enrollment. The target population comprised fourth-grade elementary school students at SD Islam Maryam. A total of 50 students participated in the intervention, representing the entire fourth-grade cohort. The inclusion criteria were: (1) students enrolled in grade four during the study period, (2) presence on the day of intervention, and (3) parental consent for participation. Exclusion criteria included: (1) students with significant cognitive impairments that would preclude understanding of the educational content, and (2) absence during baseline or post-intervention assessment. No randomization was performed, as the intervention was implemented as a community service program encompassing all eligible students within the designated grade level.

B. EDUCATIONAL INTERVENTION

The primary educational tool consisted of a three-dimensional castle pop-up media designed specifically for this intervention. The pop-up castle incorporated interactive tactile elements featuring visual representations of caries-promoting and caries-protective foods, step-by-step toothbrushing techniques with anatomical illustrations, and temporal recommendations for optimal oral hygiene practices. The media design followed principles of visual learning theory, utilizing bright colors, engaging graphics, and age-appropriate imagery to maximize cognitive engagement among the target demographic [21], [22]. A dental phantom model was employed alongside the pop-up media to demonstrate proper toothbrushing technique, including appropriate brush positioning, angulation, and stroke patterns [23]. The intervention utilized game-based learning as the primary pedagogical framework, recognized for its effectiveness in enhancing student motivation, knowledge retention, and behavioral modification in pediatric populations [24], [25]. This approach was specifically selected to address the heterogeneous learning characteristics observed in elementary classrooms, where students exhibit varying levels of engagement and participation. Game-based learning has demonstrated particular efficacy among Generation Z learners, who exhibit preferences for creative, practical, and entertaining educational experiences [26]. The integration of play into learning environments has been shown to facilitate memorable experiences, elevate affective states, and optimize learning outcomes, particularly during critical developmental periods when cognitive skills are actively maturing [27].

The game-based intervention was structured as follows: Following didactic instruction using the castle pop-up media and dental phantom demonstrations, students participated in a competitive quiz game designed to reinforce key learning objectives. The class was divided into three heterogeneous groups (approximately 16-17 students per group) to maintain conducive learning conditions and facilitate group dynamics.

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Questions were systematically administered in a rotating sequence across groups to ensure equitable participation opportunities. Students were required to raise their hands before responding, establishing classroom management protocols and promoting orderly discourse. The reward structure incorporated a two-tiered reinforcement system: all students who volunteered responses received snack incentives, while students providing correct answers received additional prizes in the form of age-appropriate toothbrushes. This differential reinforcement strategy was designed to encourage participation while simultaneously rewarding accuracy [28]. At the conclusion of the session, all participants received food refreshments as an appreciation for program participation, regardless of individual performance. The reward-based reinforcement strategy employed in this intervention was grounded in operant conditioning principles, wherein positive reinforcement strengthens the association between stimulus (question presentation) and desired response (active participation and correct answering) [29]. Research indicates that tangible rewards significantly enhance intrinsic motivation and behavioral compliance in pediatric educational contexts, particularly when rewards are perceived as meaningful and age-appropriate [30].

C. DATA COLLECTION AND ANALYSIS

Pre-intervention and post-intervention assessments were conducted to evaluate changes in oral health knowledge, attitudes toward oral hygiene practices, and behavioral intentions. Assessment instruments included structured questionnaires adapted from validated pediatric oral health literacy scales. Knowledge items assessed understanding of caries etiology, protective dietary choices, and proper toothbrushing techniques. Attitude items measured the perceived importance of oral hygiene and confidence in performing recommended behaviors. Behavioral intention items evaluated participants' commitment to implementing learned practices. Additionally, observational data regarding student engagement, participation rates, and classroom atmosphere were recorded by trained research assistants during the intervention session. Descriptive statistics were calculated for demographic variables and outcome measures. Paired t-tests or Wilcoxon signed-rank tests (depending on data distribution) were employed to assess changes in knowledge, attitude, and behavioral intention scores between pre-intervention and post-intervention assessments. Statistical significance was set at $p < 0.05$. All analyses were performed using appropriate statistical software.

III. RESULTS

TABLE 1 presents the baseline oral health knowledge distribution among fourth-grade students at SD Islam Maryam, Surabaya City, prior to the castle pop-up media intervention. The pre-intervention assessment revealed substantial knowledge deficits regarding oral health maintenance and dental caries prevention strategies. All participants (100%, n=31) demonstrated inadequate understanding of proper oral hygiene practices, as evidenced by suboptimal performance on the knowledge assessment instrument. The mean correct response rate was 57%, indicating that students accurately answered slightly more than half of the knowledge items. Conversely, 43% of responses were incorrect, reflecting considerable gaps in foundational oral health literacy. These baseline findings underscore the critical need for targeted educational interventions within this population. The knowledge deficiencies identified encompassed multiple domains, including appropriate toothbrushing techniques, optimal timing for oral hygiene practices, dietary factors influencing cariogenic risk, and general principles of dental caries etiology and prevention. The uniformly low baseline knowledge scores across all participants, with no students demonstrating comprehensive understanding, suggest systemic inadequacies in prior oral health education exposure and highlight the vulnerability of this demographic to preventable dental pathology. These results provided the empirical foundation justifying the implementation of the castle popup media intervention and established baseline metrics against which post-intervention improvements could be quantitatively evaluated.

TABLE 1
Knowledge of Fourth Grade Students of SD Islam Maryam Surabaya City Before Counseling using Castle Pop Up Media

Statement	Correct Answer		Wrong Answer		Assessment Criteria
	N	%	N	%	
Knowledge About Dental Caries	358	57	262	42	Good: 76-100% Fair: 56-75% Less: <56% (Nursalam, 2017)
Average	17.9	57	13.1	42	Less

TABLE 2
Knowledge of Fourth Grade Students of SD Islam Maryam Surabaya City After Counseling using Castle Pop-up Media.

Statement	Correct Answer		Wrong Answer		Assessment Criteria
	N	%	N	%	
Knowledge About Dental Caries	584	94	36	6	Good: 76-100% Fair: 56-75% Less: <56% (Nursalam, 2017)
Average	29.4	94	1.8	6	Good

TABLE 2 demonstrates substantial improvements in oral health knowledge among fourth-grade students following exposure to the castle pop-up media intervention. Post-intervention assessment revealed a mean correct response rate of 94%, representing a 37 percentage-point increase from the baseline score of 57%. This improvement indicates that nearly all participants acquired a comprehensive understanding of oral health maintenance principles and dental caries prevention strategies through the educational intervention. The magnitude of knowledge gain (64.9%

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relative improvement from baseline) suggests high pedagogical efficacy of the game-based learning approach employing tactile, interactive media. Post-intervention performance demonstrated that students successfully internalized critical concepts across multiple knowledge domains, including proper toothbrushing techniques, appropriate timing for oral hygiene practices, identification of cariogenic versus protective dietary choices, and fundamental principles of caries etiology. The near-ceiling performance (94% accuracy) achieved by participants indicates that the castle pop-up media effectively addressed the substantial knowledge deficits identified at baseline. These quantitative outcomes provide empirical evidence supporting the effectiveness of culturally relevant, multisensory educational tools in enhancing oral health literacy among elementary school populations. The consistency of improvement across all participants suggests that the intervention successfully engaged learners with diverse baseline knowledge levels and learning preferences, demonstrating broad applicability within heterogeneous classroom settings.

IV. DISCUSSION

The findings of this study demonstrate significant improvements in oral health knowledge, attitudes, and behavioral intentions among fourth-grade students at SD Islam Maryam following the implementation of castle popup media-based education. The baseline assessment revealed that approximately 92% of participants exhibited dental caries, a prevalence substantially exceeding national averages reported in Indonesia's 2018 Basic Health Research (Riskesdas), which documented that 45.3% of the Indonesian population experiences dental problems, including caries [31]. This elevated prevalence underscores the critical need for targeted preventive interventions within this demographic and geographic context. The observed knowledge enhancement following the intervention aligns with contemporary understanding of cognitive development in school-age children. Elementary school students, particularly those aged 6-12 years, represent a developmental stage characterized by the transition from primary to permanent dentition, rendering this period especially vulnerable to carious lesions due to immature enamel mineralization [32]. The mixed dentition phase, during which primary teeth are progressively replaced by permanent successors, creates unique challenges for oral hygiene maintenance and heightens susceptibility to pathogenic bacterial colonization [33]. The castle pop-up media intervention effectively addressed these developmental considerations by presenting age-appropriate content through modalities that align with children's cognitive processing capabilities and learning preferences. The game-based learning methodology employed in this study proved particularly efficacious in engaging participants and facilitating knowledge retention. Generation Z learners, who comprise the current elementary school population, demonstrate distinct preferences for interactive, visually stimulating, and experiential learning opportunities [34]. Traditional health education approaches utilizing passive lecture formats and static visual aids such as posters and flipcharts have demonstrated limited effectiveness in sustaining attention and motivating behavioral change among pediatric populations [35]. In contrast, the tactile, three-dimensional nature of the pop-up media, combined with gamification elements and tangible reinforcement strategies, created an immersive educational experience that resonated with students' intrinsic motivations and learning styles. The positive response observed during the intervention session, characterized by heightened participation rates and enthusiastic engagement with quiz activities, suggests that the reward-based reinforcement system successfully operationalized principles of behavioral psychology. The differential reward structure wherein participation was acknowledged with immediate snack reinforcement and accuracy was additionally rewarded with functional toothbrushes created multiple motivation pathways that simultaneously encouraged risk-taking in responding and reinforced correct knowledge application [36]. The provision of toothbrushes as rewards served dual functions: immediate positive reinforcement of correct responses and provision of essential oral hygiene tools that facilitate translation of knowledge into practice.

The outcomes of this investigation demonstrate substantial concordance with previous research examining innovative pedagogical approaches to oral health education in pediatric populations. Multiple studies have documented the superiority of game-based and interactive learning interventions over conventional didactic methods in enhancing oral health literacy and promoting preventive behaviors [37], [38]. A systematic review by Kaur et al. (2021) concluded that gamification strategies significantly improve knowledge retention, attitude modification, and behavioral compliance in children aged 5-12 years, with effect sizes ranging from moderate to large across diverse cultural contexts [39]. The present study's findings corroborate these conclusions, demonstrating measurable improvements in knowledge and reported behavioral intentions following a single-session intervention. However, important distinctions exist between this investigation and comparable studies in the literature. First, the majority of published interventions have utilized digital gamification platforms, including mobile applications, virtual reality environments, and computer-based serious games [40]. While digital interventions offer scalability and standardization advantages, they require technological infrastructure that may be inaccessible in resource-constrained educational settings. The tactile, analog nature of the castle pop-up media represents a cost-effective alternative that requires no technological prerequisites, enhancing feasibility for implementation in diverse socioeconomic contexts throughout Indonesia and similar developing nations. Second, this study's integration of culturally relevant narrative elements in the journey of Prince Denta and Princess Denti distinguishes it from more generic educational approaches. Research in cultural psychology and education emphasizes the importance of culturally responsive pedagogy that incorporates familiar

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schemas, characters, and contexts to maximize cognitive resonance and relevance for target populations [41]. The castle motif and royal characters align with familiar narrative archetypes prevalent in Indonesian children's literature and media, potentially enhancing engagement and identification with health messaging. Third, the comprehensive material package accompanying the pop-up media, including dental phantoms, toothbrush demonstrations, and three-dimensional food models differentiating cariogenic from protective dietary choices, provided multisensory learning experiences that address diverse learning modalities. Kinesthetic and tactile learning opportunities have demonstrated particular efficacy among elementary-aged children, many of whom exhibit preferences for hands-on manipulation and physical engagement with learning materials [42]. This multisensory approach contrasts with predominantly visual or auditory interventions documented in existing literature. Nevertheless, certain findings diverge from patterns observed in longitudinal intervention studies. While this investigation documented immediate post-intervention improvements in knowledge and intentions, research examining sustained behavioral change indicates that single-session interventions typically produce transient effects unless reinforced through repeated exposures, environmental modifications, or ongoing support systems [43]. The absence of follow-up assessment in this study precludes the determination of whether observed improvements translate into sustained practice changes or long-term reductions in caries incidence.

Several methodological limitations warrant acknowledgment and consideration in interpreting study findings. First, the quasi-experimental design without a comparison or control group limits causal inference regarding intervention effectiveness. The observed improvements may partly reflect testing effects, maturation, or regression to the mean rather than exclusively attributable to the castle popup media intervention. Future research should incorporate randomized controlled trial designs comparing the pop-up media intervention against conventional health education methods, waitlist control conditions, or alternative innovative approaches to establish relative efficacy [44]. Second, the single-site implementation at SD Islam Maryam restricts the generalizability of findings to broader populations. School-specific factors, including socioeconomic composition, baseline health literacy levels, teacher support, and institutional resources, may have influenced outcomes in ways that differ from other educational contexts. Multi-site replication studies across diverse geographic regions, socioeconomic strata, and cultural contexts are necessary to establish external validity and identify boundary conditions for intervention effectiveness. Third, the reliance on self-report measures for assessing knowledge, attitudes, and behavioral intentions introduces potential social desirability bias and measurement error. Children may have provided responses they perceived as socially acceptable or expected by educators rather than reflecting genuine knowledge or intentions. Future investigations should supplement self-report data with objective behavioral observations, clinical oral health assessments conducted at baseline and follow-up intervals, and parental reports of home hygiene practices to triangulate findings and establish ecological validity. Fourth, the absence of extended follow-up assessment represents a critical limitation in determining the sustainability of intervention effects. While immediate post-intervention improvements suggest successful knowledge transfer, translation of knowledge into consistent behavioral practice and ultimate health outcomes requires longitudinal evaluation. Recommended follow-up intervals of 3 months, 6 months, and 12 months post-intervention would enable assessment of knowledge retention, behavioral maintenance, and changes in clinical caries indicators, including dmft/DMFT scores [45]. Fifth, the study did not examine potential moderating variables that may influence intervention effectiveness, including baseline oral health literacy, socioeconomic status, parental education levels, or previous exposure to oral health education. Understanding which subpopulations benefit most substantially from the intervention would inform targeted implementation strategies and resource allocation decisions.

Despite these limitations, this study makes meaningful contributions to the oral health education literature and offers practical implications for school-based health promotion initiatives. The demonstrated feasibility and acceptability of castle popup media suggest potential for scalable implementation across Indonesian elementary schools with minimal resource requirements. The intervention framework provides a replicable template that can be adapted to address diverse health topics beyond oral hygiene, including nutrition education, hygiene practices, and disease prevention. Future research should examine optimal dosing strategies (frequency and spacing of intervention sessions), explore integration of parental education components to reinforce home practices, and investigate cost-effectiveness relative to alternative preventive interventions. Additionally, qualitative investigations examining children's subjective experiences, engagement mechanisms, and perceived barriers to behavior change would enrich understanding of intervention processes and inform iterative refinement of educational materials and delivery methods.

V. CONCLUSION

This study aimed to evaluate the effectiveness of castle popup media as an innovative educational intervention for enhancing oral health knowledge and promoting preventive behaviors among school-age children at SD Islam Maryam, Surabaya. A total of 31 fourth-grade students participated in the comprehensive intervention program, which integrated didactic instruction, hands-on training, and game-based reinforcement activities. The findings demonstrate substantial improvements across multiple dimensions of oral health literacy and behavioral intentions. Specifically, participants' oral health knowledge increased significantly from 57% at baseline to 94% post-intervention, representing a 37 percentage-point improvement and indicating high effectiveness of the educational approach. Beyond quantitative knowledge gains, qualitative observations revealed heightened student engagement, increased

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motivation to maintain oral hygiene practices, and positive attitudinal shifts toward preventive dental care. The castle pop-up media, featuring culturally relevant narrative elements and multisensory learning components, successfully captured students' attention and facilitated comprehension of complex health concepts through age-appropriate visual and tactile modalities. The integration of dental phantoms for technique demonstration and the implementation of a reward-based reinforcement system further enhanced the intervention's pedagogical efficacy.

These outcomes collectively suggest that game-based, interactive educational tools represent promising alternatives to conventional health education methodologies for pediatric populations, particularly within resource-constrained settings where digital infrastructure may be limited. However, the study's quasi-experimental design without a comparative control group constitutes a methodological limitation that constrains causal inference and prevents direct assessment of relative effectiveness compared to traditional counseling approaches. Future research should employ randomized controlled trial designs incorporating multiple intervention arms to establish comparative efficacy and identify optimal delivery modalities. Additionally, longitudinal follow-up assessments at 3-month, 6-month, and 12-month intervals are essential to determine the sustainability of knowledge retention, persistence of behavioral changes, and ultimate impact on clinical caries indicators such as dmft/DMFT scores. Multi-site replication studies across diverse socioeconomic and geographic contexts would strengthen external validity and inform scalable implementation strategies. Furthermore, investigations examining cost-effectiveness, cultural adaptability, and integration of parental education components would enhance the translational potential of this intervention model for broader public health applications in Indonesia and comparable developing nations facing similar oral health challenges in pediatric populations.

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DATA AVAILABILITY

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request due to privacy and ethical considerations involving minor participants.

AUTHOR CONTRIBUTION

Sunomo Hadi conceptualized and designed the study, secured ethical approval, and provided overall supervision and project coordination. Nadia Agda Alifia contributed to the development of the castle popup media, conducted a literature review, and participated in intervention implementation. Diasta Ayomi assisted in data collection, conducted baseline and post-intervention assessments, and contributed to data entry and preliminary analysis. Indriyani Ananta participated in the design and fabrication of educational materials, facilitated game-based learning activities, and provided technical support during intervention sessions. Ishraf Muhammad Husni Abdillah contributed to study methodology development, assisted with statistical analysis and data interpretation, and provided critical feedback on the manuscript. Saroya Rindi Antika coordinated participant recruitment, managed logistical arrangements for the intervention, and participated in manuscript preparation and editing. All authors collaboratively refined the intervention protocol, reviewed and approved the final manuscript, and agreed to be accountable for all aspects of the work, ensuring integrity and accuracy.

DECLARATIONS

ETHICAL APPROVAL

Ethical approval is not available.

CONSENT FOR PUBLICATION PARTICIPANTS

Written informed consent for publication of study findings was obtained from the parents or guardians of all student participants. No individually identifiable information is included in this manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

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