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The Effect of Animation Book–Based Education on Adolescents' Knowledge and Attitudes Toward Diabetes Mellitus Prevention: A Quasi-Experimental Study at Muhammadiyah 1 Junior High School, Sidoarjo, Indonesia

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ABSTRACT The increasing prevalence of diabetes mellitus (DM) among adolescents represents a significant public health challenge, largely driven by lifestyle factors and insufficient awareness of preventive measures during early life stages. Despite existing health education efforts, traditional media such as leaflets often fail to effectively engage this population, limiting their impact on knowledge and behavioral change. This study aimed to evaluate the effectiveness of animation book-based health education compared to conventional leaflet methods in enhancing knowledge and attitudes toward diabetes mellitus prevention among adolescents at Muhammadiyah 1 Junior High School, Sidoarjo, Indonesia. Utilizing a quasi-experimental design with non-equivalent control groups, 64 ninth-grade students were allocated evenly into an intervention group receiving animation book education and a control group receiving leaflet-based education. Pretest and posttest assessments were conducted using structured questionnaires to measure changes in knowledge and attitudes. Statistical analysis applying paired and independent t-tests revealed a significant improvement in both knowledge and positive attitudes in the intervention group compared to the control group ($p = 0.001$). Notably, the animation book group demonstrated a substantial increase in knowledge scores, with the percentage of students exhibiting "good" knowledge rising from 40.6% to 93.8%, while the control group showed only marginal gains. Attitudinal improvements followed a similar pattern, indicating that the animation book medium facilitates more effective cognitive and affective engagement. These findings suggest that animation book-based education serves as a superior and innovative pedagogical tool for school-based health promotion aimed at early diabetes prevention. Integration of such interactive media can enhance adolescent health literacy and support preventive behaviors, ultimately reducing the future burden of non-communicable diseases.

INDEX TERMS Diabetes mellitus prevention, animation book media, adolescent health education, knowledge improvement, attitude change.

I. INTRODUCTION

Diabetes mellitus (DM) has transitioned from a condition predominantly affecting adults to one increasingly diagnosed among adolescents, largely due to shifting lifestyle behaviors characterized by high-calorie diets, sedentary habits, and rising obesity rates [1]-[5]. The early onset of DM in youth presents complex challenges for public health, requiring effective strategies to increase awareness and promote preventive behaviors before the onset of irreversible complications [6],[7]. Studies indicate that adolescents often possess limited knowledge of DM risk factors and demonstrate less favorable attitudes towards prevention, which perpetuates unhealthy lifestyle choices [8],[9].

Current standard health education methods, including lectures and printed leaflets, typically suffer from limited appeal and engagement among adolescent populations, resulting in suboptimal knowledge retention and behavioral intention formation [10],[11]. Recent pedagogical advances advocate for the incorporation of interactive and visually stimulating media, such as animation-based educational tools, which align better with adolescents' cognitive styles and learning preferences [12],[13]. Animation integrates visual storytelling and interactive elements that can simplify complex biomedical concepts and foster deeper learning [14],[15].

Despite promising pilot studies in multimedia health education demonstrating improved knowledge and attitude

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outcomes among adolescents [16]-[19], there remains a lack of rigorous comparative research within school-based contexts, particularly in low-to-middle income settings such as Indonesia. Additionally, theoretical frameworks like the Theory of Planned Behavior and Social Cognitive Theory underline the importance of positive attitude formation and self-efficacy, which may be better achieved through animation media than passive print materials [20]-[22]. This gap requires empirical evidence evaluating animation book media's effectiveness against traditional approaches to inform policy and curricular innovation in adolescent health promotion.

Addressing these gaps, this study aims to compare the impact of animation book-based health education versus leaflet-based education on the knowledge and attitudes towards diabetes prevention among adolescents in a junior high school in Sidoarjo, Indonesia. The study makes three key contributions: (1) it provides empirical data on interactive media effectiveness in a school setting, (2) it contextualizes findings within behavioral theories to better understand mechanisms of change, and (3) it offers practical insights for integrating innovative media into school health programs.

The remainder of this article is organized as follows: Section II outlines the methodology, including study design, participant recruitment, and data analysis; Section III presents the results; Section IV discusses the findings in relation to existing literature; and Section V concludes with implications, limitations, and directions for future research.

II. METHOD

This study employed a quasi-experimental design to evaluate the effectiveness of animation book media on enhancing adolescents' knowledge and attitudes towards diabetes mellitus prevention. The methodology was developed to ensure rigorous comparison of educational interventions delivered within a school-based setting. The study protocol adhered to ethical standards and was approved by the Institutional Review Board of Poltekkes Kemenkes Surabaya (IRB Approval No. EA/3861/KEPK-Poltekkes_Sby/V/2025).

A. STUDY DESIGN

A quantitative quasi-experimental pretest-posttest control group design was implemented. This design allowed for the assessment of changes in knowledge and attitudes before and after the educational intervention between two non-equivalent groups: an intervention group and a control group. Non-randomized, purposive sampling was utilized at the class level to reduce potential contamination between groups and maintain the naturalistic classroom environment. This approach is appropriate for educational settings where individual randomization is not feasible, balancing methodological rigor and practical applicability [19], [20].

B. STUDY SETTING

The research was conducted at Muhammadiyah 1 Junior High School, located in Sidoarjo Regency, East Java, Indonesia. The school was selected based on accessibility and its cooperative administrative staff, facilitating the integration of health education interventions within regular school hours during the 2025 academic year. The controlled environment ensured consistency in the implementation of educational sessions and data collection [21].

C. POPULATION AND SAMPLE

The target population comprised students enrolled in the 9th grade at the selected school. Eligibility criteria included: active enrollment during the study period, ability to participate fully in educational sessions, and possession of parental consent and personal assent. Exclusion criteria encompassed prior receipt of formal diabetes prevention education and absence during intervention sessions. Purposive sampling yielded a total sample of 64 adolescents, evenly divided into intervention (n=32) and control (n=32) groups. This sample size aligns with recommendations for quasi-experimental designs assessing educational interventions in adolescent cohorts, achieving sufficient power to detect moderate effect sizes with a 0.05 significance threshold [22], [23].

Group allocation was performed at the classroom level to minimize inter-group information exchange. One class was designated to receive the Animation Book multimedia intervention, while a comparable class received conventional leaflet-based education comprising identical content, albeit in a text-heavy format.

D. EDUCATIONAL MATERIALS AND INTERVENTION

The experimental intervention utilized an Animation Book medium an innovative educational tool integrating visual illustrations, concise narrative text, and interactive elements (e.g., quizzes and rewards) tailored to adolescent learning preferences. The content focused on key diabetes mellitus preventive topics: disease definition, symptomatology, risk factors, long- and medium-term complications, healthy nutrition, physical activity, and behavioral prevention strategies. Animated visual storytelling was employed to simplify complex medical concepts and foster cognitive engagement [24], [25].

The control group received educational leaflets containing the same content but presented statically with minimal graphics. Both interventions were delivered during a single standardized session, lasting approximately 45 minutes and facilitated by trained health educators to ensure fidelity and consistency. The identical curriculum and instructional parameters controlled for content exposure, isolating the medium's effect on learning outcomes [26].

E.DATA COLLECTION INSTRUMENT AND PROCEDURES

Two primary outcome measures were utilized: knowledge of diabetes mellitus prevention and attitudes toward preventive behaviors. Questionnaires were developed and adapted from validated instruments previously employed in adolescent health education research [27], [28]. Content validity was established via expert panel reviews from nursing and public health educators, ensuring relevance and appropriateness for the target demographic.

1. *Knowledge Questionnaire*: Comprised 30 dichotomous items (Yes/No or True/False) based on the Guttman scale, covering five thematic domains: general diabetes knowledge (9 items), symptoms (7 items), risk factors

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(4 items), long-term complications (5 items), and medium-term complications (5 items). Scoring assigned 1 point for correct responses and 0 for incorrect, enabling composite scoring and categorization into "good" (>75%), "moderate" (56–74%), and "poor" (<56%) knowledge levels [29].

2. *Attitude Questionnaire*: Included 15 items employing a 5-point Likert scale with responses ranging from strongly disagree to strongly agree, assessing favorable disposition toward diabetes prevention. Higher aggregate scores indicated more positive attitudes.

Both instruments underwent pilot testing with a demographically similar student group, establishing construct validity through item-total correlations (Pearson's $r > 0.3$) and internal consistency reliability evaluated by Cronbach's alpha ($\alpha=0.90$ for both knowledge and attitude scales), indicating excellent reliability [30], [31].

Data collection followed a standardized procedure: participants completed the pretest in situ prior to intervention delivery. Post-intervention assessments occurred immediately after the educational sessions. This pretest-posttest design facilitated evaluation of immediate knowledge acquisition and attitudinal shifts attributable to the educational media.

F. DATA ANALYSIS

Data were analyzed using SPSS version 25.0. Descriptive statistics summarized demographic characteristics and questionnaire scores. Paired sample t-tests assessed within-group pretest-posttest differences, while independent sample t-tests compared between-group differences. Statistical significance was set at $p < 0.05$. Effect sizes were calculated to quantify the magnitude of observed changes, supporting interpretation of educational impact beyond significance testing [32].

This methodological framework permits replication and extension in similar educational contexts, providing foundational evidence on the efficacy of multimedia health education tools for adolescent populations. Although constrained by the non-randomized design and short-term assessment, the approach offers important insights for school-based interventions targeting non-communicable disease prevention.

III. RESULTS

TABLE 1
Demographic Characteristics of Students of Muhammadiyah 1 Junior High School in Sidoarjo.

Characteristic	Intervention Group (n = 32)		Control Group (n =32)	
	f	%	f	%
Gender				
Female	17	53,1	18	56,3
Male	15	46,9	14	43,8
Family history of DM				
Yes	14	43,8	12	37,5
No	18	56,3	20	62,5
Physical Activity Level				
Active	14	43,8	12	37,5
Inactive	18	56,3	20	62,5

This research was conducted in September 2025 at Muhammadiyah 1 Junior High School in Sidoarjo. Muhammadiyah 1 Junior High School in Sidoarjo is a private school located in Sidoarjo Regency, precisely at Jalan KH. Samanhudi No. 81. This school was founded in 1965. The location of this research is in Sidoarjo City where the location of this research is very strategic. The principal of the School is Mrs. Erna Herawati, S.Pd., M.Pd.

TABLE 2
Distribution of Knowledge Levels in the Intervention and Control Groups of Students of Muhammadiyah 1 Junior High School in Sidoarjo.

Knowledge Level	Intervention Group				Control Group			
	Pretest		Posttest		Pretest		Posttest	
	f	%	f	%	f	%	f	%
Good	13	40,6	30	93,8	10	31,3	13	40,6
Moderate	11	34,4	1	3,1	13	40,6	14	43,8
Poor	8	25,0	1	3,1	9	28,1	5	15,6
Total	**32**	**100,0**	**32**	**100,0**	**32**	**100,0**	**32**	**100,0**

TABLE 3
Distribution of Pretest and Posttest Attitude Categories in the Intervention and Control Groups of Students of Muhammadiyah 1 Junior High School in Sidoarjo

Attitude Category	Intervention Group				Control Group			
	Pretest		Posttest		Pretest		Posttest	
	f	%	f	%	f	%	f	%
Positive	19	59,4	31	96.9	14	43,8	26	81,3
Negative	13	40,6	1	3.1	18	56,3	6	18,8
Total	32	100,0	32	100,0	32	100,0	32	100,0

TABLE 1 presents the demographic characteristics of participants in both groups. In the intervention group, the majority of participants were female (53.1%), while males accounted for 46.9%. Similarly, in the control group, female participants represented 56.3%, and males 43.8%. Regarding family history of diabetes mellitus, 43.8% of the intervention group and 37.5% of the control group reported having a family history of DM. In terms of physical activity, 43.8% of students in the intervention group and 37.5% in the control group reported engaging in regular physical activity. These findings indicate that the baseline characteristics between the two groups were relatively comparable.

As shown in TABLE 2, the intervention group showed a substantial improvement in knowledge after receiving education through animation book media, with the percentage of students categorized as "good" rising from 40.6% to 93.8%. In comparison, the control group exhibited only a slight increase in the "good" category, from 31.3% to 40.6%, suggesting a comparatively smaller improvement following leaflet-based education.

TABLE 3 shows a marked improvement in adolescents' attitudes toward diabetes mellitus prevention following the intervention. Within the intervention group, the proportion of respondents with a positive attitude increased substantially from 59.4% at pretest to 96.9% at posttest, accompanied by a sharp decline in negative attitudes from 40.6% to 3.1%. The control group also demonstrated an increase in positive attitudes, rising from 43.8% to 81.3%, although the extent of change was smaller than that observed in the intervention group. These results indicate that health education using animation book media produced a greater improvement in positive attitudes compared to traditional leaflet-based education.

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TABLE 4
Paired Sample t-Test Results of Knowledge Scores of Students of Muhammadiyah 1 Junior High School in Sidoarjo

Group		*Mean*	*Std.Deviation*	*p-value*
Intervention	*Pretest*	70.38	18.675	0.000
	Posttest	85.88	11.804	
Control	*Pretest*	65.88	14.758	0.007
	Posttest	69.50	13.041	

Based on the results presented in TABLE 4, a paired sample t-test was conducted to compare adolescents' knowledge scores before and after receiving animation book. The analysis revealed a p-value of 0.000 ($p < 0.05$) in the intervention group. These findings demonstrate a statistically significant difference in knowledge levels pre- and post-intervention. The mean knowledge score increased substantially from 70.38 in the pretest to 85.88 in the posttest, reflecting a notable improvement following the educational intervention. Conversely, the control group demonstrated a modest but still statistically significant increase, with the average score rising from 65.88 to 69.50 ($p = 0.007$), suggesting that conventional brochure-based education produced a limited effect. Overall, these findings indicate that health education delivered through animated book media is more influential in increasing adolescents' knowledge regarding diabetes mellitus prevention.

TABLE 5
Independent Sample t-Test Results Between Groups of Knowledge Scores of Students of Muhammadiyah 1 Junior High School in Sidoarjo

Knowledge	N	*Mean*	*p-value*
Pretest			
Intervention	32	70.38	0.289
Control	32	65.88	
Posttest			
Intervention	32	85.88	0.000
Control	32	69.50	

As shown in TABLE 5, the pretest results indicated comparable baseline knowledge between the intervention group (mean = 70.38) and control group (mean = 65.88), with no statistically significant difference ($p = 0.289$). In contrast, posttest findings demonstrated a marked improvement in the intervention group (mean = 85.88) compared to the control group (mean = 69.50), with a statistically difference was identified ($p = 0.000$). These findings confirm that the Animation Book media was significantly more effective than leaflet-based education in improving adolescents' knowledge.

Beyond statistical significance, the magnitude of improvement observed in the intervention group was educationally meaningful. The mean knowledge score increased by 15.5 points following the Animation Book based intervention, compared to only a 3.62 point increase in the control group. Furthermore, the proportion of students categorized as having "good" knowledge rose markedly from 40.6% to 93.8% in the intervention group, representing a 53.2% increase. In contrast, the control group demonstrated only a modest 9.3% increase. These findings indicate that the Animation Book media produced a substantial and practically relevant enhancement in adolescents' understanding of diabetes mellitus prevention.

TABLE 6
Paired Sample T-Test of Attitude Scores in the Intervention and Control Groups of Students of Muhammadiyah 1 Junior High School in Sidoarjo

Group		*Mean*	*Std.Deviation*	*p-value*
Intervention	*Pretest*	40.31	7.635	0.000
	Posttest	45.75	5.424	
Control	*Pretest*	38.06	5.946	0.003
	Posttest	40.59	4.556	

As presented in TABLE 6, presents the comparison of pretest and posttest attitude scores within each group. Higher mean scores indicate more favorable attitudes toward diabetes mellitus prevention. In the intervention group, the mean attitude score increased from 40.31 (SD = 7.635) at pretest to 45.75 (SD = 5.424) at posttest, showing a statistically significant improvement ($p < 0.05$). In contrast, although the control group also demonstrated a slight increase in mean attitude scores, the change was smaller compared to the intervention group. This finding suggests that the animation book media contributed to a meaningful enhancement in adolescents' attitudes toward diabetes mellitus prevention.

TABLE 7
Independent Sample t-Test Results Between Groups of Groups of Knowledge Scores of Students of Muhammadiyah 1 Junior High School in Sidoarjo

Attitude	N	*Mean*	*p-value*
Pretest			
Intervention	32	40,31	0,193
Control	32	38,06	
Posttest			
Intervention	32	45,75	0.000
Control	32	40,59	

TABLE 7, shows the comparison of posttest attitude scores between the intervention and control groups. The mean posttest attitude score in the intervention group was higher than that of the control group. The independent sample t-test indicated a statistically significant difference between the two groups ($p < 0.05$), demonstrating that the animation book media was more effective than the leaflet in improving adolescents' attitudes toward diabetes mellitus prevention.
The magnitude of the difference also reflects a practically meaningful improvement, indicating that the interactive and visually engaging features of the animation book may enhance students' receptiveness to health education messages.

In addition to statistical significance, the magnitude of change in attitude scores further highlights the practical relevance of the intervention. The intervention group demonstrated an increase of 5.44 points in mean attitude scores, compared to a 2.53 point increase in the control group. Moreover, the percentage of adolescents categorized as having positive attitudes increased from 59.4% to 96.9% in the intervention group, reflecting a substantial shift in preventive health perspectives.

IV. DISCUSSION

A. INTERPRETATION OF FINDINGS

The present study reveals that educational interventions employing Animation Book media significantly enhance

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adolescents' knowledge and attitudes concerning the prevention of diabetes mellitus compared to conventional leaflet-based education. The substantial improvement in knowledge scores and favorable attitudinal shifts observed among the intervention group underscores the effectiveness of visually stimulating and interactive educational tools in adolescent health promotion.

From a cognitive perspective, this finding aligns with dual-coding theory, which posits that information presented through both verbal and visual channels facilitates deeper comprehension and memory retention [30]. Adolescents, characterized by developmental preferences for multimodal learning, demonstrated improved engagement likely due to the Animation Book's incorporation of vivid illustrations, narrative storytelling, and interactive elements. These components reduce abstractness and simplify complex biomedical concepts relating to diabetes mellitus, which traditional leaflets often fail to achieve due to their predominance of static text [31].

Moreover, the enhancement observed in attitudinal measures signifies changes not solely in cognitive domains but also in affective and behavioral intentions. Attitude formation is recognized as a critical precursor to behavior modification, particularly regarding preventive health practices during adolescence, a formative period for establishing lifelong habits [32]. By fostering positive perceptions of diabetes mellitus prevention, interactive educational media such as the Animation Book may bolster motivation and self-efficacy essential for adopting healthier lifestyles, including improved dietary patterns and increased physical activity.

Neuroscientific research supports the notion that interactive and multimedia-rich educational materials activate reward systems and enhance attention pathways in the adolescent brain, leading to more sustained engagement and better learning outcomes [33]. This biologically grounded mechanism provides a plausible explanation for the significantly greater gains in knowledge and attitudes observed within the intervention cohort.

B. COMPARISON WITH PRIOR RESEARCH

The results of this quasi-experimental study corroborate a growing body of international evidence demonstrating the superiority of multimedia-based health education over conventional text-based approaches in youth populations. Recent studies highlight that educational interventions utilizing animations, e-books, and interactive digital platforms markedly improve adolescents' understanding of chronic disease prevention, including diabetes mellitus, obesity, and cardiovascular risk factors [34], [35].

For example, Lee et al. [34] conducted a randomized controlled trial examining an animation-enhanced mobile app targeting adolescent nutrition education, reporting statistically significant gains in knowledge and more positive attitudes toward healthy eating compared to a standard pamphlet group ($p < 0.01$). Similarly, Singh and Patel [35] observed that digital storytelling integrated into school curricula significantly enhanced diabetes awareness and self-care knowledge among high school students, aligning with the present findings. Their longitudinal assessment further indicated some retention of knowledge gains after six months, suggesting the potential durability of multimedia interventions.

Contrasting these favorable outcomes, some studies have identified challenges related to scalability, digital literacy disparities, and the need for sustained engagement strategies to maintain long-term effects. A meta-analysis by Zhao et al. [36] noted that while multimedia interventions yielded initial improvements in adolescent health literacy, long-term behavior change was contingent upon continuous reinforcement and community support mechanisms. This observation underscores the limitation of one-off educational sessions, such as in the current study, and suggests avenues for integrating periodic refreshers or multimodal follow-ups to enhance enduring impact.

Furthermore, the incorporation of culturally contextualized content in animation-based materials, as employed in this study, has been highlighted as a critical determinant of efficacy in diverse adolescent populations [37]. This is particularly relevant in Indonesia's multifaceted sociocultural milieu, where tailored health messaging resonates more effectively. The emphasis on age-appropriate language and relatable visuals in the Animation Book contrasts with the generic nature of traditional leaflets, enhancing relevance and learner motivation [38].

The present findings also extend the international discourse on non-communicable disease prevention among youth by reinforcing the role of innovative educational media in low- and middle-income countries (LMICs), where resource constraints often limit access to conventional health education resources. Prior research in similar LMIC contexts has demonstrated success using low-cost digital solutions to augment diabetes awareness and self-management education [39], [40].

C. LIMITATIONS AND IMPLICATIONS

Despite promising results, several limitations warrant consideration when interpreting the study outcomes. The quasi-experimental design, while pragmatic in a school setting, lacked individual randomization, potentially introducing selection bias despite balanced baseline characteristics. Future research employing randomized controlled trials with stratified sampling could enhance internal validity and control for latent confounders.

Additionally, the sample size was relatively small (n=64), which may limit the generalizability of findings. Expanding the participant pool across multiple schools and geographic regions would strengthen external validity and account for variability in demographic and cultural factors influencing health education reception.

A further limitation is the short follow-up period, with knowledge and attitude assessments conducted immediately post-intervention. This temporal proximity precludes examination of long-term retention, behavioral adoption, or metabolic health outcomes, which are critical metrics in diabetes prevention. Longitudinal studies with multiple follow-up points are necessary to assess the sustainability of educational gains and their translation into risk-reducing health behaviors.

The study also examined self-reported attitudes without direct observation or measurement of behavioral change, which may be subject to social desirability bias.

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Incorporating objective assessments, such as biometric indicators, physical activity tracking, or dietary logs, would provide a more comprehensive evaluation of intervention effectiveness.

In terms of practical implications, the study offers valuable insights for public health practitioners, school nurses, and policymakers engaged in adolescent health promotion, particularly in LMIC contexts. The demonstrated efficacy of Animation Book–based education advocates for its integration into school health curricula as a complementary strategy to conventional approaches. By leveraging adolescents' predilection for interactive and multimedia content, such interventions can enhance health literacy, facilitate early risk awareness, and mobilize preventive action against diabetes and other non-communicable diseases.

At the policy level, adoption of animation-based health education aligns with global strategies emphasizing digital health innovation and health literacy promotion as means to reduce chronic disease burden among youth [41]. Governments and educational authorities should consider investing in the development and dissemination of culturally relevant, digitally enriched educational materials tailored to adolescent learning preferences.

Moreover, the findings underscore the imperative for capacity building among school health personnel to effectively implement and sustain multimedia-based health education. Training programs for educators and health facilitators should incorporate technological literacy and pedagogical skills pertinent to interactive media utilization.

Finally, future research agendas should explore integration of Animation Book interventions within broader digital health ecosystems, including mobile health applications, social media campaigns, and community-based initiatives, to create synergistic effects. Investigating cost-effectiveness, scalability, and acceptability across diverse settings will inform optimal deployment strategies.

V. CONCLUSION

This study aimed to evaluate the effectiveness of Animation Book–based health education in enhancing adolescents' knowledge and attitudes toward the prevention of diabetes mellitus at Muhammadiyah 1 Junior High School, Sidoarjo, Indonesia. The findings demonstrated that the Animation Book intervention significantly improved knowledge scores from a mean of 70.38 pre-intervention to 85.88 post-intervention ($p < 0.001$), representing an increase of 15.5 points, while the control group, which received conventional leaflet-based education, showed a smaller increase from 65.88 to 69.50 ($p = 0.007$). Similarly, the proportion of students exhibiting good knowledge rose drastically from 40.6% to 93.8% in the intervention group, compared to a modest increase from 31.3% to 40.6% in the control group. Furthermore, positive attitudes toward diabetes prevention increased substantially by 37.5 percentage points in the intervention group, in contrast to a 37.5 percentage points increase in the control cohort. These results highlight the superior efficacy of animation-based educational media in effectively enhancing both cognitive and affective domains related to diabetes prevention among adolescents. Based on these outcomes, the integration of interactive and visually engaging instructional tools like Animation Books in school health programs is highly recommended to foster early adoption of preventive behaviors. To strengthen and validate these findings, future research endeavors should incorporate randomized controlled trials with larger, more diverse populations and longitudinal follow-up to assess the durability of knowledge retention, attitude stability, and behavioral change, as well as metabolic risk reduction over time. Additionally, exploring integration within broader digital health promotion frameworks could provide insight into sustainable and scalable strategies for adolescent health education in Indonesia and beyond.

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DATA AVAILABILITY

No datasets were generated or examined during the conduct of this study.

AUTHOR CONTRIBUTION

Bilqis Nikma Fauzan was responsible for conceptualizing and designing this study, carrying out the data collection, conducting the data analysis, and drafting the initial version of the manuscript. Anita Joeliantina contributed to the study design, oversaw the research process, and provided critical revisions to enhance the scholarly quality and content of the manuscript. Moch Bahrudin supported the study by performing data analysis, interpreting the results, and reviewing the methodology. Sari Luthfiyah was involved in conducting the literature review, developing the educational materials, and editing the manuscript. All authors reviewed and approved the final results of manuscript and agreed to be accountable for all aspects of the work, ensuring its accuracy, reliability, and overall integrity.

DECLARATIONS

ETHICAL APPROVAL

This study was carried out in accordance with ethical standards and obtained approval from the Institutional Review Board (IRB) of Poltekkes Kemenkes Surabaya, Indonesia, under approval number [No.EA/3861/KEPK-Poltekkes_Sby/V/2025].

CONSENT FOR PUBLICATION PARTICIPANTS.

Prior to data collection, informed consent was secured from the parents of all participants, and assent was additionally

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obtained from the adolescent participants themselves. Participants were made aware that their information would be utilized solely for research and publication purposes, with strict measures in place to ensure confidentiality.

COMPETING INTERESTS

The authors affirm that they have no conflicts of interest, whether financial or non-financial, associated with this study.

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