Hybrid Simulation Model to Support the Oral Health Education Planning

Maria Hajłasz and Bożena Mielczarek
Faculty of Management,
Wrocław University of Science and Technology,
Wyb. Wyspiańskiego 27, 50-370 Wrocław, Poland
E-mail: maria.hajlasz@pwr.edu.pl

KEYWORDS
Management, educational talks, dental caries, discrete event simulation, agent-based simulation.

ABSTRACT

Health programmes are developed to prevent disease or manage the treatment process. They should be universal enough to target the largest possible group while taking into account the individual predispositions of the recipients. Important factors influencing the scope and design of health programs are also the financial capacity and availability of personnel to implement them. Thus, in addition to the experience of planners, the use of advanced decision support tools is necessary. Hybrid simulation modelling, which refers to the combination of two or more simulation approaches, is widely used to help manage various aspects of health care, including health programmes. The article is a part of a larger study in the area of using simulation modelling to support the planning of dental caries prevention programmes in primary schools in Poland. The paper focusses on one component, which are educational talks. Our goal is to provide a framework for developing simulation models to determine the potential impact of educational talks on children's oral health attitudes towards oral hygiene. The results of the experiments showed that oral health education may results in positive attitudes at the end of primary education in children.

INTRODUCTION

The dental caries prevention programme for school students is a set of preventive services that allow the achievement of planned health effects with given resources. Dental caries is a disease that can be prevented by taking specific steps, such as fluoridation of teeth, sealing of the first molars, screening or education (Ahouo-Saloranta et al. 2013, 2017, Lee 2013, Rong et al. 2003, Sosa Torices et al. 2021). In the prevention of dental caries, proper hygiene and diet are important and can be a stimulated by a well-directed education. Despite the available knowledge, dental caries is one of the most prevalent noncommunicable diseases in the world. It affects about 514 million children and is the most common chronic childhood disease (WHO 2022).

Therefore, special attention should be paid to supporting the management of dental caries prevention programmes. During the planning phase, both the perspective of the beneficiaries (students) and the perspective of the providers should be taken into account. The prevention programme should respond to the real needs of students who are individuals with a specific state of oral health, exhibit different health behaviours and are more or less susceptible to developing the disease. As dental caries is a multidimensional disease (Baker et al. 2018), planning prevention programmes requires the use of advanced methods to support decision making. Operational research methods are successfully used to support management and decision-making in healthcare (Rais and Vianaa 2011). The use of simulation methods in health care makes it possible to understand a given system by taking into account various aspects that describe it (Eldabi and Taylor 1999).

Health-related behaviours can change over the course of life; they are shaped at home, but also at school. The period of adolescence is considered critical in their formation and the most important are the early years of a child's life (Dzielska et al. 2012). The greater awareness and healthier behaviours, such as proper oral hygiene care and low sugar consumption, the lower the risk of developing dental caries. Shaping health attitudes can be achieved by conducting educational talks in schools that are directed at a large group of children. However, it is crucial to ensure that these programmes are effective. Successful implementation depends on many different factors such as, the individual characteristics of students, their toothbrushing habits, diet, the participation of parents and guardians, and many others.

The objective of the paper is to provide a framework for developing simulation models to determine the potential impact of educational talks on children's oral health attitudes towards oral hygiene. The model was built for one of the sample primary schools located in Poland. The presented work is a continuation of research on the use of simulation methods to support the management of various aspects of dental caries prevention programmes.

SIMULATION MODELLING IN PREVENTIVE HEALTHCARE MANAGEMENT

For each disease prevention program, it is necessary to develop the goal of the program, determine ways to achieve the goal, define the target group of the program,

Communications of the ECMS, Volume 37, Issue 1,
Proceedings, ©ECMS Enrico Vicario, Romeo Bandinelli,
Virginia Fani, Michele Mastroianni (Editors) 2023
ISBN: 978-3-937436-80-7/978-3-937436-79-1 (CD) ISSN 2522-2414

designate people responsible for the implementation of individual tasks, specify costs and ways to verify the results achieved. Undoubtedly, the experience of decision-makers is important when managing prevention programs. However, in the case of a complex problem, both financial constraints and human experience alone may not be enough. Therefore, various decision support methods, including simulation, are used. Simulation is most often categorized according to four approaches: discrete event simulation (DES), agent-based simulation (ABS), system dynamics (SD), or Monte Carlo (MC) (Brailsford et al. 2009).

Najafzadeh et al. (2009) used DES to compare the incremental costs and health benefits of herpes zoster vaccine versus no herpes zoster vaccine in Canada. Vaccination of individuals, especially those aged 60-75 years, appears to be a cost-effective medical intervention.

Ho et al. (2022) highlighted the problem of low influenza vaccination rates among Americans, which manifests in financial consequences and lost productivity. The authors developed an ABS model to define the optimal range of vaccine payment policies and their impact on the percentage of the population hooked and infected, and total medical costs.

Lich et al. (2014) built a population-based SD model to assess the impact of different preventive intervention scenarios on quality-adjusted life years (QALYs) in a population of US veterans. The authors estimated avoided strokes, avoided fatal strokes and the number of people to be treated over a 20-year time horizon. They developed 15 different scenarios for the three prevention categories. The study provides a basis for understanding the impact of implementing the alternative stroke prevention and treatment strategies considered.

The MC method is often combined with the Markov technique, and is used in numerous cost analyses as a method for conducting sensitivity analysis. Greving et al. (2011) conducted a cost analysis of the use of statins in the prevention of vascular disease. The authors tested different scenarios for no preventive intervention and intervention with low dose statin treatment daily over a 10-year period. In daily practice, treatment with statins seemed not to be cost-effective for prevention in populations at low risk of vascular disease.

Simulation methods have been successful in supporting various aspects of managing prevention programs for various diseases. Discrete methods such as DES and ABS can be used to track processes that require consideration of individual patient characteristics. The SD method works well for a broader view, such as when planning health policy programs. The MC method, on the other hand, finds use as a method for conducting sensitivity analysis in evaluating the cost-effectiveness of various preventive interventions. Simulation methods are also mixed in hybrid combinations. Two or more simulation methods can be combined, or they can be combined with analytical techniques (Powell and Mustafee 2014). A hybrid model makes it possible to take into account the advantages of more than one method, while minimizing the disadvantages that may occur when using only one approach (Zulkepli and Eldabi 2015).

This paper presents a hybrid model combining DES and ABS approaches for modeling educational talks as part of a dental caries prevention program dedicated to primary school in Poland. With the DES method, it is possible to observe how the indicators related to health attitudes in students are shaped during his/her primary school education. With the ABS method, on the other hand, these observations can be expanded to track individual interactions that may occur between students.

MODELLING ORAL HEALT EDUACATION

Problem Definition

The planning of dental caries prevention programs is a complex process. The needs of society vary and depend on many factors such as socioeconomic, cultural or individual characteristics and behaviors. The ability to provide care is limited both financially and in terms of human resources. Modeling health education as a component of preventive programs requires taking many factors into account. During our previous studies, the focus was on student attitudes and the fact that students can influence each other. The impact of education on caries prevention in students has also been considered. However, this part of the model should be elaborated more extensively. An identified gap is the lack of a methodology to observe students' attitudes, which can change over time, depending on educational talks, speaker involvement and other factors that shape students' health attitudes. Particularly important are such factors as parental involvement in helping with tooth brushing, frequency of tooth brushing in students, and dietary habits including frequency of consumption of fruits and vegetables, and sweets and candy bars.

This article is a planned continuation of research on the larger problem of how to approach the planning of dental caries prevention programs for primary school students. Earlier stages of our research are presented in Figure 1.

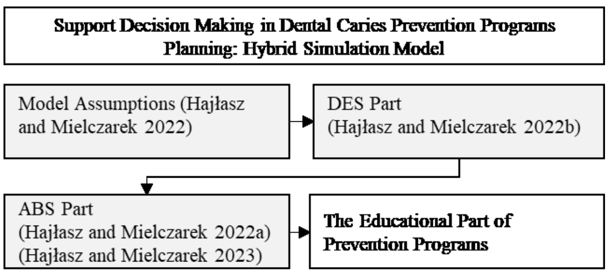

Figure 1: Our research on the problem of decision support in the area of dental caries prevention program planning using simulation modeling.

Crucial assumptions were first discussed in (Hajłasz and Mielczarek 2022). Subsequently, we developed a DES model to test different scenarios for the preventive care of dental caries (Hajłasz and Mielczarek 2022a). In the next stage, we proposed a DES–ABS hybrid model (Hajłasz and Mielczarek 2022b) in which the role of health awareness was emphasized. It was shown that the hybrid approach allows to comprehensively support the process of planning prevention programs (Hajłasz and Mielczarek 2023).

Methods

The study uses a hybrid approach combining DES and ABS. The duration of the simulation corresponds to one full cycle of primary schooling, which starts from grade zero equivalent to kindergarten through eight consecutive grades. Observations were made on dynamic objects, which are students in a class of 25. The same students were observed from the beginning to the end of their education. During the course of education, the students are provided with educational talks. It was assumed that talks are conducted by a nurse. The DES method was used to observe the effect of educational talks and the passage of time on indicators related to students' oral hygiene. ABS, on the other hand, was used to observe the relationships that occur among students. Both the indicators and the relationships that occur between students affect the formation of health attitudes in students which are represented by Individual Attitude (IA) parameter. IA refers to a student's positive or negative attitude toward hygiene and dietary habits.

We conducted 10 replications. The number of replications was determined after analyzing the confidence intervals for the observed variables. As a baseline measure, we observed the average number of students with IA positive and negative during and after primary education.

Model

Arena® by Rockwell Automation software was used to build the hybrid model. A diagram of the model is shown in Figure 2. Modelling the impact of health education on students' attitudes requires consideration of many aspects. These aspects are shown in Table 1, while the way IA is formed in students is described in Figure 3.

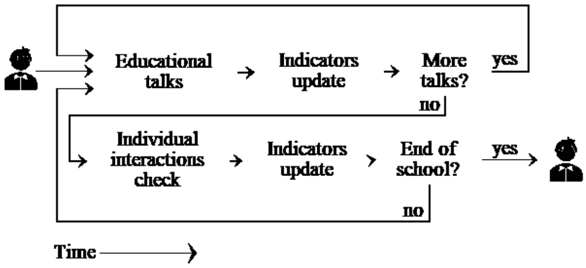

Figure 2: Overview of the educational part of the hybrid simulation model.

Students start school with baseline values for the following indicators: Dietary Habits (DH), Parents' Involvement (PI), and Tooth Brushing (TB). The PI indicator is assigned once at the beginning of the simulation and its value does not change. The initial IA can be positive or negative and depends on the sum of the TB, DH and PI indicators. The last value that students are assigned at the beginning of the simulation is the Absence Ratio (AR) and represents the probability that a given student will miss a given educational talk. Before each talk, the AR indicator is verified, and if a student misses a talk, the values of any indicators do not change.

Depending on the age of the student and what IA he or she has at a given time, each educational talk is followed

Table 1: Indicators included in this research, along with the values taken and their interpretation.

Parameter	Value	Interpretation
Absence Ratio (**AR**)	0.05-0.2	Indicator that reports the percentage chance of absenteeism of students during educational talks. It is randomly generated at the beginning of the simulation. The higher the value, the more likely the student is to miss a larger number of educational talks.
Dietary Habits (**DH**)	0-1	Indicator informs about dietary habits. The initial value is based on actual data and then updated as educational talks are received. The higher the value, the better the dietary habits in the students.
Individual Attitude (**IA**)	-1; 1	IA can take two values, -1 or 1, where -1 corresponds to a negative (N) attitude and 1 corresponds to a positive (P) attitude. IA is influenced by other learners through individual interactions, DH, PI and TB.
Negative Force of Influence (**FI–N**)	0-1	The higher the value of the indicator, the greater the persuasive power of the student with IA negative convinces students from the closest environment who have a positive attitude to change it to negative.
Parents' Involvment (**PI**)	0-1	An indicator informing about the involvement of parents in taking care of oral health in their children. The value based on real-world data describing parents' help in brushing their children's teeth, and is then updated as educational talks are received. The higher the value of the indicator, the greater the involvement of the parents.
Positive Force of Influence (**FI–P**)	0-1	The higher the value of the indicator, the greater the persuasive power of the student with IA positive convinces students from the closest environment who have a negative attitude to change it to a positive one.
Tooth Brushing (**TB**)	0-1	The initial value is based on actual data that describe the frequency of brushing teeth; the indicator is updated as educational talks are received. The higher the value, the better toothbrushing habits in the student.

by an update of the DH and TB indicators, which, along with the PI indicator, can influence the IA attitude update (see Figure 3). IA updating is also influenced by students in the closest environment through individual interactions. Each student can change his or her closest environment every year, which can range from zero to eight other students. To simulate the interactions occurring between students, a cellular automata was used. This part of the model is described in detail in (Hajłasz and Mielczarek 2022a) and (Hajłasz and Mielczarek 2023).

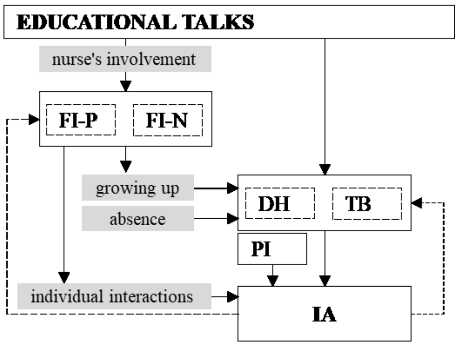

Figure 3: Interrelationship of indicators influencing students' IA.

Educational talks are conducted by a nurse, who does it with low, high or diversified involvement. The involvement of nurses is generally understood as the way in which they deliver knowledge to students, whether the nurse is motivated, whether she tailors the talk to a particular group of children, and whether she conducts the talk in a way that is interesting to students. Depending on the nurse's involvement, students are assigned values for the Positive Force of Influence (FI–P) and Negative Force of Influence (FI–N) indicators after each talk. The values for the IFs indicators indicate how forcefully a student will persuade other students with an antagonistic attitude to change it.

Data and Inputs Parameters

Students are six years old when they begin school and are one year older in each subsequent grade. Educational talks are held four times a year for children in kindergarten or twice a year for children in grades one through eight. The number of talks were assumed on the basis of recommendations (Olczak-Kowalczyk et al. 2021).

Before each educational talk, students' attendance is verified based on the AR indicator. The AR indicator value is generated from a triangular distribution ranging from 0.05 to 0.2 with the most likely value being 0.1.

The initial DH, PI and TB values are generated from uniform distributions assumed based on real data (Olczak-Kowalczyk, et al. 2021). The initial DH is based on two indicators (considered only at the beginning of the simulation) of Candy and Candy Bar (CCB) and Fruit and Vegetable (FV) consumption. PI was assumed based on the frequency of adult assistance in brushing children's teeth. TB was assumed based on the frequency of children brushing their teeth. The parameters of the distributions were defined after consultation with specialists. In the Table 2, the actual data are shown along with the assumed parameters of the distributions for PI, TB, FV and CCB. Whereas in the Table 3. it is shown how, depending on the sum of FV and CCB, the value for DH is generated.

Initial IA can be positive (P) or negative (N) and is assigned to students based on DH, PI and TB. Initially, each of these three indicators has an equal share in shaping IA. If initially the sum of DH, PI and TB is less than 1.8, then IA is N. On the other hand, if the sum is between 1.8 and 3, IA is P.

Table 2: Results of surveys conducted among parents of five-year-old children. Depending on the type of data, these were for the whole of Poland (FV, CCB), cities in Poland (PI) and Lower Silesia (TB); and the parameters of the uniform distribution assumed in the model (Olczak-Kowalczyk et al. 2021).

Factors influencing IA in students	Frequency [%]	Uniform distribution range
Parents' Involvement (PI) in helping with tooth brushing		
Often	58.45	0.5–1
Very rarely	28.79	0–0.3
Never	12.76	0
Tooth Brushing (TB)		
Twice a day and more	87.06	0.5–1
Once a day and less	12.94	0
Consumption of Fruits and Vegetables (FV)		
Every day and more	76.63	0.5–1
Several times weekly and less	23.38	0
Consumption of Candy, Candy Bars (CCB)		
Once a week and less often	56.71	0.5–1
Several times weekly and more	43.29	0

After each educational talk, indicators of DH, TB and IFs are updated. It was assumed that each talk affects DH and TB with different strength. If a child has IA positive, both TB and DH will change more strongly in a positive sense. In contrast, if child has IA negative at the end of a given talk, TB and DH will change less strongly. PI indicator does not change over time. Its contribution to the formation of IA in students decreases with the age of the children.

Table 3: Generate DH indicator values based on the sum of the auxiliary indicators FV and CCB.

Dietary habits (DH)	
FV + CCB	Uniform distribution range
<=0.5	0
0.5-0.8	0-0.3
>=0.8	0.5-1

The older the children, the smaller the contribution of the PI index to the formation of students' attitudes. When students are in grades 0 to 3 it has an equal contribution, when in grades 4 to 6 the contribution is half as much, when in grades 7 and 8 the contribution is zero.

Depending on the nurses' involvement, IFs may vary after each talk. The more involved a nurse is in conducting education, the more likely the students' FI–P is higher and FI–N is lower. The less involved the nurse, the FI–P is lower and FI–N is higher. FI–P and FI–N are generated from triangular distributions ranging from 0 to 1 with the most likely value depending on the nurse's involvement in educational talks Table 4.

Table 4: Parameters of triangular distributions for generating FI–P and FI–N according to the nurse's involvement in educational talk.

Nurse's involvement	Range	Most likely value		
	0–1	FI–P	FI–N	0–1
Low	0–1	0.15	0.8	0–1
Diversified	0–1	0.5	0.6	0–1
High	0–1	0.75	0.4	0–1

Verification and Validation

The hybrid model is still undergoing wide verification and validation due to progressive research. The extended part of the model has been subjected to many verification tests; these included visualization tests, degeneration tests and extreme conditions tests. The concept on oral health education described within the framework of this research, has been partially validated. The assumptions for the model were discussed in detail with a dental expert, who confirmed their validity. However, in order to carry out a complete validation and estimate with even greater accuracy the impacts included in the model, it is planned to conduct a school-based study that will take into account all the elements of modeling the impact of educational talks that were assumed within the framework of this research.

SIMULATION RESULTS

Overview of simulation scenarios

We conducted the simulation under 2 scenarios. Under the first scenario, we conducted 6 experiments. We observed how IA would be shaped in students for three types of nurse involvement with baseline assumptions and baseline effects of talks on indicators in students (scenario 1.1). The baseline impact of the talks on the indicators in students is shown in Table 5.

In addition, we observed the formation of IA in the students when the talks affect the students in different ways. The different impacts were modeled by multiplying the baseline impact of the talks by a value generated randomly for each student from a uniform distribution from 0 to 2 (scenario 1.2).

In the second scenario, we also conducted 6 experiments, for two types of talk's impact (as in the first scenario), but for twice less number of talks (scenario 2.1 when the impact of the talks is baseline, and scenario 2.2 when the impact is differentiated for each student).

Table 5: Base impact of educational talks on students according to IA, indicator (ind) and grade. Range of triangular distribution (ran) and most likely value (mlv).

IA	ind	grade					
		0-3		4-6		7-8	
		ran	mlv	ran	mlv	ran	mlv
P	TB	0-2	0.15	0-0.3	0.2	0-0.4	0.3
	DH	0-0.15	0.1	0-0.3	0.25	0-0.4	0.3
N	TB	0-0.1	0.05	0-0.1	0.1	0-0.1	0.1
	DH	0-0.1	0.05	0-0.1	0.05	0-0.1	0.05

RESULS AND DISCUSSION

The results of the experiments showed that systematically conducted oral health education results in the formation of positive attitudes at the end of primary education in the vast majority of children (Table 6). For scenario 2.2, detailed data on the development of IA over time are presented (Figure *4*).

Depending on the number of talks, their impact on students and the nurse's involvement, the formation of positive attitudes takes place earlier or later in primary school time. In Figure 4 it can be seen that the low involvement of the nurse in giving talks, has a negative impact on the formation of health attitudes in students, only from the fourth grade most students have IA positive, and only in the seventh grade all students. If the nurse is always involved at the highest level, by far the largest number of students already in the first grade have positive IA, and from the 5th grade onward all students. The nurse's varied involvement, on the other hand, results in 16 students already having positive IA in the second grade, and also from the 5th grade onward all students have positive IA.

It can be seen that regardless of the number of talks, the strength of their impact and the nurse's involvement in conducting them, all or almost all students graduate with a positive IA. If we reduce the number of talks by half, then the nurse's involvement is more significant than during more talks.

CONCLUSIONS

In this paper, we discussed the hybrid simulation approach to support management decisions in planning educational talks as one part of dental caries prevention programs dedicated to school children. A simulation model built according to the DES and ABS paradigms was used to observe the formation of health attitudes in students under the influence of educational talks, interactions taking place between students at school and depending on individual student characteristics.

In the proposed model, each student has individual characteristics. Each one is affected differently by the talks. The proposed model makes it possible to take into

		Diversified involvement of									Low involvement of the									High involvement of the								
No.	Initial	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8
1	N	N	N	P	P	P	P	P	P	P	N	N	N	N	P	P	P	P	P	N	P	P	P	P	P	P	P	P
2	N	N	P	N	P	P	P	P	P	P	N	P	N	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
3	N	N	P	P	P	P	P	P	P	P	N	N	N	N	P	P	P	P	P	N	P	P	P	P	P	P	P	P
4	N	N	N	P	N	N	P	P	P	P	N	N	N	N	N	P	P	P	P	N	N	P	P	P	P	P	P	P
5	P	N	N	P	P	N	P	P	P	P	N	N	P	N	P	P	P	P	P	N	N	P	P	N	P	P	P	P
6	N	P	N	N	P	P	P	P	P	P	N	N	N	N	P	P	P	P	P	P	P	P	P	P	P	P	P	P
7	N	P	N	N	P	P	P	P	P	P	P	N	N	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
8	N	N	N	P	P	P	P	P	P	P	N	N	N	N	N	P	P	P	P	N	P	P	P	P	P	P	P	P
9	N	N	N	N	P	P	P	P	P	P	N	N	N	P	P	P	P	P	P	N	P	P	P	P	P	P	P	P
10	N	N	N	N	N	N	P	P	P	P	N	N	N	P	N	P	P	P	P	N	P	P	P	N	P	P	P	P
11	N	N	P	N	P	P	P	P	P	P	N	P	P	N	P	P	P	P	P	N	P	P	P	P	P	P	P	P
12	N	N	P	P	P	P	P	P	P	P	N	N	P	N	P	P	P	P	P	N	P	P	P	P	P	P	P	P
13	N	N	N	P	P	P	P	P	P	P	N	N	N	N	P	P	N	P	P	N	N	P	P	P	P	P	P	P
14	P	N	P	P	P	P	P	P	P	P	N	P	P	N	P	P	P	P	P	P	P	P	P	P	P	P	P	P
15	N	N	N	N	P	P	P	P	P	P	N	N	N	P	N	N	P	P	P	N	P	P	P	P	P	P	P	P
16	N	N	N	P	N	P	P	P	P	P	N	N	P	N	P	P	P	P	P	N	N	P	N	P	P	P	P	P
17	N	N	N	N	P	P	P	P	P	P	N	P	N	N	P	P	P	P	P	N	P	P	P	P	P	P	P	P
18	N	N	N	N	P	P	P	P	P	P	N	N	N	N	P	P	P	P	P	N	N	P	P	P	P	P	P	P
19	N	P	N	P	N	P	P	P	P	P	N	N	P	N	P	P	P	P	P	N	P	P	N	P	P	P	P	P
20	N	P	P	P	P	P	P	P	P	P	N	N	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
21	N	N	P	P	P	P	P	P	P	P	N	P	N	P	P	N	P	P	P	P	P	P	P	P	P	P	P	P
22	N	N	N	P	P	P	P	P	P	P	N	N	P	P	P	P	P	P	P	N	P	P	P	P	P	P	P	P
23	P	N	N	P	P	P	P	P	P	P	N	N	N	P	P	P	P	P	P	N	N	P	P	P	P	P	P	P
24	N	N	N	P	P	P	P	P	P	P	N	N	N	P	P	N	P	P	P	N	N	P	P	P	P	P	P	P
25	P	N	P	P	P	P	P	P	P	P	N	N	P	N	P	P	P	P	P	P	P	P	P	P	P	P	P	P

Figure 4: Results of the scenario 2.2 that involved twice the total number of educational talks during primary school education (from 0 to 8 class), with varying impact on students and for three types of nurse involvement in conducting them; the most common values for each of 25 students at the end of the year, during 10 replications; N for negative IA and P for positive IA.

account these individual characteristics, as well as other elements that can be helpful in planning education within the framework of prevention programs dedicated to primary schools. Education in oral health and hygiene is the first step in reducing the incidence and progression of dental caries disease in students. So depending on the health goals established and the resource capacity of providers of dental caries prevention programs, it may be crucial to aim for positive IA as early as possible for students. When weighing the provision of education against the provision of other preventive services such as tooth fluoridation or sealing of first molars, and the treatment of the consequences of caries, education is by far the least expensive and most beneficial from the perspective of community health and limited health care resources.

The study is part of a larger investigation into the possibility of using a hybrid simulation approach to support the planning of dental caries prevention programs.

Table 6: IA positive initial and at the end of primary school education, depending on the nurse's involvement in giving educational talks; average of 10 replications for each simulation scenarios.

Scenario	Initial	Nurse's involvement		
		Diversified	Low	High
1.1	9.1	25	25	25
1.2	9.1	25	25	25
2.1	9.1	24.6	24.1	24.6
2.2	9.1	24.2	22.1	24.9

The limitation of the present study was the lack of access to detailed data. In this article, we were able to demonstrate that it is possible to model the impact of health education on students' attitudes, but to do so with greater precision, the necessary real data would need to be collected.

Future research plans to conduct an empirical study among a group of students and expand the study to include more schools within the region.

ACKNOWLEDGEMENTS

This work is the result of research project Hybrid modelling of the demand for specialist dental care in the field of dental caries prevention in children using computer simulation No. 2021/41/N/HS4/03282 funded by the National Science Center, Poland.

REFERENCES

Ahovuo-Saloranta, A.; H. Forss; T. Walsh; A. Hiiri; A. Nordblad; M. Mäkelä; and H.V. Worthington. 2013. "Sealants for preventing dental decay in the permanent teeth." *Cochrane Database Syst Rev.* 28;(3):CD001830.

Ahovuo-Saloranta, A.; H. Forss; T. Walsh; A. Nordblad; M. Mäkelä; and H.V. Worthington. 2017. "Pit and fissure sealants for preventing dental decay in permanent teeth." *Cochrane Database Syst Rev*. 31;7(7):CD001830.

Baker, S.R.; L. Foster Page; W.M. Thomson; T. Broomhead; K. Bekes; P.E. Benson; F. Aguilar-Diaz; L. Do; C. Hirsch; Z. Marshman; C. McGrath; A. Mohamed; P.G. Robinson; J. Traebert; B. Turton; and B.J. Gibson. 2018. "Structural Determinants and Children's Oral Health: A Cross-National Study." *J Dent Res*. 97(10):1129-1136.

Brailsford, S.C.; P.R. Harper; and M. Pitt. 2009. "An Analysis of the Academic Literature on Simulation and Modelling in Health Care". *Journal of Simulation* 3(3):130–140.

Dzielska, A.; J. Gajewski; A. Kowalewska; M. Malinowska-Cieślik; A. Małkowska-Szkutnik; J. Mazur; I. Tabak; and B. Woynarowska. 2012. *Tendencje zmian zachowań zdrowotnych i wybranych wskaźników zdrowia młodzieży szkolnej w latach 1990–2010.* University of Warsaw, Warsaw, Poland. (in Polish).

Eldabi, T.; R.J. Paul; and S.J.E. Taylor. 1999. "Computer Simulation in Healthcare Decision Making". *Computers & Industrial Engineering* 37(1-2):235–238.

Greving, J.P.; F.L. Visseren; G.A. de Wit; and A. Algra. 2011. "Statin treatment for primary prevention of vascular disease: whom to treat? Cost-effectiveness analysis." *BMJ* 342:d1672.

Hajłasz, M.; and B. Mielczarek. 2022. "Reflections on Assumptions for a Simulation Model of Dental Caries Prevention Planning in a Primary School". In *Proceedings of the 36th ECMS International Conference on Modelling and Simulation ECMS 2022 (*Norway, Ålesund, May 30–June 3). European Council for Modelling and Simulation, 45-50.

Hajłasz, M.; and B. Mielczarek. 2022a. "Modelling of the Influence of the Peer Environment on the Prevention of Caries Development in Schoolchildren using a Hybrid Simulation Approach." In *Proceedings of the 12th International Conference on Simulation and Modeling Methodologies, Technologies and Applications* (Portugal, Lisbon, July 14-16). SciTePress, 340-347.

Hajłasz, M.; B. and Mielczarek. 2022b. "Simulation Model for Planning Dental Caries Prevention at the Regional Level." In Proceedings of the 2022 Winter Simulation Conference (Singapore, December 11-14). IEEE, Picataway, N.J., 1045-1056.

Hajłasz, M.; and B. Mielczarek. 2023. "Agent-Based Simulation Framework to Plan Dental Caries Prevention: Awareness Aspect". LNNS, Springer. (Under review).

Ho, T.Y.; B.Z. Zabinsky, P. A. Fishman; and S. Liu. 2022. "Prevention of seasonal influenza outbreak via healthcare insurance." *IISE Transactions on Healthcare Systems Engineering.*

Lee, Y.”; 2013. Diagnosis and Prevention Strategies for Dental Caries." *J Lifestyle Med*. 3(2):107-9.

Lich, K.H.; Y. Tian; C.A. Beadles; L.S. Williams; D.M. Bravata; E.M. Cheng; H.B. Bosworth; J.B. Homer; and D.B. Matchar. 2014. "Strategic planning to reduce the burden of stroke among veterans: using simulation modeling to inform decision making". *Stroke*. 45(7):2078-2084.

Najafzadeh, M.; C.A. Marra,, E. Galanis; and D.M. Patrick. 2009. "Cost Effectiveness of Herpes Zoster Vaccine in Canada." *Pharmacoeconomics* 27, 991–1004.

Olczak-Kowalczyk, D.; A. Turska-Szybka; J. Tomczyk; A. Kobylińska; S. Shamsa-Nieckula; and M. Lipiec. 2021. *Uwarunkowania stanu zdrowia jamy ustnej i uszkodzenia urazowe*. Medical University of Warsaw, Warsaw, Poland. (in Polish).

Powell, J.; and N. Mustafee. 2014. "Soft OR Approaches in Problem Formulation Stage of a Hybrid M&S Study." In Proceedings of the 2014 Winter Simulation Conference., (Savannah). IEEE, Picataway, N.J., 1664–1675.

Rais, A.; and A. Viana. 2011. "Operations Research in Healthcare: a survey." *International Transactions in Operational Research* 18: 1-31.

Rong, W.S.; J.Y. Bian; W.J. Wang; and J.D. Wang. 2003. "Effectiveness of an oral health education and caries prevention program in kindergartens in China." *Community Dent Oral Epidemiol.* 31(6):412-416.

Torices, S.S.; R. Álvarez-Vaz; F. Massa; M. López Jordi; and J. Liberman. 2021. "Impact of the number of periodic dental checkups on oral health at a university pediatric dentistry clinic." *Odontoestomatología* 23 no.38.

WHO. 2022. *Global oral health status report: towards universal health coverage for oral health by 2030*. Geneva: World Health Organization; 2022.

Zulkepli, J.; and T. Eldabi. 2015. "Towards a framework for conceptual model hybridization in healthcare". In Proceedings of the 2015 Winter Simulation Conference (Huntington Beach, CA, USA). IEEE, Picataway, N.J., 1597-1608.

AUTHOR BIOGRAPHIES

MARIA HAJŁASZ was born in Poland and went to Wrocław University of Science and Technology, where she studied management science and obtained her degree in 2018. She works as an Assistant in the Department of Operations Research and Business Intelligence and she is a PhD student in Management and quality studies at Wrocław University of Science and Technology. Her research includes decision support in the management of preventive health care using simulation methods. Her e-mail address is: maria.hajlasz@pwr.edu.pl

BOŻENA MIELCZAREK is currently an Associate Professor in the Department of Operational Research and Business Intelligence, Wrocław University of Science and Technology (WUST), Poland. She received an MSc in Management Science, a PhD in Economics, and a D.Sc. in Economics from Wrocław University of Science and Technology. Her research interests include simulation modeling, health-service research, decision support, hybrid simulation, and financial risk analysis. She is the head of the MBA executive program at WUST. Her e-mail address is: bozena.mielczarek@pwr.edu.pl