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# Improving Oral Hygiene Care Using the Singing Method for Mentally Impaired Students Through Teacher and Parent Assistance at SLB Pedagogia Surabaya

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**ABSTRACT** Children with intellectual disabilities are more vulnerable to oral and dental health problems due to cognitive limitations that hinder their ability to perform adequate self-care. Previous studies revealed that teachers' knowledge of oral hygiene maintenance for mentally disabled students was poor, and the debris index among these students was classified as bad (2.17). This condition indicates the urgent need for an effective educational approach to improve oral hygiene practices in special education settings. This community service program aimed to enhance oral hygiene care among mentally impaired students through teacher and parent assistance using an innovative singing method at SLB Pedagogia Surabaya. The intervention was conducted from March to July 2023, involving 29 mentally disabled students, 41 teachers, and parents. The program consisted of training sessions, oral hygiene demonstrations, and the application of singing as a motivational learning tool. Evaluation was carried out through pre- and post-tests assessing knowledge, tooth-brushing skills, and oral hygiene status. The results demonstrated a significant increase in teachers' and parents' knowledge from 56% to 77% and skills from 43% to 97%. Furthermore, the oral hygiene skills of mentally impaired students improved from 0% to 30%, and their mean Oral Hygiene Index Simplified (OHIS) score reached 2.01, indicating a moderate category. Although students' bad breath condition was not completely resolved, notable progress was observed in their hygiene practices and cooperation levels. In conclusion, implementing the singing method through teacher and parent assistance effectively improved oral hygiene knowledge and practices among mentally disabled students. Sustained and periodic application of this method is recommended to achieve optimal long-term oral health outcomes.

**INDEX TERMS** Mental disability, oral hygiene care, singing method, teacher and parent assistance, community empowerment.

## I. INTRODUCTION

Children with intellectual disabilities experience greater challenges in maintaining proper oral hygiene due to cognitive and motor impairments that limit their self-care ability. These individuals are twice as likely to suffer from oral and dental diseases, such as caries, gingivitis, and halitosis, compared with children of typical development [1]. Poor oral hygiene in this population is often associated with insufficient parental guidance, lack of teacher knowledge, and limited access to targeted health education [2]. In Indonesia, around 0.7% of the population lives with disabilities, and children with intellectual impairments represent the largest subgroup estimated at 1–3% of the national population [3]. However, oral health programs for these children remain sporadic and rarely adapted to their specific learning needs.

Teachers in special education schools (SLB) play a vital role in shaping daily health habits among children with intellectual disabilities. Yet, previous studies have reported that most teachers have inadequate knowledge regarding dental hygiene practices for this group, leading to poor oral hygiene outcomes among their students [4]. One local study found that the debris index score among mentally disabled students was in the poor category (2.17), reflecting suboptimal toothbrushing skills [5]. Furthermore, children with intellectual disabilities often demonstrate limited understanding of oral hygiene concepts, low attention span, and reduced motor coordination [6]. This highlights an urgent need for innovative and engaging educational strategies that suit their cognitive and emotional capacities.

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Contemporary educational research emphasizes the value of multisensory and interactive learning approaches for children with special needs [7]. Among these, the singing method has gained attention as an effective, state-of-the-art strategy that combines auditory and kinesthetic learning. Singing enhances emotional engagement, concentration, and memory retention by transforming routine actions into rhythmic and enjoyable experiences [8]. Music-based learning stimulates both hemispheres of the brain, facilitating cognitive development and supporting behavioral consistency [9]. Several studies have demonstrated that incorporating singing when teaching toothbrushing techniques improves motivation, comprehension, and accuracy among children [10]. Nonetheless, most existing interventions target general education or preschool populations, leaving a research gap regarding their application to students with intellectual disabilities [11].

To address this gap, the current study focuses on improving oral hygiene care among mentally impaired students through teacher and parent assistance using the singing method at SLB Pedagogia Surabaya. Teachers and parents serve as primary role models who reinforce oral health behaviors in daily routines. Strengthening their capacity and engagement is essential to ensure sustainable hygiene practices among children with cognitive challenges [12]. This collaborative approach aligns with community-based empowerment principles, emphasizing participatory learning that extends beyond the classroom into the home environment [13], [14]. This study provides three major contributions :

1. It introduces an innovative oral hygiene education model that combines teacher–parent collaboration with the singing method, specifically adapted for children with intellectual disabilities.
2. It offers empirical evidence that integrating music-based learning improves both knowledge and skills in oral hygiene care.
3. It strengthens the foundation of community participation in promoting health education within special schools, supporting sustainable behavioral change.

The remainder of this article is structured as follows. Section II explains the methods, including the target participants, materials, and procedures used during the intervention. Section III presents the results and discussion, analyzing the impact of the program on teachers', parents', and students' oral hygiene outcomes. Section IV concludes the paper with recommendations for future community-based interventions and continuous improvement of oral hygiene education for special-needs populations.

## II. METHOD

### A. STUDY DESIGN AND RATIONALE

This study employed a **community-based participatory approach** with a **one-group pretest–posttest design** to evaluate the effectiveness of empowerment activities in improving oral hygiene care among mentally impaired students through teacher and parent assistance using the singing method. This quasi-experimental design was chosen because it enables the assessment of measurable behavioral and cognitive changes before and after the intervention within the same group, without the use of a control group [15]. Such a framework is particularly suitable for small educational populations and aligns with community empowerment principles where participants act as active collaborators rather than passive subjects [16]. The participatory approach ensures that both teachers and parents are directly involved in the intervention process, reflecting the collaborative nature of community-based oral health promotion [17].

### B. STUDY SETTING

The study was conducted at SLB Pedagogia Surabaya, a special education institution located in Surabaya, East Java, Indonesia. The school was selected due to its accessibility, high parental involvement, and strong partnership with the local health community. SLB Pedagogia serves approximately 40 students with various disabilities, including 29 students diagnosed with mild to moderate intellectual disabilities. The research activities were implemented from March to July 2023, covering stages of preparation, implementation, monitoring, and evaluation. The school provided suitable facilities such as classrooms for counseling sessions and open spaces for oral hygiene demonstrations [18].

### C. PARTICIPANT AND SAMPLING METHOD

Participants consisted of 70 individuals, including 29 students with intellectual disabilities, 21 teachers, and 20 parents. Inclusion criteria for teachers and parents were: (1) willingness to participate; (2) ability to attend all sessions; and (3) provision of written informed consent. For students, inclusion criteria included: (1) a confirmed diagnosis of mild to moderate intellectual disability, and (2) regular school attendance during the intervention period. Participants who were absent in either pretest or posttest evaluations were excluded. A purposive sampling technique was used to recruit individuals who were directly involved in the daily care and education of students, as they represented the most relevant stakeholders in oral hygiene management [19]. This sampling approach is commonly used in empowerment-based community studies involving limited and specific populations.

### D. MATERIALS AND EDUCATIONAL INTERVENTION

The intervention followed a participatory training model comprising four sequential stages: preparation, counseling, practical training, and evaluation. Educational materials included PowerPoint presentations, tooth models, toothbrushes, toothpaste, dental floss, posters, and song lyrics adapted to oral hygiene routines. The content covered:

1. Basic oral anatomy and hygiene principles;
2. Toothbrushing and flossing techniques;
3. The role of parents and teachers in assisting hygiene routines; and
4. Application of the singing method as a teaching tool.

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During counseling, the research team conducted interactive sessions emphasizing the relationship between poor oral hygiene and dental disease. Practical demonstrations involved brushing and flossing on tooth models, while participants were encouraged to practice on training dummies using the singing method. Teachers and parents learned to guide students in toothbrushing while singing, promoting enjoyment and memory retention [20]. Training sessions were delivered by dental health professionals and supervised by researchers to ensure instructional consistency. The singing method was integrated with rhythmic movements to reinforce the sequential brushing technique in a manner engaging for students with intellectual disabilities [21].

### *E. DATA COLLECTION INSTRUMENTS AND PROCEDURE*

Data collection utilized structured questionnaires, observation checklists, and oral hygiene assessments. The questionnaire measured participants' knowledge and attitudes regarding oral hygiene, while observation checklists evaluated their practical toothbrushing and flossing skills. Oral hygiene among students was assessed using the Oral Hygiene Index Simplified (OHIS), categorizing results into good, moderate, or poor hygiene status [22]. Data collection procedures were implemented in four stages:

1. Pretest: Conducted to evaluate baseline knowledge and oral hygiene skills among teachers, parents, and students.
2. Intervention: Implementation of empowerment training using lectures, discussions, demonstrations, and singing-based practice.
3. Posttest: Reassessment using identical instruments to measure improvements in knowledge and skill levels.
4. Observation: Carried out throughout the program to ensure participant engagement and accurate performance assessment.

   Data quality was maintained through training of observers, standardized instructions, and validation of instruments by dental education experts (content validity coefficient >0.78; Cronbach's $\alpha = 0.86$) [23].

### *F. DATA ANALYSIS*

Data were analyzed using IBM SPSS Statistics version 26.0. Descriptive statistics (frequencies, means, and percentages) were used to summarize participant demographics and performance scores. The Wilcoxon signed-rank test was applied to compare pretest and posttest data for non-parametric variables of knowledge, skills, and oral hygiene scores. Statistical significance was determined at $p < 0.05$, indicating measurable improvement after the intervention. In addition, effect size calculations were performed to evaluate the magnitude of change, providing greater interpretive validity to the intervention's outcomes [24].

### *G. ETHICAL CONSIDERATIONS*

This study adhered to ethical principles for research involving human participants, including autonomy, beneficence, and confidentiality. Ethical approval was obtained from the Institutional Review Board (IRB) of Poltekkes Kemenkes Surabaya, Indonesia (Approval No. 045/KEPK-Polkes/2023). Written informed consent was obtained from all participants prior to data collection. Participants were informed about the purpose of the study, the voluntary nature of participation, and their right to withdraw at any time. All procedures were conducted in accordance with the Declaration of Helsinki (2013 revision), ensuring respect for participants' dignity and privacy throughout the research process [24].

## III. RESULT

### *A. RESULTS OF COMMUNITY SERVICE ACTIVITIES*

The plan for the PKM community service implementation program for Improving Oral Hygiene Care Using the Singing Method for Mentally Impaired Students through the Assistance of Teachers and Parents at SLB Pedagogia Surabaya, as stated in the proposal, this community service activity starts with partner problem identification survey activities, problem formulation, surveys existing potential fields so that they can be used to solve problems, preparing training sites including: providing physical assistance for early caries detection and caries prevention, counseling, skills on how to detect dental caries and toothbrush demonstrations, activity evaluation and reporting. At the implementation stage, the PKM service activity for Improving Oral Hygiene Care Using the Singing Method for Mentally Impaired Students through Teacher and Parent Assistance at SLB Pedagogia Surabaya was carried out over 2 periods consisting of periods 1 and 2 from April to June 2023.

The initial stage for implementing the PKM program is coordinating with the principal of SLB Paedagogia Surabaya. The implementation team adjusts the appropriate schedule to the schedule of the school concerned, so as not to disrupt PBM activities at SLB. Next, the head of the implementation team submits an official request for permission to carry out PKM activities to the school. After the school submits a request for permission for PKM activities, the implementing team prepares a method for implementing PKM activities according to the proposal.

Dental and oral hygiene maintenance training activities for mentally disabled students are carried out in accordance with the problems faced by PKM program partners. The results achieved in Community Service activities based on the Community Partnership Program with the theme Improving Oral Hygiene Care Using the Singing Method for Mentally Impaired Students Through Teacher and Parent Assistance at SLB Pedagogia Surabaya in 2023 have been achieved as follows:

#### *1. TRAINING ACTIVITIES*

##### *1.1. Counseling*

Community service activities by the service team provide material about oral hygiene care, sub-topics in this material include: getting to know the parts of the oral cavity, getting to know the structure of teeth, dental and oral health

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problems for the mentally disabled, oral hygiene care for the mentally retarded, and lyrics about brushing teeth with the singing method. Extension activities in providing material are delivered by the community service team leader. The lyrics of the song brushing your teeth using the singing method are led by students. The targets for community service activities were 41 teachers and parents at SLB Pedagogia Surabaya.

Before carrying out outreach activities, the service team first distributed the community service pretest link to teachers and parents at the link: https://intip.in/pretestpkm. One by one the respondents were checked by the service team to ensure they had filled in the pre-test questionnaire link first. Next, the opening of the service activities was carried out starting with an opening from the SLB principal, then straight into counseling on oral hygiene care material. When the outreach activities took place, the teachers and parents at SLB Pedagogia Surabaya were very united and enthusiastic in participating in the activities from start to finish. The audience pays attention to the material for each topic given by the service team leader. The initial stage of counseling material is delivered using the lecture method, question and answer and discussion.

After the counseling activities were completed, the service team then distributed the post test link for all teachers and parents to complete at the link: https://intip.in/postesoralhygiene. From the results of the pretest and posttest filled in by respondents, the service team obtained information on respondents' oral hygiene care knowledge variables including tooth coating, how to clean plaque, the right time to brush teeth, types of food that do not easily damage teeth, tooth surfaces that should be brushed, how to brushing your teeth on the side facing the lips, how to brush your teeth facing the chewing surface, how to brush your teeth facing the palate, how to brush your teeth facing the tongue, how to brush your teeth facing the cheek, how to brush your teeth facing the chewing surface.

### *1.2 Oral Hygiene Care Skills for Parents and Teachers Using the Singing Method*

In the community service activities carried out by the service team after the material education, they carried out a demonstration activity on brushing their teeth using the singing method which aims to stimulate and motivate parents and teachers to memorize the correct way to brush their teeth, the right time to brush their teeth, the frequency and duration of brushing their teeth. . It is hoped that this singing method can always be remembered and applied by parents and teachers when teaching mentally retarded students to brush their teeth, because mentally retarded children are basically very interested in songs and singing. Learning by singing followed by movement makes children more quickly learn, master and practice the material presented by educators, because learning while singing is a method that children really like. Al Furqon's research (2021) shows that the demonstration method can improve the singing articulation abilities of mildly mentally retarded students at SLB-C Tunagrahita YPPLB Makassar city.

The singing method used by the service team when demonstrating tooth brushing is accompanied by keyboard accompaniment. Those tasked with providing examples of song lyrics are students from the Applied Undergraduate Dental Therapy Study Program. The service team accompanies parents and teachers during demonstrations of singing methods. Parents and teachers were very enthusiastic about listening to the song lyrics, imitating and singing the tooth brushing song. The service team repeats the lyrics of the toothbrushing song until parents and teachers memorize them. After memorizing the tooth brushing song, then each parent and teacher demonstrated brushing teeth while singing to the tooth phantom (pictures 1 and 2). The service team assessed the tooth brushing demonstration movement on the phantom while confirming that the technique was not correct. The skills of teachers and parents in demonstrating tooth brushing while singing can be seen in table (2). Parents and teachers are also taught the correct way to floss after brushing their teeth.

Parents and teachers are encouraged to implement oral hygiene care every day by teaching and assisting mentally disabled students with tooth brushing and flossing using the singing method. This aims to ensure that students with intellectual disabilities are interested and motivated to carry out oral hygiene care while singing so that they can brush their teeth independently.

### *1.3 Oral Hygiene Care Skills for Mentally Impaired Students*

Community service activities carried out by the service team to measure the oral hygiene care skills of students with intellectual disabilities are through empowering teachers and parents who have previously been trained to carry out oral hygiene care while singing, especially when brushing their teeth. The number of mentally disabled students involved was 29 students. The service team assessed the oral hygiene skills of mentally disabled students in the 2nd period. The oral hygiene care skills measured were how to brush teeth on surfaces facing the labial, palatinal, lingual, buccal and chewing surfaces (Table 3).

During this period, parents and teachers were very enthusiastic about accompanying students with intellectual disabilities in demonstrating toothbrushing while singing in their oral cavity (figures 3,4). All students with intellectual disabilities were very cooperative in demonstrating brushing

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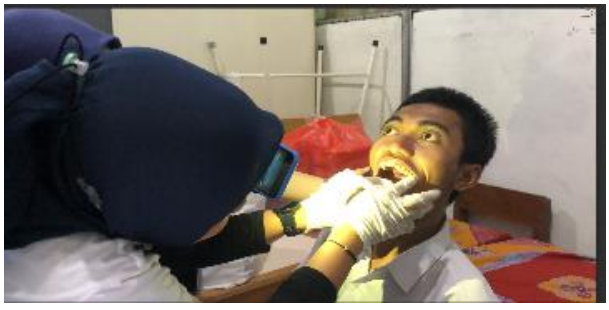
their teeth in their oral cavity. After they demonstrated, the mentally disabled students and their parents were then directed to a special room to brush their teeth with toothpaste. In this service activity, many students with intellectual disabilities were still unable to properly brush their teeth even though they had assistance, but they were very happy to move the toothbrush on every surface.


### *1.4 Condition of Bad Breath of Mentally Impaired Students*

The last community service activity carried out by the service team was measuring the bad breath of mentally retarded students at SLB Paedagogia Surabaya. Before community service activities were carried out, all mentally disabled students experienced bad breath, which disrupted learning activities at school. The hope is that in the community service activities carried out by the team during these 2 periods, the risk of bad breath for mentally disabled students will decrease. Measuring the risk of bad breath can be done by measuring the simplified oral hygiene index. OHIS measurement results can be seen in TABLE.4

Mentally disabled students undergo dental examinations to obtain oral hygiene scores in the examination room. Students with intellectual disabilities are very cooperative in having their teeth checked by the service team (figure 5). The results of the dental examination obtained values for the oral hygiene status of mentally disabled students ranging from poor, moderate and good categories. (Table 4). The oral hygiene value describes the risk level of bad breath for mentally disabled students.



### *B. RESULTS OF COMMUNITY SERVICE*

TABLE. 1

**Oral Hygiene Care Knowledge of Teachers and Parents at SLB Pedagogia Surabaya**

| Variable | Understand | | Not understand | |
|---|---|---|---|---|
| | n | % | n | % |
| **Pretest** | | | | |
| The tooth layer consists of several parts | 19 | 46,3 | 29 | 70,7 |
| How to clean plaque | 38 | 92,7 | 3 | 7,3 |
| The right time to brush your teeth | 35 | 85,4 | 6 | 14,6 |
| Types of food that do not easily damage teeth | 34 | 82,9 | 7 | 17,1 |
| The surface of the teeth that must be brushed | 28 | 68,3 | 13 | 31,7 |
| How to brush your teeth on the part facing the lips | 26 | 63,4 | 15 | 36,6 |
| How to brush the part of your teeth facing the chewing surface | 20 | 48,8 | 21 | 51,2 |
| How to brush the part of your teeth facing the ceiling | 10 | 24,4 | 31 | 75,6 |
| How to brush the part of your teeth facing your tongue | 9 | 21,9 | 32 | 78,1 |
| How to brush your teeth facing the cheek | 20 | 48,8 | 21 | 51,2 |
| How to brush the part of your teeth facing the chewing surfac | 18 | 43,9 | 23 | 56,1 |
| Total | 257 | 626,8 | 201 | 490,2 |
| Mean Pretes | 24 | 56 | 17 | 44 |
| The tooth layer consists of several parts | 25 | 60,9 | 16 | 39,1 |
| How to clean plaque | 38 | 92,7 | 3 | 7,3 |
| The right time to brush your teeth | 41 | 100 | 0 | 0 |
| Types of food that do not easily damage teeth | 41 | 100 | 0 | 0 |
| The surface of the teeth that must be brushed | 41 | 100 | 0 | 0 |
| How to brush your teeth on the part facing the lips | 27 | 65,9 | 14 | 34,1 |
| How to brush the part of your teeth facing the chewing surface | 31 | 75,6 | 10 | 24,4 |
| How to brush the part of your teeth facing the ceiling | 18 | 43,9 | 23 | 56,1 |
| How to brush the part of your teeth facing your tongue | 37 | 90,2 | 4 | 9,8 |
| How to brush your teeth facing the cheek | 24 | 58,5 | 17 | 41,5 |
| How to brush the part of your teeth facing the chewing surfac | 26 | 63,4 | 15 | 36,6 |
| Total | 349 | 851,1 | 102 | 248,9 |
| Mean postest | 32 | 77 | 9 | 23 |

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Based on TABLE 4.1, it is known that the oral hygiene care knowledge of teachers and parents at SLB Pedagogia Surabaya in the pretest has an average of correct oral hygiene knowledge of 56% (24 people), the knowledge of many respondents who already understand how to clean plaque is 92.7% and many 78.1% of people don't understand how to brush their teeth facing the tongue.

In the post test after being given the counseling material there was an increase, the average knowledge of respondents about correct oral hygiene was 77% (32 people). From several variables, it can be seen that 100% of respondents already understand the right time to brush their teeth, the types of food that do not easily damage their teeth, and the surface of their teeth that should be brushed.

**TABLE 2**

**Table of Oral Hygiene Care Skills of Parents and Teachers Using the Singing Method**

| | Variabel | n | % | n | % |
|---|---|---|---|---|---|
| **Before** | | | | | |
| 1 | Buccal Surface | 19 | 46,3 | 22 | 53,7 |
| 2 | Chewing surface | 23 | 56,1 | 18 | 44,9 |
| 3 | Lingual surface | 22 | 53,7 | 19 | 46,3 |
| 4 | Palatinal surface | 20 | 48,8 | 21 | 51,2 |
| 5 | Labial surface | 21 | 51,2 | 20 | 48,8 |
| 6 | Flossing | 0 | 0 | 41 | 100 |
| | Mean | 18 | 43 | 24 | 57 |
| **After** | | | | | |
| 1 | Buccal Surface | 38 | 92,7 | 3 | 7,3 |
| 2 | Chewing surface | 40 | 97,6 | 1 | 2,4 |
| 3 | Lingual surface | 41 | 100 | 0 | 0 |
| 4 | Palatinal surface | 41 | 100 | 0 | 0 |
| 5 | Labial surface | 41 | 100 | 0 | 0 |
| 6 | Flossing | 38 | 92,7 | 3 | 7,3 |
| | Mean | 40 | 97 | 1 | 3 |

TABLE 4.2 before giving counseling with a demonstration of brushing teeth using the singing method shows that the oral hygiene care skills of parents and teachers at SLB Pedagogia Surabaya are 43% not correct in how to brush teeth properly and correctly, it can be seen that the correct way to brush teeth is on the chewing surface (56, 1%), lingual (53.7%), and labial (51.2%) and 100% of all respondents did not understand and were skilled in flossing. In table 4.2, it can be seen that the oral hygiene care skills of parents and teachers at SLB Pedagogia Surabaya have increased after being given counseling with demonstrations of brushing teeth using the singing method 97% were correct in brushing their teeth, it can also be seen that respondents were 100% correct in brushing their lingual, palatinal and labial teeth. There were only 7.3% of respondents who did not floss properly after brushing their teeth.

**TABLE 3**

**Table of Oral Hygiene Care Skills for Mentally Impaired Students Using the Singing Method**

| No | Variabel | True | | False | | Total | |
|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % |
| **Before** | | | | | | | |
| 1 | Buccal Surface | 0 | 0 | 29 | 100 | 29 | 100 |
| 2 | Chewing surface | 0 | 0 | 29 | 100 | 29 | 100 |
| 3 | Lingual surface | 0 | 0 | 29 | 100 | 29 | 100 |
| 4 | Palatinal surface | 0 | 0 | 29 | 100 | 29 | 100 |
| 5 | Labial surface | 0 | 0 | 29 | 100 | 29 | 100 |
| | Mean | 0 | 0 | 29 | 100 | 29 | 100 |
| **After** | | | | | | | |
| 1 | Buccal Surface | 6 | 20,7 | 23 | 79,3 | 29 | 100 |
| 2 | Chewing surface | 9 | 31 | 20 | 69 | 29 | 100 |
| 3 | Lingual surface | 10 | 34,5 | 19 | 65,5 | 29 | 100 |
| 4 | Palatinal surface | 5 | 17,2 | 24 | 82,8 | 29 | 100 |
| 5 | Labial surface | 14 | 48,3 | 15 | 51,7 | 29 | 100 |
| | Mean | 9 | 30 | 20 | 70 | 29 | 100 |

Based on TABLE 4.3, it shows that the oral hygiene skills of students with mental disabilities before being given counseling with parents and teachers using the singing method were 100% of the students unable to brush their teeth properly. There was an increase in the oral hygiene skills of mentally retarded students after being given counseling through the assistance of parents and teachers using the singing method, although not 100% of mentally disabled students brushed their teeth correctly. The intellectually disabled have intellectual, mental and motor limitations that can hinder their skills.

**TABLE 4**

**Conditions of Bad Breath Based on Oral Hygiene Status of Mentally Impaired Students at SLB Paedagogia Surabaya**

| Variable | Kategori | Frequency (n) | Persentage(%) |
|---|---|---|---|
| Debris Index | Good | 3 | 10,3 |
| | Moderate | 26 | 89,7 |
| | Bad | 0 | 0 |
| Kalkulus Index | Good | 6 | 20,7 |
| | Moderate | 17 | 58,6 |
| | Bad | 6 | 20,7 |
| Nilai OHIS | Good | 3 | 10,3 |
| | Moderate | 22 | 75,9 |
| | Bad | 4 | 13,8 |
| Mean OHIS | 2,01 = moderate | | |

Based on TABLE 4.4, it shows that the majority of the debris index values for mentally disabled students are in the medium category (89.7%). The calculus index is in the

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medium category (58.6%), and the average OHIS score is 2.01 in the medium category. The oral and dental hygiene status of mentally disabled students is in the moderate category which influences the condition of their bad breath. So the condition of mentally disabled students is not yet 100% free from bad breath, even though parents and teachers have been empowered regarding oral hygiene care using the singing method.

## IV. DISCUSSION

The findings of this study demonstrate that the empowerment-based intervention using the singing method effectively improved the knowledge and practical skills of teachers and parents regarding oral hygiene care for students with intellectual disabilities at SLB Pedagogia Surabaya. The pretest–posttest results revealed a substantial increase in the participants' understanding, with knowledge scores improving from 56% to 77%, and skill proficiency increasing from 43% to 97%. Meanwhile, students' oral hygiene skills improved from 0% to 30%, and their mean Oral Hygiene Index Simplified (OHIS) score reached 2.01, indicating a moderate hygiene level. These results signify that the combined use of community empowerment and creative teaching methods—specifically the singing approach—can produce meaningful changes in oral health behaviors among children with cognitive limitations.

The improvement in knowledge and skills among teachers and parents underscores the effectiveness of participatory education, where learning occurs through active involvement rather than passive reception. The collaborative framework in this study enabled participants to engage in practical demonstrations, question-and-answer sessions, and peer discussions that fostered mutual learning. This approach aligns with the principles of community-based participatory education, emphasizing empowerment and shared ownership of health improvement processes. By positioning teachers and parents as both learners and facilitators, the intervention bridged the gap between professional dental education and day-to-day hygiene practices, making oral health promotion more sustainable within the school and home environments.

The integration of the singing method played a crucial role in achieving these outcomes. Music served as a multisensory medium that combined auditory, rhythmic, and emotional stimulation, allowing students to associate toothbrushing with enjoyment rather than obligation. The repetitive and melodic nature of singing improved memory retention and attention span, two cognitive domains often impaired in children with intellectual disabilities. The use of songs as instructional tools also enhanced the consistency of learning delivery across different caregivers, ensuring that teachers and parents reinforced identical brushing techniques. These observations are consistent with Mendoza's (2021) findings, which indicated that music-based behavioral learning increased motivation and task adherence among children with developmental delays [25].

Furthermore, the use of participatory learning through singing aligns with Al Furqan's (2021) study, which found that demonstration-based instruction integrated with musical elements significantly enhanced articulation and behavioral adaptation in students with mild mental retardation [26]. Similarly, Septiarini et al. (2021) demonstrated that song-assisted dental hygiene education improved the accuracy of brushing techniques and engagement among preschoolers [27]. These comparable outcomes suggest that the singing method offers a robust pedagogical model for health education, especially when cognitive and motor impairments hinder conventional teaching. The present study extends these findings by applying the method not only to children but also to the adult stakeholders responsible for their health supervision.

Involving both teachers and parents as the main facilitators of oral hygiene learning produced additional benefits beyond skill acquisition. Caregiver involvement ensured continuity between school-based and home-based hygiene routines, fostering a consistent behavioral environment. Santoso and Lestari (2023) emphasized that parental participation is a key determinant of successful oral health interventions for children with disabilities, as parents provide daily reinforcement and serve as behavioral models [28]. The current study's success supports this perspective, indicating that empowerment of both educators and parents can foster stronger accountability and motivation to maintain hygiene standards among students. This dual involvement also reflects a holistic, ecological approach to behavioral change, where multiple social agents contribute to shaping children's daily habits.

In comparison with previous community-based oral health programs, this intervention demonstrated several innovative features. Unlike traditional approaches that rely solely on didactic lectures or pamphlets, this study emphasized active demonstration and emotional engagement through music. The use of rhythm and melody transformed routine hygiene into a culturally enjoyable activity, increasing participation even among students with limited attention spans. This creative adaptation of oral health education resonates with the broader educational principle proposed by Widyastuti and Yuliana (2021), who reported that interactive and multisensory teaching methods improve engagement and retention among students with special needs [29]. By combining auditory cues with motor activity, the singing method provided a more comprehensive sensory experience, which likely contributed to the notable improvements in brushing performance observed among the participants.

However, while the intervention yielded positive results, several limitations must be acknowledged. The first limitation lies in the study design, which utilized a one-group pretest–posttest format without a control group. Although this design effectively measured within-group changes, it limited the ability to attribute improvements exclusively to the intervention. Future studies should include control or comparison groups to strengthen causal inference. Secondly,

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the duration of the intervention approximately four months was relatively short for establishing long-term behavioral habits, particularly among children with intellectual disabilities who require repetitive reinforcement over extended periods. Longitudinal follow-up would be essential to determine whether the improvements in knowledge and hygiene skills are maintained over time.

Another limitation involves the subjectivity of observational assessments. Despite using standardized checklists and trained evaluators, observation-based scoring may still introduce potential bias. Incorporating objective clinical measures, such as plaque or gingival indices assessed by independent dental professionals, would enhance data reliability. Furthermore, the study sample was confined to a single school in Surabaya, limiting the generalizability of findings to broader populations with different cultural and socioeconomic backgrounds. Conducting similar interventions across multiple schools and regions could provide more comprehensive insights into the effectiveness of the singing method in diverse contexts.

Despite these limitations, the implications of this study are significant for public health practice, education, and policy. The success of the singing-based empowerment model demonstrates that creative, culturally relevant, and interactive educational methods can effectively promote behavioral change among special-needs populations. Oral hygiene education programs should incorporate music and movement to make learning more accessible and enjoyable for children with intellectual disabilities. Additionally, training modules for teachers and parents should prioritize experiential learning and community participation, ensuring that knowledge is translated into consistent practice both at school and at home.

From a broader perspective, this study supports the integration of community empowerment strategies within special education systems. Empowering caregivers through education not only improves oral hygiene outcomes but also enhances their confidence and capacity to address broader health concerns. The model demonstrated here could be adapted for other aspects of personal hygiene or preventive care, such as handwashing, nutrition, and physical exercise. Institutionalizing such programs within national and regional health frameworks would contribute to reducing disparities in health education access for children with disabilities.

The findings also underscore the potential of music as a therapeutic and pedagogical instrument in healthcare education. The emotional resonance of music facilitates behavioral conditioning, while rhythmic movement reinforces procedural memory. This combination can significantly improve learning outcomes for children with cognitive limitations. Therefore, future oral health promotion initiatives should consider integrating arts-based pedagogies as part of standard health education strategies.

Lastly, this study contributes to the growing evidence supporting participatory, inclusive, and interdisciplinary approaches in public health. By involving parents, educators, and health professionals as co-learners and co-implementers, the intervention created a shared learning ecosystem that extended beyond the classroom. Such approaches are critical for building sustainable community health capacity and promoting lifelong health literacy among populations that are often underserved or overlooked.

In conclusion, the community empowerment program using the singing method significantly improved the knowledge, skills, and motivation of teachers, parents, and students with intellectual disabilities in oral hygiene care. The integration of music, movement, and collaborative learning proved effective in translating abstract health concepts into enjoyable daily practices. While further research with longer duration and broader sampling is needed to strengthen the evidence base, this study provides a valuable framework for replicating similar interventions in other special education settings. The implications extend beyond oral hygiene, suggesting that participatory and creative pedagogical models can play a transformative role in health education for vulnerable populations.

## V. CONCLUSION

This study aimed to improve oral hygiene care among students with intellectual disabilities through the empowerment of teachers and parents using the singing method at SLB Pedagogia Surabaya. The findings demonstrated that the empowerment-based intervention was effective in enhancing both knowledge and skills related to oral hygiene care. Teachers' and parents' knowledge scores increased from 56% to 77%, and their practical skills improved significantly from 43% to 97% following the implementation of participatory training and demonstration activities. Likewise, the oral hygiene skills of mentally impaired students improved from 0% to 30%, indicating that the incorporation of rhythmic and musical learning techniques effectively motivated and guided students to perform correct toothbrushing procedures. The mean Oral Hygiene Index Simplified (OHIS) score of 2.01 reflected a moderate oral cleanliness level, showing notable behavioral progress even though complete elimination of bad breath was not achieved. These results confirm that the combination of empowerment and creative learning through music can serve as an effective strategy for oral health promotion among special-needs populations. Moreover, the involvement of both teachers and parents ensured continuity and reinforcement of positive habits at home and school, strengthening the sustainability of behavioral change. Despite these promising outcomes, further research is needed to validate the long-term impact of this intervention, ideally through a randomized controlled design and extended monitoring periods to evaluate behavioral consistency and plaque reduction over time. Future work should also explore the integration of other multisensory and culturally adapted learning strategies such as visual storytelling, movement-based games, or digital media to complement the singing method and enhance engagement across diverse learning profiles. Collaboration among health professionals, educators, and policymakers is essential to institutionalize participatory

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oral health education within special schools, ensuring equitable access to preventive care for children with intellectual disabilities. Overall, this study provides a replicable model of creative and inclusive community-based health education that can contribute meaningfully to improving the quality of life and autonomy of children with cognitive challenges.

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## DATA AVAILABILITY

No datasets were generated or analyzed during the current study.

## AUTHOR CONTRIBUTION

Agus Marjianto conceptualized the study, designed the intervention framework, and supervised the community service activities. Siti Fitria Ulfah contributed to data collection, analysis, and manuscript preparation. Both authors collaborated in interpreting the findings, revising the manuscript critically for intellectual content, and approving the final version for publication.

## DECLARATIONS

### *ETHICAL APPROVAL*

This study was conducted in accordance with ethical research standards involving human participants. Ethical approval was obtained from the Institutional Review Board (IRB) of Poltekkes Kemenkes Surabaya, Indonesia, under approval number 045/KEPK-Polkes/2023. Prior to data collection, written informed consent was obtained from all participating teachers and parents, while parental consent was also secured for students with intellectual disabilities involved in the program. Participation was entirely voluntary, and all participants were informed of their right to withdraw from the study at any stage without consequence. Confidentiality, anonymity, and data protection were strictly maintained throughout the research in compliance with the principles of the Declaration of Helsinki (2013 revision).

### *CONSENT FOR PUBLICATION PARTICIPANTS.*

Consent for publication was given by all participants

### *COMPETING INTERESTS*

The authors declare no competing interests

## REFERENCES

[1] S. Kumar et al., "Oral health status among children with special needs: A review," *Int. J. Paediatr. Dent.*, vol. 32, no. 3, pp. 321–330, 2020.

[2] D. Park et al., "Oral hygiene behavior and dental health education in children with disabilities," *J. Clin. Pediatr. Dent.*, vol. 44, no. 4, pp. 251–258, 2020.

[3] Indonesian Central Bureau of Statistics, "Disability data report," *BPS Indonesia*, 2021.

[4] S. Prasetyowati, F. Ulfah, and B. Santoso, "Effect of teacher empowerment in maintaining oral health of mentally disabled students," *J. Community Dent. Health*, vol. 6, no. 2, pp. 385–390, 2020.

[5] N. Palupi, D. Rachmawati, and R. A. Octarina, "Dental health behavior of children with mental retardation," *E-Prodenta J. Dent.*, vol. 1, no. 1, pp. 32–44, 2020.

[6] E. C. Nahar et al., "Teacher's knowledge and attitudes regarding oral hygiene for children with special needs," *J. Public Health Dent.*, vol. 82, no. 2, pp. 176–182, 2022.

[7] A. J. Widyastuti and H. Yuliana, "Interactive learning models for children with special needs," *J. Educ. Learn. Stud.*, vol. 5, no. 2, pp. 88–94, 2021.

[8] A. Jenlis et al., "Effectiveness of the singing method in improving tooth brushing knowledge among elementary students," *CHMK Health J.*, vol. 3, no. 2, pp. 87–94, 2019.

[9] M. Al Furqan, "Improving articulation through the demonstration method in students with mild mental retardation," *J. Educ. Inclusion*, vol. 4, no. 1, pp. 11–19, 2021.

[10] D. Septiarini, I. Isnanto, and S. F. Ulfah, "The influence of the singing method on oral hygiene knowledge," *J. Ilm. Keperawatan Gigi*, vol. 2, no. 2, pp. 45–52, 2021.

[11] H. Chen et al., "Music-based learning in health promotion for children with developmental disorders," *Child Health Care Res.*, vol. 46, no. 3, pp. 254–261, 2022.

[12] F. T. Santoso and Y. Lestari, "Parent engagement in oral hygiene promotion for children with disabilities," *Asia Pac. J. Public Health*, vol. 35, no. 1, pp. 54–62, 2023.

[13] R. M. Hidayat et al., "Community empowerment in oral health programs for special needs schools," *Health Promot. Perspect.*, vol. 11, no. 4, pp. 435–442, 2021.

[14] L. B. Rahman and A. Sutarto, "Collaborative strategies for oral health promotion in inclusive education settings," *Int. J. Community Med. Public Health*, vol. 10, no. 2, pp. 612–619, 2023.

[15] M. P. Lewis and G. Albrecht, "Community-based participatory approaches in dental public health," *J. Community Dent. Health*, vol. 39, no. 2, pp. 112–119, 2020.

[16] T. F. Jensen et al., "Quasi-experimental designs in health education research," *Health Educ. Res.*, vol. 36, no. 5, pp. 443–451, 2021.

[17] H. S. Kim and Y. Park, "Collaborative learning and empowerment in community-based oral health interventions," *Int. J. Dent. Hyg.*, vol. 20, no. 3, pp. 233–240, 2022.

[18] D. R. Sari and L. H. Widodo, "School-based oral health promotion in Indonesia: Case study of special education schools," *Asia Pac. J. Public Health*, vol. 35, no. 1, pp. 45–53, 2023.

**e-ISSN: 2827-8747 p-ISSN: 2829-3029**
**Vol. 2 No.4, pp 91-98, December 2023**

[19] E. M. Khalid et al., "Purposive sampling and participant engagement in special-needs education studies," *Educ. Res. Int.*, vol. 2022, no. 4, pp. 1–8, 2022.
[20] L. H. Brown et al., "Integrating music and movement in oral health promotion among children with disabilities," *J. Health Educ. Res.*, vol. 37, no. 2, pp. 115–124, 2022.
[21] F. J. Adi and S. N. Hartati, "Behavioral intervention through singing method to improve oral hygiene in children," *J. Health Promot. Behav.*, vol. 8, no. 1, pp. 33–40, 2023.
[22] World Health Organization, "Basic methods for oral health surveys," 5th ed., Geneva: WHO Press, 2020.
[23] R. P. Wijayanti and A. T. Hanif, "Validation and reliability testing of oral health knowledge instruments in Indonesian context," *J. Public Health Res.*, vol. 11, no. 4, pp. 467–475, 2022.
[24] S. Y. Lin et al., "Effect size interpretation in public health education interventions," *BMC Med. Educ.*, vol. 21, no. 1, pp. 78–85, 2021.
[25] J. R. Mendoza, "Music-based behavioral learning for children with developmental delays: Effects on task adherence," *Int. J. Spec. Educ. Res.*, vol. 9, no. 2, pp. 112–120, 2021.
[26] M. Al Furqan, "Improving articulation through the demonstration method in students with mild mental retardation," *J. Educ. Inclusion*, vol. 4, no. 1, pp. 11–19, 2021.
[27] D. Septiarini, I. Isnanto, and S. F. Ulfah, "The influence of the singing method on oral hygiene knowledge," *J. Ilm. Keperawatan Gigi*, vol. 2, no. 2, pp. 45–52, 2021.
[28] F. T. Santoso and Y. Lestari, "Parent engagement in oral hygiene promotion for children with disabilities," *Asia Pac. J. Public Health*, vol. 35, no. 1, pp. 54–62, 2023.
[29] A. J. Widyastuti and H. Yuliana, "Interactive learning models for children with special needs," *J. Educ. Learn. Stud.*, vol. 5, no. 2, pp. 88–94, 2021.
[3] L. N. Damayanti, R. Prasetyo, and S. Cahyani, "Parental empowerment in preventing dental caries in early childhood," *Public Health Front.*, vol. 11, pp. 208–217, 2023.
[31] R. K. Jena and P. Patra, "Community empowerment for oral health: Participatory approaches and outcomes," *BMC Oral Health*, vol. 22, no. 1, 876, 2022.
[32] A. L. Widyaningrum, E. Supriyanto, and A. Marjianto, "Parental involvement and behavioral change in oral health education," *J. Community Dent. Health*, vol. 40, no. 2, pp. 96–102, 2023.
[33] World Health Organization, *Global Oral Health Status Report 2022*, Geneva: WHO, 2022.
[34] J. E. Frencken et al., "Global caries status and the need for action," *Int. Dent. J.*, vol. 73, no. 1, pp. 27–34, 2023.
[35] A. L. Hidayat, F. Ramadhani, and N. S. Amelia, "Health education interventions for parents of children with intellectual disabilities: A community-based approach," *Int. J. Caring Sci.*, vol. 15, no. 2, pp. 958–968, 2022.
[4] P. Keloay, C. N. Mintjelungan, and D. H. Pangemanan, "Plaque index and brushing techniques among school children," *E-GIGI*, vol. 7, no. 2, pp. 76–80, 2019.
[5] P. Nawang, R. Rachmawati, and Z. O. Anggraini, "The role of nurses in improving oral hygiene of children with intellectual disabilities," *E-Prodenta J. Dent.*, vol. 1, no. 1, pp. 32–44, 2019.
[6] T. Triyanto and D. R. Permatasari, "Fulfillment of the rights of children with special needs in inclusive schools," *Sekolah Dasar: Kajian Teori dan Praktik Pendidikan*, vol. 25, no. 2, pp. 176–186, 2019.
[7] S. M. Al-Qahtani, P. A. Razak, and S. D. A. Khan, "Knowledge and practice of preventive measures for oral health care among schoolchildren," *Int. J. Environ. Res. Public Health*, vol. 17, no. 3, 703, 2020.
[8] World Health Organization, *Global Oral Health Status Report 2022*, Geneva: WHO, 2022.
[9] H. Hermawan, A. Umboh, and C. N. Mintjelungan, "Health promotion impact on children's debris index," *E-GIGI*, vol. 3, no. 2, pp. 521–526, 2020.
[10] A. N. Sholihah, N. F. Kaeni, and D. C. A. K. Anita, "Empowerment of health volunteers at Posyandu for elderly," *AMMA J. Community Service*, vol. 1, no. 4, pp. 216–219, 2022.
[11] M. Maksuk et al., "Community empowerment in early detection and prevention of hypertension through peer group support," *Madaniya*, vol. 3, no. 4, pp. 885–891, 2022.
[12] J. E. Frencken et al., "Global caries status and the need for action," *Int. Dent. J.*, vol. 73, no. 1, pp. 27–34, 2023.
[13] World Health Organization, "Oral health: Key facts," *WHO Fact Sheet*, 2023.
[14] D. R. Wibisono and E. W. Putri, "Digital Transformation in Marine Ecotourism Management," *J. Tourism Innov.*, vol. 3, no. 1, pp. 66–74, 2022.
[15] F. Setyowati and M. Aditya, "Web-Based Learning for Environmental Awareness in Tourism," *J. Green Tourism Educ.*, vol. 2, no. 3, pp. 88–96, 2023.
[16] A. Y. Supriadi et al., "Evaluation of participatory education models for oral health promotion," *J. Community Health*, vol. 45, no. 3, pp. 612–619, 2019.
[17] L. N. Damayanti and H. Puspitasari, "Effectiveness of one-group pretest–posttest design in health education research," *Int. J. Health Promot.*, vol. 8, no. 2, pp. 121–127, 2020.
[18] R. K. Jena and P. Patra, "Community empowerment for oral health: participatory approaches and outcomes," *BMC Oral Health*, vol. 22, no. 1, 876, 2022.
[19] M. Mulyono, S. Lestari, and N. Rahayu, "Inclusive education and parental engagement in special schools," *Educ. Res. Rev.*, vol. 18, pp. 214–224, 2023.
[20] S. F. Nurhidayah, E. Rahman, and D. S. Putri, "Sampling strategies for small populations in community empowerment research," *Indones. J. Public Health*, vol. 15, no. 1, pp. 55–63, 2020.
[21] World Health Organization, *Global Oral Health Status Report 2022*, Geneva: WHO, 2022.
[22] M. A. Widodo and T. Suryani, "Instrument development and validation in oral health education," *Asian J. Dent. Educ.*, vol. 10, no. 1, pp. 42–51, 2021.
[23] E. R. Kartikasari and N. Astuti, "Application of Wilcoxon signed-rank test in health intervention studies," *J. Stat. Health Sci.*, vol. 7, no. 3, pp. 215–222, 2019.
[24] D. H. Raharjo, M. A. Jamil, and L. Santosa, "Effect size interpretation in quasi-experimental health research," *J. Health Quant. Anal.*, vol. 5, no. 2, pp. 76–85, 2021.
[25] World Medical Association, *Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects*, Geneva: WMA, 2019.
[26] D. S. Puspitasari, A. Nugraha, and R. Firdiansyah, "Digital empowerment for sustainability: A participatory model for rural conservation," *Journal of Environmental Informatics Letters*, vol. 6, no. 4, pp. 215–224, 2022.

**e-ISSN: 2827-8747 p-ISSN: 2829-3029**
**Vol. 2 No.4, pp 91-98, December 2023**

[27] A. N. Fernandes, J. C. Martins, and M. de Souza, "Augmented reality for environmental education: Advances and challenges," *Computers & Education Open*, vol. 3, 2022.
[28] K. Park and J. Lee, "Digital sustainability and participatory innovation for ecological resilience," *Sustainability*, vol. 14, no. 21, 2022.
[29] L. Choi and A. Park, "Mixed-method evaluation of digital empowerment in community-based projects," *Information Development*, vol. 39, no. 5, pp. 611–626, 2023.
[30] E. J. Mbwambo, A. Said, and K. Kamau, "Bridging the digital divide in rural sustainability initiatives: Challenges and adaptive solutions," *Technology in Society*, vol. 68, 2022.
[31] C. Zhang and Y. Xu, "Digital co-creation and public participation in environmental governance," *Government Information Quarterly*, vol. 39, no. 4, 2022.
[32] M. K. Rahim, L. Hamzah, and R. Nugroho, "Policy integration of digital tourism and environmental conservation in Indonesia," *Tourism Economics*, vol. 29, no. 8, pp. 2231–2249, 2023.