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Efficacy of the Foodbot Factory digital curriculum-based nutrition education intervention in improving children's nutrition knowledge, attitudes and behaviours in elementary school classrooms: protocol for a cluster randomised controlled trial

Jacqueline Marie Brown ,[1] Saman Tahir,[1] Beatriz Franco-Arellano,[1] Ann LeSage,[2] Janette Hughes,[2] Bill Kapralos,[3] Wendy Lou,[4] Ellen Vogel,[1] Michael Farkouh,[5] Claire Tugault-Lafleur,[6] JoAnne Arcand [1]

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For numbered affiliations see end of article.

Correspondence to
Dr JoAnne Arcand;
joanne.arcand@ontariotechu.ca

ABSTRACT

Introduction Schools are an important setting for supporting children's development of food literacy, but minimal research has assessed which strategies are most suitable for school nutrition education. The Foodbot Factory intervention, consisting of serious game (ie, a digital game designed for education) and curriculum-based lesson plans, was developed to support teachers and children ages 8–12 with nutrition education. Pilot data have demonstrated that Foodbot Factory can significantly improve children's nutrition knowledge, but it has not yet been evaluated in classrooms.

Methods and analysis A single-blinded cluster randomised controlled trial was designed in 2022 by a research team based at Ontario Tech University to determine the efficacy of the Foodbot Factory intervention in improving children's nutrition knowledge, attitudes and behaviours. 32 grade 4 and 4/5 classrooms in Ontario will be randomised to receive (1) the Foodbot Factory intervention or (2) a control nutrition education intervention using conventional materials (eg, activity sheets). The study's primary outcome is to determine the overall nutrition knowledge acquired from the intervention. Secondary outcomes include nutrition knowledge subscores (ie, knowledge of specific food groups), nutrition attitudes, dietary intake, general nutrition behaviours (eg, eating breakfast) and intervention acceptability. An Ontario-certified teacher will deliver the intervention to both groups for 35–40 min/day for five consecutive days. Outcomes will be assessed at baseline, immediately postintervention, and 4 weeks and 3 months postintervention using the Nutrition Attitudes and Knowledge questionnaire, the Block Kids Food Screener, a modified Family Nutrition and Physical Activity screener and an acceptability questionnaire. Generalised linear mixed models will assess changes in outcomes between groups.

Ethics and dissemination The study protocol is approved by research ethics boards at Ontario Tech University and participating school boards. Results of the trial will be published in peer-reviewed journals and lay summaries will be available to stakeholders.

Trial registration number NCT05979259.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The Foodbot Factory intervention consists of a serious game and nutrition lesson plans, which were designed and informed by the perspectives of end-users (children, teachers and dietitians), increasing intervention acceptability and feasibility.
⇒ The study assesses a range of outcomes providing a holistic view of the intervention's effects.
⇒ Follow-up assessments at 4 weeks and 3 months will allow us to assess longer-term retention and changes in nutrition knowledge outcomes.
⇒ The nutrition education intervention is limited by a short duration; however, this duration is reflective of current curriculum expectations.
⇒ Secondary outcomes of dietary intake and nutrition behaviours are obtained via validated self-report measures, which may be susceptible to social desirability bias.

INTRODUCTION

Healthy eating is essential for non-communicable disease risk reduction and is facilitated by a supportive food environment and strong food literacy skills among a population.[1] Food literacy encompasses the interconnected attributes of food and nutrition knowledge (eg, awareness of different foods, the nutrients in foods), food preparation

skills and attitudes (ie, self-efficacy and confidence), that interact with the broader food and cultural environment to influence our dietary behaviours.[2] High levels of food literacy are positively correlated with diet quality among children and adults.[3 4] Furthermore, higher levels of nutrition knowledge, a core component of food literacy, have been associated with higher water consumption and vegetable intake in children, demonstrating that food literacy is important and can influence dietary intake among this age group.[5 6] Current estimates of food literacy levels among Canadians are low, as evidenced by low nutrition knowledge among children and low food preparation skills among adults.[7 8] Developing food literacy in Canada is especially relevant as most individuals do not consume the recommended amounts of vegetables, fruit and whole grain foods and exceed recommendations for highly processed foods,[9 10] a dietary pattern that can increase the risk of developing diet-related non-communicable diseases.[1] Thus, Canada's Dietary Guidelines have made improving food literacy a public health priority to help improve diet quality.[11]

Schools can support food literacy development through food provision programmes, policies and educational curriculum for nutrition.[12] Embedding opportunities for food literacy development through school nutrition education allows all children to acquire knowledge and skills to make informed food choices.[13] Nutrition education interventions that are explicitly linked to the provincial curriculum expectations are shown to reduce the prevalence of obesity and salt intake and improve nutrition knowledge and dietary diversity.[14–16] They also have the advantage of fulfilling existing learning expectations and providing relevant educational resources for teachers. However, most research conducted in Canada on school nutrition interventions has not evaluated curriculum-based interventions, creating a paucity of evidence on which teaching strategies can successfully engage children with nutrition education.[17] While current practices for nutrition education vary from teacher to teacher, many use existing resources and activities they have found online or from peers.[18] Teachers typically receive minimal training on nutrition,[19] and they face challenges in implementing curriculum-based nutrition education, including a lack of time dedicated to nutrition, evidence-based resources and reduced funding.[20 21] Thus, further research is needed to better understand teaching strategies that are effective and suitable for curriculum-based nutrition education.

To address this research gap, our interdisciplinary team of researchers, teachers and dietitians developed the Foodbot Factory curriculum-based nutrition education intervention to help improve nutrition knowledge for children ages 8–12 (grades 4 and 5).[22 23] The intervention consists of a serious game (ie, a game designed specifically for educational purposes) and five daily lessons that cover content on food groupings (drinks, whole grain foods, vegetables and fruit, animal protein foods and plant protein foods) aligning with Canada's Food Guide (CFG) and the Ontario Health and Physical Education curriculum, which is similar to most Canadian provinces.[24 25] Foodbot Factory was developed as a serious game since game-based learning allows users to control and learn from their actions in the game, which is a form of experiential learning that has demonstrated effectiveness for nutrition education.[26 27] Technology-based interventions, such as serious games, can also address some of the challenges teachers face regarding nutrition education, as they are time-effective and accessible with 65% of Canadian classrooms using technology daily.[28 29] While existing research on nutrition-focused serious games has found that they can improve children's nutrition knowledge and vegetable and fruit intake,[30 31] very few serious games have been studied as part of curriculum-based classroom interventions.[32 33]

Our preliminary data suggest Foodbot Factory has the potential to positively influence children's nutrition knowledge.[34] First, the Foodbot Factory serious game was developed and tested with children[23] and was later upgraded to include augmented reality components and improve accessibility.[35 36] A pilot study, conducted in a simulated classroom setting, found that the Foodbot Factory serious game, when played for 15–20 min/day for five consecutive days, significantly improved children's nutrition knowledge from 51% to 68%, compared with a control.[34] The Foodbot Factory intervention was then pilot-tested in a non-randomised study to determine the feasibility of evaluating the intervention in grade 4 and 4/5 classrooms as part of research protocol.[22 37] The next stage is to evaluate the efficacy of the Foodbot Factory intervention in real-world classrooms to understand the intervention's effect on children's nutrition knowledge, attitudes and behaviours (KAB), and compare these effects to conventional nutrition education (ie, usual practice and reflecting the current state of nutrition education in Ontario classrooms). This comparison will inform whether Foodbot Factory offers a viable alternative to non-tech-supported teaching strategies and its potential integration into the established nutrition education curriculum to support food literacy development.

Aim and objectives

The primary objective of this efficacy cluster randomised controlled trial (cRCT) is to determine whether the Foodbot Factory nutrition education intervention offers a viable alternative to conventional teaching methods in improving children's nutrition knowledge. The primary outcome examined in this study is the overall nutrition knowledge score of CFG recommendations, with secondary outcomes that include nutrition knowledge subscores (ie, knowledge of a specific food grouping), dietary intake, general nutrition attitudes and behaviours (eg, frequency of eating in front of the television) and the acceptability of both interventions. It is hypothesised that classrooms in the intervention group will show greater improvements in their nutrition KAB.

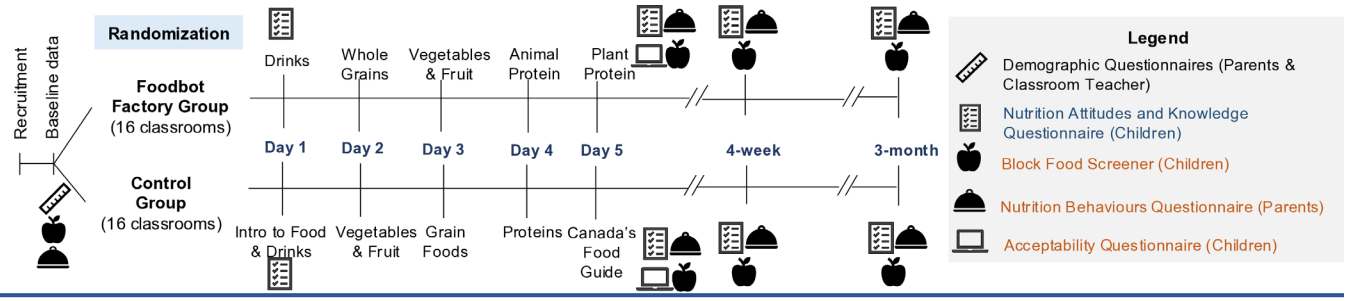

Figure 1 Foodbot factory cRCT study design. cRCT, cluster-randomised controlled trial.

METHODS AND ANALYSIS

The reporting of the protocol follows the Standard Protocol Items: Recommendations for Interventional Trials guidelines.[38] This trial is registered at ClinicalTrials.gov under the identifier NCT05979259.

Study design

A single-blinded cRCT will be conducted in Ontario classrooms to determine the efficacy of Foodbot Factory in improving nutrition knowledge. An overview of the research design is illustrated in figure 1.

This trial was designed by our research team of interdisciplinary researchers based on a previous feasibility study.[22 37] Members of the public who are practising teachers and dietitians contributed to developing the intervention content and input from individuals working on school boards informed the study design to ensure the acceptability of the research and value to knowledge users.[22] A cRCT design was chosen since the intervention is classroom based, reflecting the implementation of this intervention in its intended setting. Considering the setting, it is not logistically feasible to randomise children within the same classroom and provide them with different interventions. Grade 4 and 4/5 split classrooms will be recruited from participating school boards across the province of Ontario, Canada. While the intervention content is appropriate for grade 5 classrooms it does not cover all nutrition curriculum requirements for this grade, therefore, they will not be included in this study. Classrooms will be randomly assigned in a 1:1 ratio to one of two arms: the intervention arm using the Foodbot Factory intervention or the control arm using conventional educational materials. In this study, the conventional teaching materials for the control intervention were predominantly sourced and vetted from existing nutrition education materials, thus, the learning topics for the control group were restricted by the availability of existing materials. Both study groups will receive the nutrition education intervention for five consecutive days for 35–40 min per day (details below) from an Ontario-certified teacher who is a member of our research team (study teacher). Outcome assessments will occur at baseline, immediately postintervention (day 5), and 4 weeks and 3 months postintervention.

Eligibility criteria

All children in grade 4 and 4/5 split classrooms in participating schools and school boards in Ontario, Canada will be eligible to participate in the study. Classrooms that have already covered the Ontario Healthy Eating curriculum, which includes CFG, will be excluded as this is the same content covered in the study interventions.

Study interventions: overview

Both the Foodbot Factory and control group classrooms will receive nutrition education for 35–40 min per day for five consecutive days, with each day having a lesson focused on a different nutrition topic. This time frame was chosen as it corresponds to the typical length of an educational unit in classrooms. This time frame also aligns with school board expectations for classroom time that can be used for research purposes. All lessons will be led by a study teacher who will receive training and follow standardised research protocols when providing the intervention, ensuring a high level of fidelity. The intervention content for both groups covers similar topics and learning goals (table 1), for example, both interventions have lessons covering vegetables and fruit and whole grain foods, and both interventions are aligned with Ontario curriculum and CFG.[24 25] The Foodbot Factory and control interventions were codesigned using a multistage participatory process with practising teachers and registered dietitians to ensure acceptability, feasibility and suitability.[22] This participatory process engaged teachers and dietitians in partnership across three stages of intervention development and evaluation where they directly contributed to content creation, participated in stakeholder meetings to come to consensus on the intervention content and completed a final evaluation to ensure they viewed both the Foodbot Factory and control interventions as acceptable and suitable.

Foodbot Factory intervention

Classrooms randomised to the intervention group will receive nutrition education using the Foodbot Factory intervention, consisting of the Foodbot Factory serious game and curriculum-based lesson plans. The educational content and features of the Foodbot Factory serious game have been described in detail elsewhere.[23 35] The Foodbot Factory intervention is organised into five

Table 1 Overarching learning goals for the intervention and control groups

Learning focus	Overarching learning goals
Canada's Food Guide	► Understand how much of a plate should be dedicated to different types of food and drink. ► Identify key messages from Canada's Food Guide.
Drinks	► Identify and evaluate the best beverage choices for health and hydration.
Whole grain foods	► Identify the nutritional difference between whole grain foods and refined grain foods. ► Explain the health benefits of choosing whole grain foods.
Vegetables and fruit	► Identify how choosing vegetables and fruit of different shapes, textures and colours adds variety to the diet. ► Explain the health benefits of vegetables and fruit.
Protein foods	► Identify what foods (animal and plant) typically contain protein. ► Explain why protein foods are important for health.

nutrition education lessons with each lesson covering a different food group. One lesson will be provided to the classroom each day throughout the course of the intervention period and the learning goals are summarised in table 1. Embedded within the lesson plan materials are instructions and resources for teachers to discuss nutrition using food-neutral language, incorporate cultural foods and dishes, and suggestions to adapt the lesson plan content to provide accommodations for different learning needs.[22] Each lesson follows the three-phase lesson structure, an inquiry-based learning method commonly used by teachers.[39] In the first phase of the lesson, the classroom will be introduced to the topic through discussion and expectations for the lesson will be set (5–10 min). In the second phase of the lesson, the classroom will explore the topic by playing one module in the Foodbot Factory game that corresponds to the topic for the day's lesson (10–15 min). The research team will provide each child in the classroom with their own tablet to play the game independently. In the third and final lesson phase, the classroom will consolidate their learning through discussion questions and teacher-led activities (10 min).

Control intervention

Classrooms randomised to the control group will receive a nutrition education intervention designed to emulate teacher's usual practices for nutrition education using conventional educational materials (eg, activity sheets and teacher-led activities). Similar to the intervention group, the control intervention consists of five nutrition education lessons that will follow the three-phase lesson structure.[39] However, instead of using the Foodbot Factory serious game, in the second lesson phase, the control group will use pre-existing nutrition education materials sourced from a popular online learning repository.[40] These materials were selected to be included in the control intervention after they were vetted by our research team and teacher and dietitian stakeholders to ensure their quality, accuracy, appropriateness and alignment with both Ontario curriculum and the Foodbot Factory intervention. However, due to the paucity of nutrition education resources available, it was not possible to match learning topics one-to-one with the Foodbot Factory intervention (eg, lack of materials focused on plant protein foods). Thus, learning materials and additional learning activities were chosen to ensure the interventions covered the same learning goals, acknowledging some variation in them (online supplemental material-table 1).

Sample size

A sample size calculation was conducted using the 'Group Randomised Trial Sample Size Calculator', indicating that 14 classrooms per group with 18 participants in each cluster give rise to 80% power at a significance level of 0.05 for detecting changes in the primary outcome of nutrition knowledge.[41] Based on a pilot study and similar studies in the literature, this sample size allows for detecting effect sizes between 0.15 and 0.5.[33 34] The calculation also considers that school-based interventions assessing academic outcomes have an intraclass correlation coefficient ranging from 0.05 to 0.30.[42–44] To account for an anticipated attrition rate of 15% at the 3 month follow-up, we will recruit four additional classrooms, for a total of 16 classrooms per group to ensure sufficient power.[45] Based on the average class size of 24 students in Ontario classrooms, approximately 768 children will be eligible for recruitment.[46]

Recruitment

We will recruit 32 classrooms from South-Central, South-Eastern and North-Western Ontario to participate in the study after receiving ethical approval from each school board. These regions from Ontario were selected as they represent a majority of the province, provide diversity in demographics and are regions that maximise study resources based on the research team's location. The recruitment process is summarised in figure 2.

School boards were selected within each region to provide a sample that would be representative of the diverse cultures and geographies in the province of Ontario (ie, applying to schools in different cities within each region and capturing rural, suburban and urban areas). Schools within each board will be selected based on the Fraser Institute school report card rankings, which rank schools based on performance on standardised

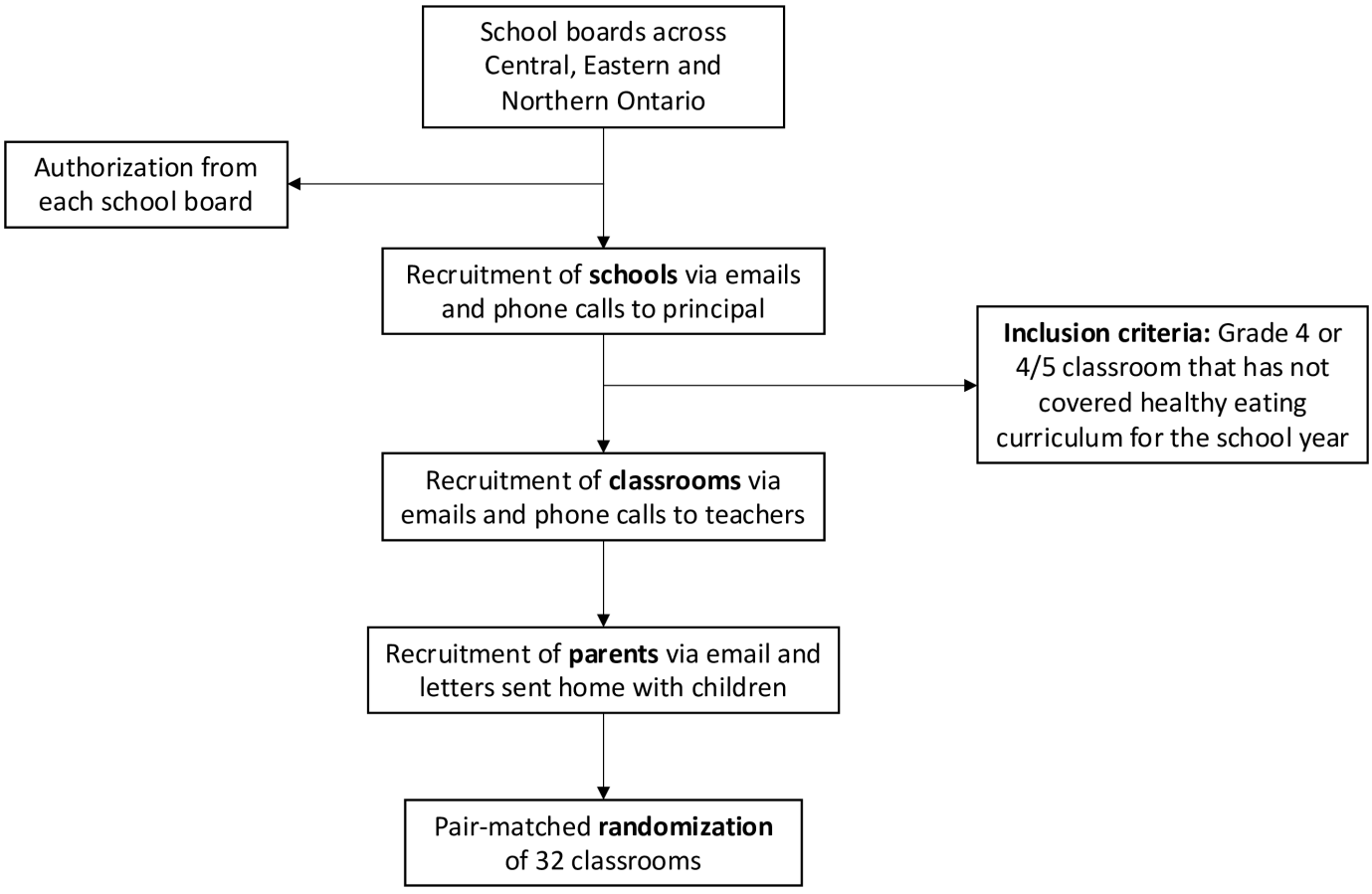

Figure 2 Foodbot factory cRCT recruitment overview. cRCT, cluster-randomised controlled trial.

provincial test results. We will organise all schools in a school board into quintiles based on their ranking, and randomly select from these quintiles for recruitment.[47] 10 schools from a school board will be selected for recruitment at a time. Schools will continue to be randomly selected from a school board on a weekly basis until recruitment efforts within that board are successful (ie, the intended number of schools within that board have agreed to participate in the study). Schools without a Fraser Institute ranking will only be contacted if all other recruitment efforts at ranked schools within that board are unsuccessful. Schools will continue to be recruited until the sample size is met. If we are unsuccessful in recruiting from a specific region of Ontario, additional schools may be recruited from other areas with similar demographics. The school principal of selected schools will be contacted via email and phone calls. Principals who approve the study will subsequently forward a recruitment letter of information to grade 4 and 4/5 classroom teachers in their school. Classroom teachers who agree to have their classroom participate will have an introductory phone call with study personnel, where an overview of the study and expectations of the classroom teacher will be discussed. Subsequently, the classroom teacher will complete an online consent form. The classroom teacher will then share a consent form with parents/guardians (available online and via paper copy) a minimum of 2 weeks prior to the study start date (online supplemental material-parent consent form). Digital, written and in-person reminders will also be used to encourage parents to complete the consent form. Study personnel will acquire assent from children who have parental consent to participate on the first day of the study. As the intervention does not apply extraneous approaches and is aligned with provincial curriculum requirements, children without parental consent or who do not provide assent will still participate in the intervention. All children in a participating classroom will receive an Ontario Tech University water bottle, classroom teachers will receive a CAD$50 gift card and parents/guardians will receive a CAD$25 gift card.

Randomisation, concealed allocation and blinding

REDCap, a web-based data management system that conceals the allocation sequence, will be used to conduct classroom randomisation after baseline data collection.[48] A blocked random allocation sequence will be generated using a random number generator with a block size of 2. Randomisation will be completed by study personnel who are not involved in delivering the intervention or outcome assessment. A pair-matching approach will be used during randomisation, where two classrooms either in the same school or geographical area will be matched together.[49] The pair-matching approach was chosen to balance neighbourhood-level factors between groups

that may influence the outcomes of interest. Classrooms from different schools will only be matched when they are from sparsely populated rural communities. In this context, schools tend to be smaller and matching two classrooms in a single school is not always feasible. In cases where a grade 4 and 4/5 classroom are matched, the grade 4 classroom will be randomised, and the grade 4/5 classroom will be assigned to the opposite group. When two classrooms of the same grade are matched, the randomised classroom will be based on alphabetical order of the classroom teacher's last name. The allocation sequence will remain concealed until the end of the study. To prevent contamination of the intervention to the control group, the Foodbot Factory serious game will be removed from the app marketplace. Furthermore, all study materials are brought into schools and owned by the research team which precludes children in the control group from accessing the Foodbot Factory intervention on study tablets. This is a single-blinded study, where only the outcome assessor, who is a research associate who will collect data with children in the classroom, will be blinded to the classroom's group. The outcome assessor will remain blinded until the end of the trial. It is necessary for the purposes of the study that the study teacher is unblinded to provide the interventions to each classroom.

Outcome assessment

Primary outcome assessment

The primary outcome of changes in overall nutrition knowledge is measured as a composite score from the Nutrition Attitudes and Knowledge (NAK) questionnaire from baseline to immediately postintervention (day 5).[50] Secondary outcomes for this study that are also assessed by the NAK are retention of overall nutrition knowledge (4 weeks, 3 months), changes in and retention of nutrition knowledge subscores (ie, knowledge of healthy food choices for a specific food group) and nutrition attitudes. The NAK questionnaire consists of 20 questions evaluating overall nutrition knowledge, and the overall knowledge score is calculated as the number of correct responses out of all 20 questions. Among these 20 questions, 5 questions are specific to each of the CFG food groups (drinks, whole grains, vegetables and fruit and protein foods) and subscores are calculated as the number of correct responses out of the five questions for that subscore. Four questions evaluate nutrition attitudes (eg, healthy eating should be an important part of my life) on a 5-point Likert scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree and 5=strongly agree). The NAK questionnaire was evaluated for face and content validity and is sensitive to detecting changes in nutrition knowledge.[34 50] The NAK questionnaire will be administered to children in the classroom by a blinded outcome assessor. Children will be instructed to independently complete the questionnaire with a pencil. To ensure children remain focused on the questionnaire and understand the meaning of each question, the outcome assessor will read each question out loud twice, an approach similar to provincial standardised tests for this age group.[51] After completing the questionnaire, the outcome assessor will verify that each question has been answered and ask children to verify any responses that are unclear (eg, if two responses have been circled for one question). We expect this approach to result in a low level of missing data on this questionnaire.

Secondary outcome assessment

The Block Kids Food Screener (BKFS) will be used to evaluate the secondary outcome of dietary intake at baseline, immediately postintervention, 4 weeks and 3 months postintervention.[52] It consists of 41 items evaluating servings of fruit, vegetables, dairy, whole grains, proteins and sources of saturated fat and added sugars consumed over the past week and was designed for children ages 2–17. The outcomes assessed by the BKFS align with the education provided in the Foodbot Factory intervention, which focuses on making healthier choices within each food group and consuming meals that have a balance of food groups. The BKFS was validated among children ages 10–17 and the outcome measures correlate significantly with 24-hour recall measures.[52] It was chosen over other dietary assessment tools as it provides an estimate of usual intake and it can be completed in approximately 10 min, which was considered to be a reasonable time request for data collection by participating school boards. The BKFS will be completed by children online with parental assistance. A nutrition behaviours questionnaire (completed online by parents) will evaluate general child nutrition behaviours at baseline, immediately postintervention, 4 weeks and 3 months postintervention. The nutrition behaviours questionnaire was modified from the Family Nutrition and Physical Activity Screening Tool,[53 54] which has been demonstrated to have strong internal consistency and is commonly used in school settings. The questionnaire was modified to only include questions on nutrition behaviours (10 questions) and to add in an additional question on water consumption and nine questions on changes in food behaviours and requests (eg, if their child requested healthier foods be purchased), parent-reported contamination (eg, if their child discussed the study with peers outside of the classroom) and cointervention (eg, seeking nutrition advice from a dietitian for their child). Intervention acceptability will be evaluated immediately postintervention with an acceptability questionnaire, consisting of 11 items on a 5-point Likert scale based on theory-informed questionnaires derived through a prevalidation method from the theoretical framework of acceptability.[55 56] The acceptability questionnaire will be administered by an outcome assessor, using the same procedure as described above for the NAK questionnaire.

Covariates

Demographic questionnaires will be completed at baseline by parents to document covariates that may impact

Table 2 Summary of data collection tools, their associated outcomes and time points of data collection

Data collection tool	Description	Study outcome(s)	Completed by	Time point completed
Nutrition Attitudes and Knowledge Questionnaire	20 items on nutrition knowledge (1 point each) 5/20 items each dedicated to specific food groupings creating sub-scores (eg, drinks, whole grain foods) 4 items on a 5-point Likert scale evaluating nutrition attitudes	1. Overall nutrition knowledge 2. Nutrition knowledge subscores 3. Nutrition attitudes	Children (paper)	Day 1, day 5, week 4, month 3
Nutrition Behaviours Questionnaire	20 items evaluating general nutrition behaviours (eg, eating in front of the television, eating breakfast, drinking water)	General child nutrition behaviours	Parents (online)	Baseline, day 5, week 4, month 3
Block Kids Food Screener	41 items evaluating the consumption of fruit, vegetables, whole grains, proteins, fat and added sugar in the past week	Dietary intake	Children with parental support (online)	Baseline, day 5, week 4, month 3
Acceptability Questionnaire	11 items on a 5-point Likert scale evaluating acceptability (eg, length, difficulty, overall experience)	Intervention Acceptability	Children (paper)	Day 5
Parent Demographic Questionnaire	15 items on demographic variables (eg, dietary restrictions, socioeconomic status, food insecurity)	Covariates	Parents (online)	Baseline
Teacher Demographic Questionnaire	11 items on teacher-level (eg, years spent teaching) and school-level variables (eg, nutrition policies and programmes)	Covariates	Classroom teacher (online)	Baseline
Field notes	14 items assessing fidelity of the intervention delivery (eg, attendance, timing, modification of intervention)	Covariates	Study teacher (online)	Days 1–5

the outcomes of interest at the household level (eg, parent-reported food insecurity). The classroom teacher will also complete a demographic questionnaire to document covariates that may influence study outcomes at the teacher (eg, personal nutrition attitudes) and school level (eg, presence of school food programmes). Each day of the intervention period, the study teacher will complete structured field notes to document participant absences and intervention fidelity. Table 2 summarises when and how all outcomes in the study will be assessed.

Data management and monitoring

REDCap will be used as the primary data management software and will automatically administer all online questionnaires.[48] In cases where parents are unable to complete online data collection forms, anonymised paper data collection forms will be sent to them and returned by mail. All paper data forms will be entered into REDCap by study personnel with data entry validated by a second study team member. Deidentified paper data forms will be housed securely in the principal investigator's office. The interventions in this study are not above and beyond standard teaching practice, therefore, there are no safety concerns beyond the risks associated with the everyday classroom environment and a data monitoring committee will not be needed. Our previous research has found no adverse events associated with the Foodbot Factory intervention.[22 34] However, it is appreciated that talking about food may be psychologically triggering for participants prone to disordered eating or who may experience food insecurity. The study teacher will monitor for signs of distress related to the nutrition content and document them in daily field notes. In the event of extreme stress, child participants may sit out of the classroom for the lessons and appropriate nutrition resources will be shared with the child's parents/guardians. A question on the acceptability questionnaire will also document feelings of stress. Adverse events will be reported to the Ontario Tech University research ethics board (REB) and the classroom teacher, who will follow school board procedures for the event.

Statistical analysis

Data will be analysed per-protocol, an approach that assesses the maximum impact of the intervention on the outcomes of interest when participants complete the entire intervention.[57] As this is an efficacy study, this approach is appropriate for our aim to understand the influences of the intervention delivered under ideal circumstances.[58] A secondary analysis will use the

intention-to-treat approach to assess the impacts of being assigned to the intervention.[59] Descriptive statistics will be used to summarise participant demographics, nutrition knowledge and attitudes, dietary intake, general child nutrition behaviours and intervention acceptability. Generalised linear mixed models (GLMMs) and generalised estimating equations will be used for multiple variables.[60] Changes in nutrition knowledge (overall and subscores), nutrition attitudes, dietary intake and nutrition behaviours between the intervention and control groups will be assessed with GLMMs. Changes in the outcomes will be assessed from baseline to day 5, week 4 and month 3 and analysis will account for correlations within and between each classroom cluster. T-tests will be used to compare the acceptability of the Foodbot Factory and control interventions. Since we expect a low level of missing data on the NAK questionnaire, multiple imputation will be used to address missing data on this questionnaire.[61] A robustness check of the main analysis will be done using a difference-in-difference analysis.[62]

Trial status

The protocol version number and date are V.1.2, 5 April 2023. This trial began in November 2023 and is ongoing. The anticipated end date for the trial is June 2025.

Ethics and dissemination

This study has been reviewed by the Ontario Tech University REB (File No. 17109) and has been approved by six school boards across Central, Eastern and Northern Ontario. Per the school boards' policies, specific school boards will not be named to preserve participant privacy. In the event of a protocol amendment, the amendment will first be submitted to the Ontario Tech University REB. On REB review, amendments will be subsequently submitted to each participating school board. Protocol amendments will only be implemented with approval from both the Ontario Tech University REB and the school boards. Any protocol amendments will be shared with all participants in updated consent and assent forms and on the ClinicalTrials.gov registry. Study data will only be accessed by authorised personnel who have signed a confidentiality agreement. The results of this trial will be published in peer-reviewed journals and presented at academic conferences and conferences targeted to practising teachers. Findings will be interpreted and written by research team members who have made significant contributions to the research and meet the International Committee of Medical Journal Editors authorship criteria.[63] Each participating school board will receive a summary of results and lay summaries will be available to participants on the principal investigator's website. Lay summaries will also be shared by collaborating organisations to dietitians and teacher stakeholders via their websites, social media and listservs. The Foodbot Factory intervention will also be made available to the public for free, with the serious game available on the Apple App and Google Play Stores and lesson plans available for download on the principal investigator's website. After the results of the trial have been published, an anonymised copy of the data will be available in an online repository.

Patient and public involvement

Members of the public who are practising teachers and dietitians contributed to developing the intervention content. Input from individuals working at school boards informed the study design to ensure the acceptability of the research and value to knowledge users.

Author affiliations
[1]Faculty of Health Sciences, University of Ontario Institute of Technology, Oshawa, Ontario, Canada
[2]Mitch and Leslie Frazer Faculty of Education, University of Ontario Institute of Technology, Oshawa, Ontario, Canada
[3]Game Development and Interactive Media Program, University of Ontario Institute of Technology, Oshawa, Ontario, Canada
[4]Biostatistics, University of Toronto Dalla Lana School of Public Health, Toronto, Ontario, Canada
[5]Cedars-Sinai Health System, Los Angeles, California, USA
[6]Faculty of Health Sciences, University of Ottawa, Ottawa, Ontario, Canada

Contributors JMB, BF-A and JA conceived the project. All authors (JMB, ST, BF-A, AL, JH, BK, WL, EV, MF, CT-L and JA) were involved in the design of the study. JA, JMB, BF-A, AL, JH and BK were involved in the design of the intervention materials. WL contributed to the statistical analysis plan. JMB wrote the first draft of the manuscript. All authors (JMB, ST, BF-A, AL, JH, BK, WL, EV, MF, CT-L and JA) approved the final manuscript. JA is the corresponding author and guarantor of this manuscript.

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

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ORCID iDs
Jacqueline Marie Brown http://orcid.org/0000-0003-3806-0802
JoAnne Arcand http://orcid.org/0000-0002-1995-6905

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