Co-design approach in developing oral health applications for school age children

Pendekatan *co-design* dalam pengembangan aplikasi kesehatan mulut untuk anak usia sekolah

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ABSTRACT
Oral health promotion among school age children requires innovative and engaging strategies to address persistent challenges such as dental caries and poor hygiene practices. Co-design methodology emphasizes the active involvement of end user children, parents, teachers, and health professionals in developing interventions tailored to their needs and context. This study reviews the use of a co-design approach in developing a school-based digital health application to improve oral health behaviors in children. The review examined stakeholder involvement, including children, parents, teachers, and health professionals in shaping content, usability, and engagement features of oral health applications. Evidence indicates that co-design enhances the relevance, usability, and acceptability of digital oral health interventions by integrating the lived experiences and preferences of target users. Applications developed through co-design showed higher levels of engagement, improved oral health knowledge, and better adherence to preventive behaviors among school children. It is concluded that co-design enhances the relevance, usability, and acceptability of digital oral health interventions by integrating the lived experiences and preferences of target users.
Keywords: child, co-design, health behavior, mobile application, oral health

ABSTRAK
Promosi kesehatan mulut pada anak usia sekolah memerlukan strategi inovatif dan menarik untuk mengatasi tantangan yang persisten seperti karies gigi dan kebiasaan higiene yang buruk. Metode *co-design* menekankan keterlibatan aktif pengguna akhir, yaitu anak-anak, orang tua, guru, dan tenaga kesehatan, dalam mengembangkan intervensi yang disesuaikan dengan kebutuhan dan konteks mereka. Studi ini mengeksplorasi penggunaan pendekatan *co-design* dalam mengembangkan aplikasi kesehatan digital berbasis sekolah untuk meningkatkan perilaku kesehatan mulut pada anak. Dilakukan tinjauan naratif untuk menganalisis pustaka tentang praktik *co-design* dalam kesehatan gigi digital, dengan fokus pada aplikasi untuk populasi usia sekolah. Bukti menunjukkan bahwa *co-design* meningkatkan relevansi, kegunaan, dan penerimaan intervensi kesehatan mulut digital dengan mengintegrasikan pengalaman dan preferensi pengguna target. Aplikasi yang dikembangkan melalui *co-design* menunjukkan tingkat keterlibatan yang lebih tinggi, peningkatan pengetahuan kesehatan mulut, dan kepatuhan yang lebih baik terhadap perilaku pencegahan di kalangan anak sekolah. Disimpulkan bahwa *co-design* meningkatkan relevansi, kegunaan, dan penerimaan intervensi kesehatan mulut digital dengan mengintegrasikan pengalaman dan preferensi pengguna target.
Kata kunci: anak, *co-design*, perilaku kesehatan, aplikasi seluler, kesehatan mulut
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INTRODUCTION

Dental caries remains one of the most prevalent chronic diseases among school-age children globally. According to Huang et al., the incidence of caries in permanent teeth to children aged 5-14 years increased by 15.25% in 1990-2019, with incidence rates staying high at approximately 34% during that period.[1,2] The 2018 Basic Health Research (Riskesdas) findings, the prevalence of dental and oral health problems in Indonesia was 57,6%, according to age group characteristics stated that 92.6% of children aged 5-9 years experienced caries and 28.5% experienced root caries.[3] Based on the 2023 Indonesian Health Survey, the prevalence of dental caries in children aged 5-9 years is very high, reaching 84.8%.[4]

Children with dental and oral health problems can have a detrimental effect on their quality of life. In elementary school, regular efforts to maintain dental and oral health are required, including education, examinations, and oral health care by parents, schools, and relevant government agencies.[5] Dental caries has been associated with a negative impact on the OHRQoL of children, through functional limitations and impairment to social relationships.[6] Dental caries remains one of the most prevalent chronic conditions among children worldwide and has profound consequences beyond physical discomfort. Evidence consistently demonstrates that untreated caries negatively affects children's Oral Health-Related Quality of Life (OHRQoL), particularly through functional limitations and social impairments. For instance, a cross-sectional study among Brazilian schoolchildren aged 8-11 years reported that children with active carious lesions experienced significantly poorer OHRQoL, with chewing and eating difficulties emerging as primary complaints.[7] Research conducted among Kuwaiti children aged 11-12 years found that higher counts of decayed teeth (DMFT/dmft) were strongly associated with functional limitations, emotional distress, and impairment in social well-being, underscoring the psychosocial burden of the disease.[8] A study in Hong Kong also demonstrated that preschool children with caries (dmft>0) had more than double the odds of reporting negative impacts on both child and family dimensions of OHRQoL.[9] Dental caries is among the most disruptive oral conditions for adolescents, impairing essential daily activities such as eating, speaking, and social interaction.[10] Dental caries in school aged children is not only essential for maintaining oral function but also for ensuring psychosocial well-being and overall quality of life.[11] Sustainable oral health promotion faces persistent obstacles, such as low adherence to regular toothbrushing often less than twice daily across many countries, reduced uptake of preventive dental visits due to socioeconomic and informational barriers, and limited access to reliable oral health resources, especially in low and middle income setting.[12,13]

Various methods can be used to deliver oral health education, including posters, lectures, and videos. Among these, visual and interactive media such as videos are generally more attractive to children, while posters are often

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perceived as less engaging.[14,15] Traditional oral health education methods such as lectures and posters are frequently considered less effective and fail to sustain children's interest, leading to only short-term knowledge gains without lasting behavioral changes. A major limitation of these approaches is the minimal participation of children in the design of health interventions, which results in strategies that overlook their perspectives, needs, and daily contexts.[16] In recent years, digital health technologies have been increasingly adopted to promote oral health in school settings, offering interactive platforms and gamified tools. There is many existing applications remain poorly adapted to the cultural, cognitive, and social contexts of children, thereby limiting usability, engagement, and long term impact.[17] This highlights the urgent need for participatory approaches such as co-design, involving children as active stakeholders to ensure that digital oral health solutions are both contextually relevant and developmentally appropriate.[18]

In contrast, mobile applications present significant potential as interactive educational platforms for children's oral health. These apps can integrate gamified features, personalized reminders, and engaging interfaces that align with children's technological habits and preferences. A pilot study of a *virtual pet* oral health app revealed that users found it fun, clear, and helpful resulting in more effective toothbrushing habits and better technique across tooth surfaces.[19] A randomized controlled trials and school-based interventions have shown that video-based edutainment and e-learning programs whether through animation or peer-led formats effectively reduce plaque indices and improve oral hygiene knowledge and behavior in school age children.[20] Many mobile health tools remain misaligned with users' needs due to limited involvement of children in their design. Without active end-user participation, apps risk being unsuitable or failing to engage, underscoring the urgent need for co-design approaches that ensure relevance, context-sensitivity, and longevity.[21]

Mobile health applications offer significant potential in promoting oral hygiene among schoolchildren, many programs fail to achieve sustained engagement because they are developed without sufficient involvement of the intended users.[22] This limitation emphasizes the need for participatory methodologies that integrate user experiences and perspectives into the design process, ensuring that digital health interventions are not only informative but also meaningful and practical for children.[23] Co-design also referred to as collaborative design, is a participatory methodology that involves the active engagement of children, parents, teachers, and health professionals from the earliest stages of intervention development.[22,24] Unlike conventional top-down models, co-design prioritizes the voices of end users, allowing their lived experiences and preferences to directly shape the features, usability, and content of applications.[25]

The objective of this systematic review is to critically analyze and synthesize the existing evidence on the application of co-design methodologies in developing digital oral health interventions for school-age children. Specifically, this review aims to examine how children, parents, teachers, and health professionals have been actively involved in co-design processes. Also to evaluate the impact of co-design on the relevance, usability, and engagement of oral health applications. The third objective is to and identify gaps and opportunities for integrating co-design into future school-based oral health promotion strategies.[26,27]

METODE

A narrative review methodology was applied to map and synthesize the existing literature on co-design practices in digital oral health applications targeting school-age children. This approach was chosen because it allows for the integration of diverse study designs, theoretical frameworks, and empirical findings, which are essential in capturing the multidisciplinary nature of co-design. A comprehensive literature search was conducted across major databases, including PubMed, Scopus, ScienceDirect (Elsevier), SpringerLink and Google Scholar, covering publications January 2020 to June 2025. The search combined controlled vocabulary (MeSH terms) and free-text keywords such as *co-design, collaborative design, participatory design, oral health, children, school-based,* and *mobile applications.* Boolean operators (AND, OR) were used to refine the search. Reference lists of relevant articles were also screened manually to capture additional eligible studies.

Review

Relevance and contextual adaptation

Relevance in digital health applications refers to the extent to which the design, content, and functionality of an app align with the specific needs, preferences, and cultural context of its intended users.[28] In the context of oral health applications for school age children, relevance is not only about providing accurate health information but also about ensuring that the app speaks the *language* of children and integrates seamlessly into their daily routines. When health applications fail to be relevant or contextually adapted, they often face low adoption rates, poor engagement, and limited long-term impact.[29,30]

One of the most common reasons for the failure of digital health tools is the lack of contextual adaptation. Many apps are designed based on assumptions drawn from high-income settings, which may not translate effectively in low and middle income countries (LMICs). Cultural mismatches, differences in oral health literacy, and variations in technology access all contribute to this problem.[28,30] For example, an oral health app developed for children in the United States that uses advanced gamified features and assumes daily parental monitoring may be less suitable in rural Indonesia, where digital access is uneven, and parental health literacy may be limited. Similarly, literacy barriers can prevent children or parents from fully understanding textual health messages, resulting in underutilization of the app.[28,31] Interventions must be adapted to local sociocultural settings in order to achieve both usability and effectiveness, highlighting the

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importance of embedding interventions within the daily realities of children's lives.[32]

Co-design offers a powerful approach to addressing these challenges by involving children, parents, teachers, and health professionals throughout the development process.[33] Through participatory workshops, feedback sessions, and iterative prototyping, co-design ensures that the language, imagery, and features of the app are directly informed by the lived experiences of users.[33,34] For children, this might mean incorporating playful elements that align with their developmental stage, such as characters or interactive storytelling. For parents, co-design can help identify appropriate reminders or tips that align with family routines, ensuring they are realistic and feasible. For teachers and schools, co-design may integrate oral health education into class activities without disrupting academic schedules.[35]

Daily routines play a critical role in oral health behaviviors, particularly toothbrushing, which is often tied to specific times of the day, such as after breakfast and before bedtime.[36,37] By embedding reminders and gamified incentives within these daily routines, co-designed apps can reinforce healthy habits in ways that are culturally and developmentally appropriate. Embedding oral health promotion into school contexts ensures that children receive consistent reinforcement of healthy behaviors, while parental involvement strengthens the continuity of these practices at home.[36]

Health knowledge and behavior change

Sustainable digital education is a cornerstone in promoting long-term oral health behavior among school-age children.[38] Traditional health education methods often result in temporary knowledge gains without leading to consistent behavioral change. In contrast, digital interventions provide an opportunity for continuous reinforcement through reminders, interactive features, and gamified elements, which have been shown to enhance oral health literacy and practice adherence among children.[38,39]

Evidence from randomized controlled trials and quasi-experimental studies confirms the positive impact of digital health applications on children's oral health outcomes.[40,41] For instance, Alqarni et al. demonstrated that a smartphone based intervention significantly improved brushing frequency and plaque index scores in children over a six month period compared to a control group.[42] Bramantoro et al. reported that e-learning modules combined with interactive games effectively increased oral health literacy and improved daily brushing habits in Indonesian schoolchildren. These findings suggest that digital platforms can provide both immediate and sustained improvements in children's oral health knowledge and hygiene practices.[43]

Co-design plays a critical role in ensuring that educational materials are not only evidence-based but also understandable and memorable for children. By involving children, parents, and teachers in the development process, the content can be tailored to age specific cognitive levels and cultural contexts, making it more engaging and relatable.[44] This participatory process helps transform abstract health messages into practical daily routines, such as supervised brushing before bedtime or integrating fun narratives around toothbrushing.[36,45]

Stakeholder collaboration and ownership

Co-design emphasizes the involvement of multiple stakeholders: children, parents, teachers, and dental professionals throughout the development process of digital oral health interventions.[46] Engaging diverse stakeholders ensures that applications reflect the lived realities of users while embedding practical solutions into children's daily routines.[47] This participatory approach not only enhances usability but also fosters a sense of ownership, which has been shown to significantly improve compliance with oral health behaviors.[48]

Parental involvement plays a particularly critical role, as parents act as gatekeepers of health practices in the home environment.[49] Applications developed with co-design have demonstrated success in facilitating parental supervision, for instance by integrating reminders for twice-daily toothbrushing that parents can monitor through digital platforms.[42]

Teacher participation in co-design processes also significantly strengthens the school based delivery of oral health interventions.[43] In the Indonesian context, where teachers are often central figures in health education, their involvement ensures that digital health applications are aligned with existing curricula and daily school practices.[50,51] Evidence shows that when teachers actively contribute to design and implementation, oral health programs achieve higher levels of engagement and behavioral change among students.[52] Collaboration with dental professionals ensures that content remains evidence-based and clinically relevant, bridging the gap between professional knowledge and children's daily health practices.[53] Integrating the perspectives of all stakeholders, co-design interventions cultivate both trust and accountability, which are essential for sustaining behavior change in oral health promotion.[54] In conclusion, stakeholder collaboration in co-design not only produces culturally and contextually relevant applications but also fosters shared responsibility among children, parents, teachers, and health professionals, thereby ensuring stronger compliance and long-term impact.[55]

Challenges and limitations

The implementation of co-design approaches in developing oral health applications for school-aged children is not without challenges. Technical barriers remain one of the most significant, particularly in low- and middle-income countries where access to smartphones, reliable internet connectivity, and digital literacy is limited.[56] Studies in rural Indonesia and other LMIC contexts highlight that unequal access to devices and bandwidth reduces the reach and scalability of digital health interventions. This digital divide risks excluding vulnerable groups of children who may benefit most from preventive oral health programs.

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Potential solutions have been suggested in the literature. Developing low-cost applications compatible with basic devices can help reduce barriers to access.[42] Integrating digital tools with existing school-based program, such as Indonesia's *usaha kesehatan gigi sekolah* (UKGS), may provide sustainable platforms for regular reinforcement.[57] Public private partnerships involving governments, universities, and technology companies can mobilize resources and expertise, enhancing both scalability and sustainability of digital oral health promotion.[58,59]

This narrative review highlights the potential of co-design as an innovative and participatory methodology in developing digital oral health applications for school aged children. It is concluded that involving children, parents, teachers, and dental professionals from the earliest stages of design ensures that interventions are contextually relevant, developmentally appropriate, and culturally sensitive. Applications developed through co-design not only enhance usability and engagement but also improve oral health knowledge, brushing frequency, and adherence to preventive behaviors. Despite the promising outcomes, challenges remain, including technical barriers in low-resource settings, sustainability of long-term engagement, and ethical considerations surrounding children's data privacy. Addressing these limitations through strategies such as low cost app development, integration with school based programs like UKGS, and fostering public-private partnerships will be essential for scalability.

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