The Development and Evaluation of a mHealth Nutrition Education Intervention

By

Jacqueline M. Brown

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Submitted by: **Jacqueline Brown**

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Examining Committee:

Chair of Examining Committee	Dr. Jennifer Abbass Dick
Research Supervisor	Dr. JoAnne Arcand
Research Co-supervisor	N/A
Examining Committee Member	Dr. Janette Hughes
Examining Committee Member	Dr. Bill Kapralos
Examining Committee Member	Dr. Milly Ryan-Harshman
University Examiner	N/A
External Examiner	Dr. Janet McCabe, UOIT

The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

Abstract

An environmental scan of the app marketplace evaluated publicly available mHealth nutrition apps targeted to children and found that there were few high-quality evidence-based apps available to educate children on healthy eating. To fill this gap in the availability of mHealth child nutrition apps, an iterative multi-method approach was taken to develop a novel app, Foodbot Factory, to help children aged 9-12 improve their food literacy skills and nutrition knowledge. Foodbot Factory was created by an interdisciplinary team with each prototype being informed by data collected in 5 iterative user testing sessions. The app educates users on foods and nutrients, integrating behaviour change and gamification techniques to enhance engagement. Data from the most recent testing session demonstrates that students are able to gain knowledge about nutrition from Foodbot Factory and that the app is an engaging, usable, and acceptable intervention for children to learn about healthy eating and nutrition.

Keywords: mHealth; child nutrition; nutrition education; food literacy; gamification;

Author's Declaration

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The research work in this thesis that was performed in compliance with the regulations of UOIT's Research Ethics Board/Animal Care Committee under **REB Certificate numbers 14426 and 14879.**

Jacqueline Brown

Statement of Contributions

The work described in Chapter 4 has been presented at the Canadian Nutrition Society annual conference in 2019 and the American Society for Nutrition annual conference in 2019. The work described in Chapter 5 has been presented at the 2019 Canadian Obesity Summit and at the Canadian Nutrition Society annual conference in 2019. I co-developed research protocols with my thesis supervisor Dr. Arcand, performed data collection in conjunction with my colleagues, completed data analysis, and am the primary author of the work presented in this thesis.

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Table of Contents

List of Abbreviations

Abbreviations	Definitions
BCTs	Behaviour Change Techniques
CFG	Canada's Food Guide
CCHS	Canadian Community Health Survey
eHealth	Electronic Health
IDEAS	Integrate, DEsign, Assess and Share
MARS	Mobile Application Rating Scale
mHealth	Mobile Health
NCDs	Non-Communicable Diseases
ORBIT	Obesity-Related Behavioral Intervention Trials
SSBs	Sugar-Sweetened Beverages

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Chapter One: Introduction

High diet quality is of vital importance for the Canadian population to prevent the onset of diet-related non-communicable diseases (NCDs), such as hypertension, cardiovascular disease, and obesity (Health Canada, 2011). During childhood and adolescence, nutrition also plays a critical role in growth and development, cognitive functioning, and the maintenance of a healthy body weight (Haapala et al., 2015). In Canada, many children are at risk of poor nutritional outcomes and associated NCD development since nearly 1 in 3 people under the age of 18 have overweight or obesity (Public Health Agency of Canada, 2011). Overweight and obesity are risk factors for the development of other NCDs, evidenced by rising incidence rates of hypertension and type 2 diabetes for Canadian children and adolescents (Amed et al., 2010; Nerenberg et al., 2018). Early interventions that can improve diet quality and food literacy skills are critical for ensuring the health and well-being of the Canadian population. A key area for nutrition intervention involves educating individuals on healthy eating practices and empowering individuals to make healthy food choices through improved food literacy skills (Thomas et al., 2019).

From a socio-ecological perspective, action is needed at the government, community, and individual levels to improve child nutrition and related health outcomes (Story, Kaphingst, Robinson-O'Brien, & Glanz, 2008). Since many factors that influence a child's diet are often beyond the individual's control, various interventions have targeted parents to improve their child's diet or taken a policy approach such as the current campaign in Canada to ban directed food advertising to children under the age of 13 (Golley, Hendrie, Slater, & Corsini, 2011; Stop Marketing to Kids Coalition, 2017).

Schools are also an important community setting to provide nutrition education within the curriculum and can foster the development of healthy eating habits (Basch, 2011). Interventions in schools that enhance existing curriculum or incorporate cross-curriculum activities, such as technology and experiential learning, have been effective in improving child nutrition knowledge and diet quality (Dudley, Cotton, & Peralta, 2015).

The creation of an effective nutrition education intervention for children requires extensive knowledge on the specific nutritional problems relevant for Canadian children and adolescents. An understanding of these problems will allow public health professionals to tailor interventions and resources towards specific dietary deficits or excesses within this population. A promising new way to deliver educational health promotion interventions involves mobile technology. Mobile health (mHealth) is defined as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices" (World Health Organization, 2011). Given the exponential increase in access to mobile devices, for both individuals and in educational settings, innovative health interventions that capitalize on mobile technology can be cost-effective and equitable to distribute to large audiences (Tate et al., 2013).

Despite the rapid uptake of mobile technology in Canadian society, minimal research has been conducted on the potential efficacy of mHealth interventions to improve child nutrition knowledge and related health outcomes. mHealth apps created by researchers are often required to compete with popular industry apps where evidence-based content is variable. No existing literature is available on the content and use of evidence-based techniques in publicly available nutrition apps marketed to children. Furthermore, there is no existing literature on the use of child nutrition mHealth interventions within school settings. The objectives of this research are to conduct an environmental scan of the app marketplace to evaluate existing child nutrition apps, and to design and develop a mHealth nutrition education app for children using a multi-method iterative development approach.

Chapter Two: Literature Review

2.1 Health Outcomes Associated with Diet in Childhood

2.1.1 Energy intake and weight.

The increasing rate of overweight and obesity is one of the greatest public health concerns in Canada and across the globe (Public Health Agency of Canada, 2011; World Health Organization, 2013). Excess body weight increases NCD risk, including type 2 diabetes, certain types of cancers, osteoarthritis, and cardiovascular disease (Public Health Agency of Canada, 2011). It is also a risk factor for poor psychological well-being (Rankin et al., 2016). Weight stigmatization, or the prejudices, negative stereotyping, and discrimination experienced by those living with excess weight, has been identified as a mediating factor for the development of depression and low body satisfaction in young adults who experienced weight stigma during childhood and adolescence (Stevens, Herbozo, Morrell, Schaefer, & Thompson, 2017).

The prevalence of overweight and obesity in Canadian youth is high, affecting approximately 1 in 5 children and 1 in 3 adolescents (Health Canada, 2012a, 2012b). Furthermore, approximately 25% of Canadian adults have obesity with a further 29.5% of adult females and 44.1% of adult males having overweight (Public Health Agency of Canada, 2011). Overweight and obesity, along with the lifestyle factors that influence weight, often track into adulthood making childhood obesity one of the greatest predictors of obesity in adulthood (Craigie, Lake, Kelly, Adamson, & Mathers, 2011). The relationship between obesity in childhood and adulthood requires public health officials to use a life-course perspective for both prevention and treatment. There is a critical need for early interventions to reduce the health burden of excess weight in Canadian youth (Ontario Healthy Kids Panel, 2012).

The etiology of childhood overweight and obesity is extremely complex, since many factors, including lifestyle, environment, and genetics, contribute to excess weight gain (Lytle, 2009). Polygenetic hereditary factors may account for up to 50% of variation in adiposity; however, the main etiological cause of obesity can be attributed to a positive energy balance, where calories in exceed calories out (Kumar & Kelly, 2017). Higher quality diets can play a role in preventing and treating excess weight in Canadian youth by reducing excess calories, particularly calories that are consumed from low-quality sources, like sugar-sweetened beverages (SSBs) and processed meat and potato products, which constitute 23-31% of calories consumed by Canadian youth (Jessri, Nishi, & L'Abbe, 2016).

2.1.2 Fibre, sugar, and type 2 diabetes.

Type 2 diabetes, formerly known as adult-onset diabetes, is becoming increasingly common in youth with a minimum of 1.54 incident cases per 100,000 annually in the Canadian pediatric population (Amed et al., 2010). Type 2 diabetes occurs when the body cannot properly utilize insulin due to an imbalance between insulin sensitivity and insulin secretion, also known as insulin resistance. This leads to a progressive decline in pancreatic cell function, and ultimately the diagnosis of type 2 diabetes (D'Adamo & Caprio, 2011; Sinaiko & Caprio, 2012).

One of the most important risk factors for the development of type 2 diabetes is obesity and the quality of calories consumed plays a role in the development of insulin resistance (Panagiotopoulos, Riddell, Sellers, & Committee, 2013). A meta-analysis of 11 studies indicated that SSBs were not only associated with obesity and weight gain, but also contributed to the development of metabolic syndrome and type 2 diabetes. Those who consumed the highest amount of SSBs, approximately 1-2 servings a day, had a 26% higher risk of developing type 2 diabetes than those who consumed the lowest amount, less than or equal to 1 serving per month (Malik et al., 2010). Furthermore, the majority of Canadian youth do not consume adequate amounts of fibre, which has been linked to improved blood glucose control (Dworatzek et al., 2013; Health Canada, 2012a, 2012b). Many cases of type 2 diabetes can be prevented and managed with a diet that follows Canada's Food Guide (CFG) recommendations (Dworatzek et al., 2013; Ransom et al., 2013).

2.1.3 Sodium, potassium, and hypertension.

Hypertension, or high blood pressure, is the greatest contributor to the global burden of disease since it is a significant risk factor for the development of cardiovascular disease, stroke, and end-stage renal disease (Bromfield & Muntner, 2013). It is also one of the most common NCDs in Canada, affecting 25% of adults and 2% of children and adolescents (Nerenberg et al., 2018). Obesity is a leading risk factor for hypertension development as an estimated 11% of youth living with obesity have hypertension, compared to the estimated 1-5% in the general population (Ahern & Dixon, 2015). Once thought to be rare in children and adolescents, the prevalence of hypertension has increased in the Canadian population two-fold over the past two decades indicating the need for effective prevention and treatment to improve quality of life and reduce the risk of future morbidity and mortality (Padwal, Bienek, McAlister, Campbell, & Outcomes Research Task Force of the Canadian Hypertension Education Program, 2016)

Increased blood pressure is significantly associated with dietary intake of sodium and potassium (Hou et al., 2016). Sodium and potassium are important for maintaining fluid balance and vascular function, ultimately influencing blood pressure (Hellwig, Meyers, & Otten, 2006). Reductions in sodium intake have been consistently linked to reductions in blood pressure, and therefore the morbidity and mortality associated with hypertension (Whelton, 2014). When consumed in adequate amounts, potassium has the ability to reduce blood pressure independently of sodium intake (Aburto et al., 2013). The Dietary Approaches to Stop Hypertension diet, a low sodium and high potassium diet, has been proven to help treat and manage hypertension, indicating the importance of both of these nutrients for maintaining a healthy blood pressure (Sacks et al., 2001).

The average Canadian child does not consume adequate amounts of potassium and consumes sodium in excess (Health Canada, 2012a, 2012b, 2018). Part of this is due to a cultural shift towards ready-made, processed foods that are high in sodium and a simultaneous shift away from fresh fruits and vegetables that are high in potassium (He & MacGregor, 2008). Given that dietary interventions can be extremely effective for maintaining a healthy blood pressure, it is important to intervene early with Canadian youth to prevent and manage hypertension (Ahern & Dixon, 2015).

2.2 Food Intake and Dietary Patterns of Canadian Adolescents

The 2004 and 2015 Canadian Community Health Surveys (CCHS) are the primary sources of data on the eating patterns and dietary intake of Canadian children and adolescents (Health Canada, 2012a, 2012b, 2018). This data defines children as those aged 2-8 and adolescents as those aged 9-18. Adolescence is a critical time for dietary interventions as this age group is able to exercise more autonomy in their food decisions.

Since this research concerns intervention development for those aged 9-12, dietary and nutritional data will only be reviewed from the adolescent age group.

Data from the 2015 CCHS show that on average, Canadian children and adolescents under consume foods that are beneficial for health. Vegetable and fruit consumption has declined in 2015 to an estimated average of 4.3 servings/day compared to 4.5 servings/day in 2004 (Tugault-Lafleur & Black, 2019). Adolescents also under consume whole grain foods (average 1 servings/day), fish and shellfish (average 0.1 servings/day), and legumes, nuts, and seeds (average 0.2 servings/day), all foods recommended in CFG (Health Canada, 2019; Tugault-Lafleur & Black, 2019). A promising finding from the 2015 CCHS is that consumption of SSBs has declined for adolescents compared to 2004 by an average of 58 kcal/day, however, consumption of high fat and/or high sugar foods showed no significant difference, contributing a mean of 148 kcal/day (Tugault-Lafleur & Black, 2019).

In an analysis of the nutritional quality of Canadian youth dietary patterns, Jessri and colleagues (2016) analyzed data from the 2004 CCHS using the Health Canada Surveillance Tool Tier System to evaluate the diets of a nationally representative sample of youth aged 2-18 years of age. The Tier System ranks foods based on how well they align with the dietary recommendations provided in the 2007 CFG (Health Canada, 2011). Tier 1 and 2 foods are considered to be in line with CFG guiding statements, Tier 3 foods are partially in line, and Tier 4 foods are not recommended in CFG.

The main classifications for the Tier System are based on total fat, sugar, and sodium contents, with each of the four food groups (Vegetables and Fruits, Grains, Meat and Alternatives, and Milk and Alternatives) having different Tier Systems. Data from 2004 shows that the mean consumption of vegetable and fruit servings was also below the recommendation for all age groups, with the majority of fruit calorie intake (50%) from Tier 2 fruit juices and the majority of vegetable calorie intake (48%) from Tier 3 and 4 potatoes (Jessri et al., 2016).

Recommended servings from Tier 1-3 grains and milk and alternatives for adolescents aged 9-18 were not met. For grain calories, 74% came from refined non-whole grain products with only 13% of grain calories from whole grain foods. For milk and alternatives 45% of calories came from milk and fortified non-dairy beverages. Only females aged 9-13 consumed adequate servings of meat and alternatives. The majority of calories consumed in this category for those aged 9-18 came from Tier 3 beef products (19%) and Tier 4 processed meats (17%), followed by Tier 3 poultry (10%). In total, Tier 4 foods, those not recommended by CFG, contributed nearly a third, 23-31%, of overall calorie consumption for Canadian youth. The majority of Tier 4 calories came from processed meat and potatoes, followed by high calorie SSBs. Overall, this informative analysis of diet quality from Jessri and colleagues (2016) has indicated that many adolescents are not consuming high-quality nor adequate servings from the food groups identified in CFG, particularly vegetables and fruits, with foods that are not recommended by these guidelines contributing a large portion to overall energy intake.

2.3 Nutrient Intake of Canadian Adolescents

Data on the energy, macronutrient, and micronutrient intakes of Canadian adolescents aged 9-18 come from the 2004 and 2015 CCHS (Health Canada, 2012a, 2012b, 2018). The majority of Canadian adolescents have energy intakes within the acceptable macronutrient distribution range for the consumption of carbohydrates, protein, and fat. However, consumption of fat is of an increasing concern for adolescents since 10.8-13.4% of adolescents exceed the acceptable macronutrient distribution range for total fats (Table 2-1). Furthermore, about 10% of adolescent energy intake comes from saturated fat, a nutrient where consumption should be minimized because of its relation to NCD development (Trumbo et al., 2002). Canadian adolescents have widespread inadequate consumption of fibre (Table 2-2), with the average adolescent consuming approximately half of the adequate intake level, the recommended daily intake of a nutrient (Hellwig et al., 2006).

Macronutrients	% adolescents below AMDR		% adolescents within AMDR		% adolescents above AMDR		AMDR (% of total energy intake)
	Boys	Girls	Boys	Girls	Boys	Girls	
Total fat							
9-13 years	F	6.5^E	**86.3**	**81.4**	10.8^E	12.1^E	**25-35%**
14-18 years	F	F	**84.4**	**82.6**	13.4^E	12.9^E	
Protein							
9-13 years	<3	F	**99.1**	**97.8**	0.0	0.0	**10-30%**
14-18 years	<3	3.9^E	**98.8**	**96.1**	<3	0.0	
Carbohydrates							
9-13 years	<3	<3	**99.0**	**96.4**	<3	F	**45-65%**
14-18 years	F	F	**95.5**	**97.1**	<3	<3	

E : Data with a coefficient of variation from 16.6% to 33.3%; interpret with caution.
<3 : Data with a coefficient of variation greater than 33.3% with a 95% confidence interval entirely between 0 and 3%; interpret with caution.
F : Data with a coefficient of variation greater than 33.3%with a 95% confidence interval not entirely between 0 and 3%; suppressed due to extreme sampling variability.

Table 2-1: *Proportion of adolescents consuming carbohydrates, protein, and fat, above, within, and below the acceptable macronutrient distribution range (Health Canada, 2012a)*

	Adequate Intake for Fibre	Median Fibre Intake
Girls Ages 9-18	26 g/day	12.0 g/day
Boys Ages 9-13	31 g/day	16.3 g/day
Boys Ages 14-18	38 g/day	18.3 g/day

Table 2-2: *Comparison of adequate intake for fibre to median fibre intake for Canadian adolescents (Health Canada, 2012a)*

The adequate intake recommendations for vitamins and minerals vary greatly between genders and age groups (Hellwig et al., 2006). For nutrients with an estimated average intake, dietary inadequate intake in younger male adolescents (aged 9-13) is most concerning for Vitamin A (11.6%), D (84.5%), and calcium (43.9%). For older male adolescents (aged 14-18) primary nutrients of concern for inadequate intakes are the same as the 9-13 population and magnesium (41.4%). For younger female adolescents, inadequate intakes are seen for Vitamins A (23.1%) and D (47.0%), magnesium (18.3%), zinc (14.6%), phosphorus (30.2%), and calcium (17.0%). Older female adolescents showed the most problematic intakes of vitamins and minerals with inadequate intakes for Vitamins A (42.2%), B6 (11.1%), B12 (15.8%) and D (59.1%), calcium (16.8%), folate (20.1%), iron (11.9%), magnesium (66.3%), phosphorus (35.1%), and zinc (19.6%) (Health Canada, 2009, 2012a). For vitamins and minerals with adequate intake levels, potassium and sodium intakes were concerning for all adolescents. The median intake of potassium for all adolescents fell below the adequate intake level of 4500 mg for 9-13-year olds and 4700 mg for 14-18-year olds (Table 2-3). CCHS data from 2015 demonstrates that up to 92% of Canadian adolescents consume excessive amounts of sodium. The mean intake of sodium for all adolescents fell above the recommended consumption level of 1500 mg (Table 2-4), and above 2300 mg, the recommended consumption level to reduce chronic disease risk (Health Canada, 2018; National Academies of Sciences & Medicine, 2019). In sum, many Canadian adolescents have inadequate intake of fibre and potassium, and excess intake of sodium and saturated fat. There are also specific vitamin and mineral deficiencies that may be best addressed based on age and gender, such as B vitamins, folate, iron, magnesium, phosphorus, and zinc (Health Canada, 2009, 2012a).

Age Group	Males	Females
9-13	3153	2664

14-18	3635	2669

Table 2-3: *Mean potassium intakes (mg) for Canadian adolescents (Health Canada, 2009)*

Age Group	Males	Females
9-13	2740	2410
14-18	3320	2350

Table 2-4: *Mean sodium intakes (mg) for Canadian adolescents (Health Canada, 2018)*

2.4 Factors Influencing Food Intake

It is important to consider the multi-leveled context in which foods are consumed in order to understand the behavioural influences on dietary choices. The Social-Ecological Model demonstrates that food choices are influenced by factors on four different levels: macro, physical environment, social, and individual illustrated in Figure 2-1 (Story et al., 2008). Macro-level factors include the ways in which government and industry shape eating behaviours through agriculture and the distribution of food, marketing, policy implementation, and food pricing. These factors have a more indirect but powerful influence on an individual's food choices. Physical environment factors include the multitude of settings, such as the home, school, workplace and supermarkets, where individuals eat, purchase, and prepare food. Social factors are the influences that family, friends, and peers exert on an individual's food choices and behaviours. Individual factors include attitudes, behaviours, and knowledge related to food as well as biological determinants and demographic factors. A comprehensive understanding of how children and adolescents make food choices and develop food behaviours is critical for the development of any successful nutrition intervention.

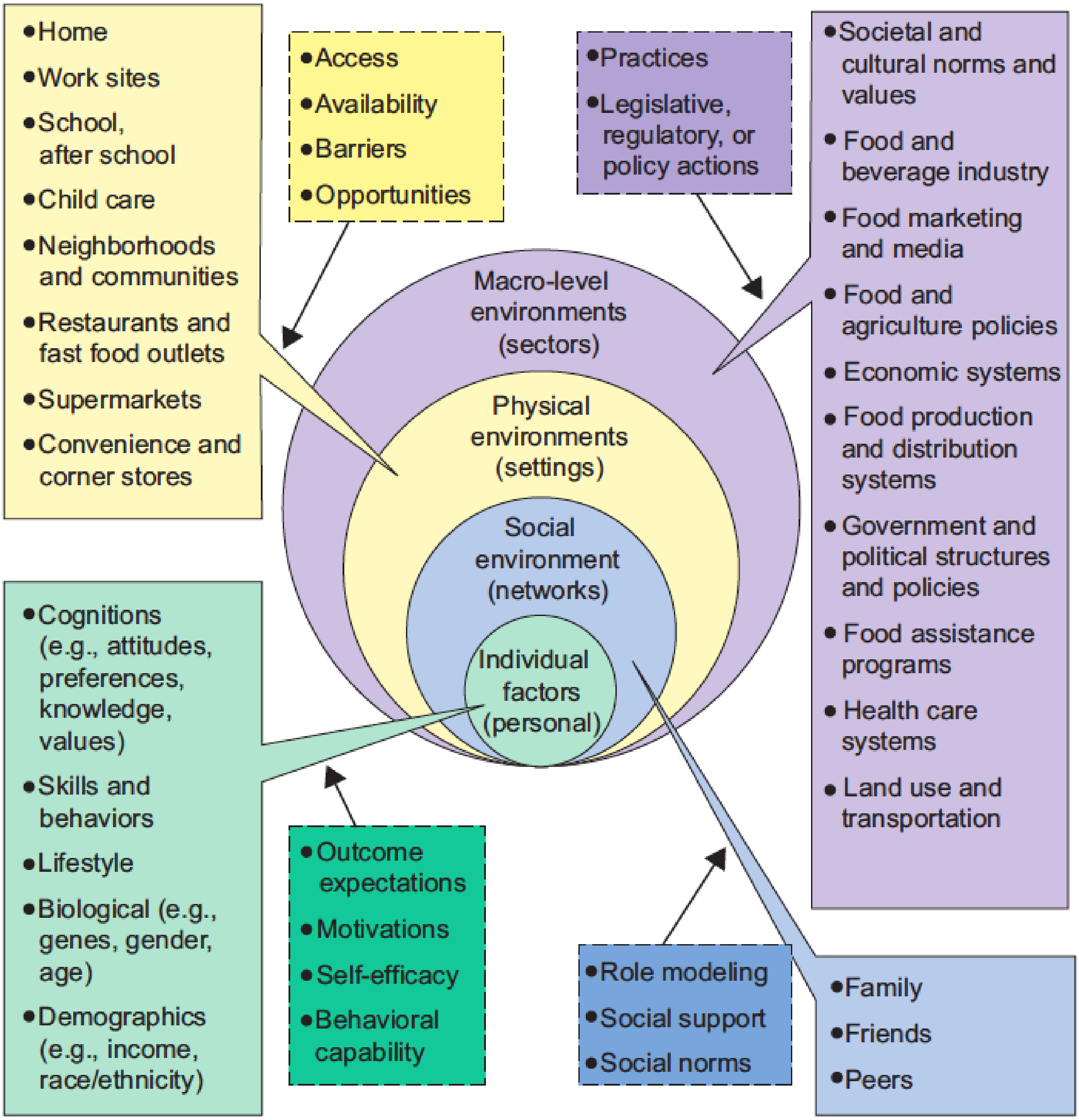

Figure 2-1: *The social-ecological model (Story et al., 2008)*

2.4.1 Macro-level environments.

Macro-level environments influence eating behaviours by shaping our agricultural practices, food systems, determining the costs of foods, and creating sociocultural norms for eating practices (Story et al., 2008). Policy interventions that target upstream influences on eating behaviour can be one of the most effective ways to improve a population's nutritional outcomes; however, they are also extremely difficult to develop and implement (Golden, McLeroy, Green, Earp, & Lieberman, 2015). An excellent example of a macro-level intervention is Bill S-228: The Child Protection Act; if passed, this bill would ban the direct advertising and marketing of food and beverages to children under the age of 13 (Stop Marketing to Kids Coalition, 2017). Appealing and persuasive marketing strategies, particularly for foods and beverages that are high in sugar, fat, and/or sodium, can influence food preferences and intake such that children who view targeted advertisements are more likely to prefer high carbohydrate and high fat foods. The influence of marketing on food intake and preferences is even stronger for children who have excess weight (Boyland & Halford, 2013). Children exposed to targeted food marketing have higher intakes of advertised foods and are more likely to choose energy dense processed foods with low nutritional value (Sadeghirad, Duhaney, Motaghipisheh, Campbell, & Johnston, 2016). If Bill S-228 passes a final vote in the Senate, it would be a substantial step forward to shaping the Canadian food environment in a positive way for children (Library of Parliament of Canada, 2018). Any intervention aiming to improve the dietary intake of youth, whether enacted at a policy level or not, still needs to consider how overarching macro-level factors influence dietary behaviours and determine the nutritional status for the population of concern.

2.4.2 Physical environments.

The physical food environment can be understood as the access and availability one has to food in their geographic area, including the amount and type of food outlets within an area, and features of the consumer experience, such as the variety of foods that are available, and the quality and price of that food (Health Canada, 2013). The food environment is critical to promoting high-quality diets as it directly influences the ability to make food choices and determines the affordability of healthy foods. The prevalence of obesity has doubled globally since the 1980s and this increase has largely been driven by changes in the physical food environment (World Health Organization, 2013). Prevalence of obesity is higher in communities that have multiple fast food restaurants and minimal access to supermarkets (Morland & Evenson, 2009). In a systematic review of the food environment literature, Caspi, Sorensen, Subramanian, and Kawachi (2012), found that accessibility to healthy foods was consistently linked to healthier diets, as measured by increased vegetable and fruit intake and reduced consumption of fast foods.

Another important physical environment to consider regarding healthy eating by Canadian children and adolescents is school because this is where the majority of their day is spent. The implementation of healthy eating programs can have a positive impact on nutritional outcomes, including reduced body mass index (Driessen, Cameron, Thornton, Lai, & Barnett, 2014). Furthermore, education in school on nutrition and healthy eating is essential to provide Canadian youth with the knowledge and critical thinking skills required to make healthy choices in an obesogenic food environment. Educational nutrition interventions, particularly those that are experiential, can be beneficial for children leading to reduced energy intakes and increased vegetable and fruit consumption (Dudley et al., 2015). Schools can also foster healthier eating based on the way that the schedule is structured. When students are provided with a longer time to eat lunch they are significantly more likely to finish their meal, along with accompanying vegetables and milk (Cohen et al., 2016). Since children spend over 50% of their waking hours in school, intervening within this environment can be extremely beneficial for improving food and nutrition knowledge along with healthy eating outcomes.

2.4.3 Social environments.

The social environment, or interactions with family, friends, and community members, exert a great influence on eating behaviours (Story et al., 2008). Since youth have limited autonomy when making food choices, the influences of their parents and family are one of the most critical to consider for nutritional outcomes (Couch, Glanz, Zhou, Sallis, & Saelens, 2014). Family mealtimes have been known to foster healthy eating habits as children who consistently enjoy a meal with their family members are significantly more likely to eat five or more servings of vegetables and fruits on a daily basis (Christian, Charlotte, Hancock, Nykjaer, & Cade, 2013). Eating breakfast as a family has also been linked to positive eating attitudes in adolescents (Larson, Wang, Berge, Shanafelt, & Nanney, 2016). When children and adolescents are involved in the preparation of meals with their family members, they are more likely to consume healthier diets and increase vegetable and fruit consumption compared to their peers who are uninvolved with meal preparation (Chu, Storey, & Veugelers, 2014). Involvement in food preparation can also increase knowledge about food and enhance confidence in preparing healthy meals (Rodriguez, Applebaum, Stephenson-Hunter, Tinio, & Shapiro, 2013). The home social environment should be viewed as an important target for fostering healthy eating patterns and increasing food literacy in Canadian youth.

There is mixed evidence on the role of social interactions with friends and peers and how they influence the eating habits of children and adolescents. One study found that adolescents' diet quality is positively influenced by the encouragement and support of their parents, particularly their mother, but diet quality was negatively influenced by encouragement from peers (Vanhelst et al., 2018). Other researchers have found that peers may exert a positive influence on children's physical activity levels, but no relationship was found between peer influence and diet (Finnerty, Reeves, Dabinett, Jeanes, & Vögele, 2010). In contrast, peer norms on eating behaviours have been found to influence healthy eating intentions and the consumption of both healthy and unhealthy foods (Stok et al., 2015). Despite the mixed results of research in this field, the influence of peers is important to consider when developing nutrition interventions, particularly those that take place in a school setting where peer influence may be greater.

2.5 Food Literacy

Individual factors that influence dietary intake include modifiable attitudes, behaviours, and cognitions regarding food as well as non-modifiable factors such as demographics, genetics, and taste (Story et al., 2008). Food literacy is a key individual factor to consider when creating nutrition interventions targeted to individuals because it is amenable to change. Food literacy encompasses a wide range of knowledge and skills that enable an individual to make healthy food choices, and has been identified by the Ontario Food and Nutrition Strategy Group (2017) as a focal point of intervention for improving nutrition outcomes in the province. The Locally Driven Collaborative Project, supported by Public Health Ontario, has identified four different interconnected components of food literacy at both the individual and societal level that influence food decisions and dietary behaviours, displayed in Figure 2-2 (Thomas et al., 2019). Individual level factors include food and nutrition knowledge, encompassing knowledge of food groups and how the nutrients in foods affect health and well-being, food skills or the ability to cook and prepare foods, and self-efficacy in making dietary decisions (Thomas et al., 2019). Food and nutrition knowledge can be viewed as a critical underpinning of food literacy as a whole, where someone who has high food and nutrition knowledge will possess skills to read recipes and create healthy meals, be able to critically interpret nutrition information, have greater confidence in making healthy choices, understand where foods come from and, ultimately, will be able to make informed healthy eating decisions.

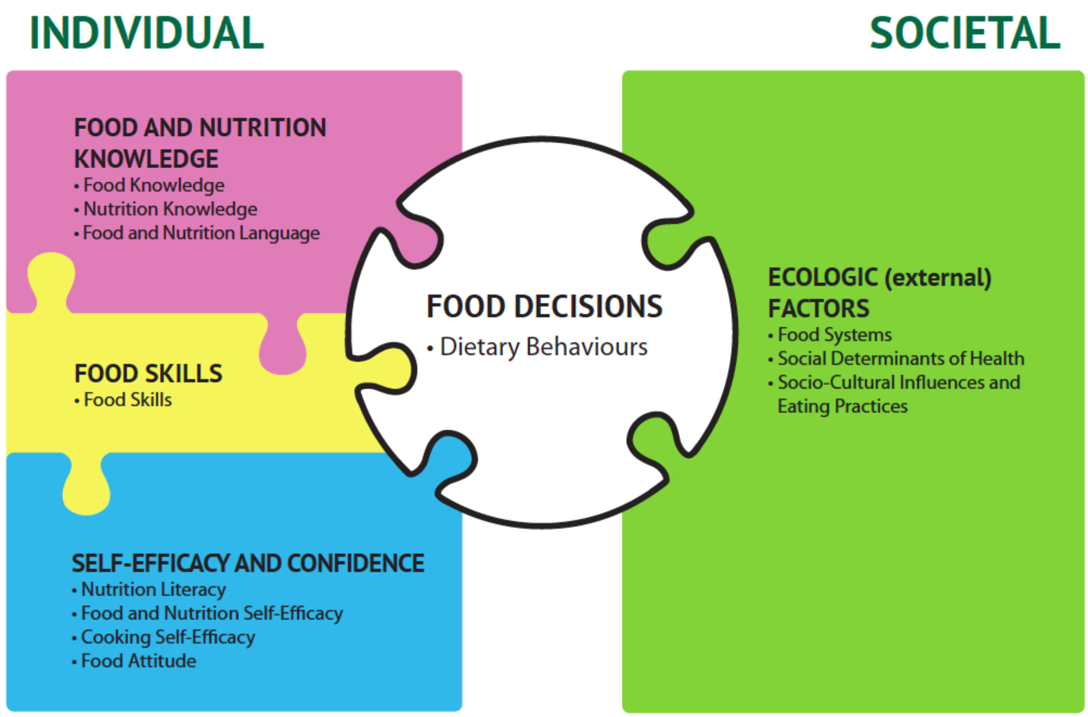

Figure 2-2: *Food literacy framework (Thomas et al., 2019)*

Higher levels of food literacy skills have been linked to improved dietary and nutritional outcomes in the Canadian population. Adults who make grocery lists and read food labels are significantly more likely to eat five or more servings of vegetables and fruits daily (Ontario Food and Nutrition Strategy Group, 2017). Young adults with high levels of health literacy, a broader set of health skills that food literacy is a part of, are more likely than those with low health literacy to use food labels when making food choices. The use of food labels increases diet quality and this food literacy skill may also be associated with self-efficacy, or one's belief in their own capabilities (Cha et al., 2014). Food literacy skills and self-efficacy may have a reciprocal relationship wherein higher levels of food literacy increase one's self-efficacy regarding healthy eating (Cha et al., 2014). Being able to make healthier choices may further develop food literacy skills and self-efficacy in tandem.

A literature search on health and food literacy demonstrated linkages to empowerment, whereby greater health literacy knowledge may lead to an increased ability to take control of one's life and health. The relationship between health literacy and empowerment is greatest when health literacy interventions enable the participant to question and reflect upon the social determinants of health and subjectively identify their own health needs (Crondahl & Eklund Karlsson, 2016). Given the relationship between food literacy, healthy eating choices, and self-efficacy, Canadian public health interventions should aim to increase these skills in both adult and pediatric populations.

Increased food literacy has been linked to improved diet quality in multiple studies; however, varying definitions of the concept exist and interventions that target different aspects of food literacy have made it difficult to establish a strong relationship between food literacy and nutritional outcomes (Vaitkeviciute, Ball, & Harris, 2015). Currently, there is no valid and reliable measure to assess Canadians' food literacy but there is evidence that food literacy is declining in the adult population due to the increasing popularity of convenience foods and decreased opportunities to gain food skills at school and at home. Researchers have argued that our culture is currently in a "culinary transition" where the availability of processed foods has increased and individual priorities and opportunities surrounding food preparation have shifted, leading to a decline in food and nutrition knowledge and food preparation skills for adults (Chenhall et al., 2010). Children and adolescents are also likely to be experiencing a similar decline in food literacy since the home food environment and social influence of parents is central for the development of food literacy skills (Couch et al., 2014). Low levels of health and food literacy within the family have been identified as a barrier to healthy eating and the prevention of childhood obesity (Cyril, Nicholson, Agho, Polonsky, & Renzaho, 2017). Ensuring that children are equipped with food literacy skills at a younger age can help them make healthy food choices. Children who participated in a food literacy program at school showed statistically significant changes in their perceptions of the healthiness of foods, which translated to positive dietary choices during lunchtime, with children being less likely to choose chocolate milk and ice cream and more likely to choose vegetables compared to children who did not participate in the program (Jung, Huang, Eagan, & Oldenburg, 2019).

2.6 Education Interventions to Improve Nutrition Related Health Outcomes

Existing food literacy interventions for children and adolescents have specifically targeted food literacy skills as a means of increasing diet quality. Focus groups with adolescents identified that they desire to have more food and nutrition knowledge to help them make healthy eating decisions. Participants recognized the importance of developing food preparation skills; however, they felt they had limited opportunities to learn and utilize these skills (Ronto, Ball, Pendergast, & Harris, 2016). Interventions could aim to increase food and nutrition knowledge during childhood and then provide opportunities to improve food preparation skills in adolescence and young adulthood when participants would have more autonomy to make their own meals.

Schools are an excellent setting to deliver food literacy interventions because this is where children and adolescents spend the majority of their days. A systematic review and meta-analysis conducted by Dudley and colleagues (2015) assessed the impact of nutrition interventions located in a school setting on child and adolescent health outcomes. This search identified 49 school-based interventions that targeted increased vegetable and fruit consumption (n =16), reduced energy intake (n = 11), increased nutrition knowledge (n = 12), and reduced sugar consumption (n = 10). Forty-eight out of 49 of the studies were conducted in OECD countries and only one was conducted in Canada. Eight teaching strategies were utilized to deliver these interventions, the most popular being enhanced curriculum (n = 29) and cross-curricular approaches (n = 11). The least popular were board or card games (n = 2) and web-based approaches (n = 2). The meta-analysis showed that experiential learning approaches, such as school gardens and cooking activities, had the greatest influence on nutritional health outcomes. High-quality curriculum interventions, particularly those grounded in behavioural theory, were effective for improving nutritional knowledge with a mean effect size of $M_d = 1.35$. However, the sample of school-based nutrition interventions was extremely diverse, making it difficult for Dudley and colleagues (2015) to draw firm conclusions on any one approach, especially for game and web-based approaches which were under-represented. The authors were also unable to parse the effects of interventions that incorporated more than one teaching approach. This informative analysis demonstrates that school-based nutrition interventions can have significant impacts on health outcomes and behaviours but also highlights important gaps in the literature including that no mobile interventions have been developed for this setting (Dudley et al., 2015).

2.7 Effectiveness of e- and mHealth in Improving Health Outcomes

Using mobile devices to deliver medical and public health interventions, also known as mobile health (mHealth), can be a fairly equitable way to introduce health promotion and education interventions to the Canadian population as 76% of adults report owning a smartphone (Statistics Canada, 2017; World Health Organization, 2011) Additionally, 47% of children aged 0-11 and 80% of teens aged 12-17 are estimated to own smartphones and these numbers are expected to increase with 90% of the global population anticipated to own smartphones by 2020 (Carroll et al., 2017; eMarketer, 2016). Mobile devices are often accessible outside of the home, evidenced by the government of Ontario investing over $150 million dollars to integrate iPad technology into schools which has provided 96% of students access to technology in the classroom (Howell, O'Donnell, & Canadian Electronic Library, 2017; Rieti, 2014). Given the high rate of access to mobile devices, mHealth interventions are an equitable way to deliver health interventions when they are available to the public for free or at low-cost. Distribution of mHealth interventions is also cost-effective since minimal work is required to keep the intervention available after its release (Tate et al., 2013).

Previous research has shown promising results for the effectiveness of mHealth interventions and their ability to positively influence health behaviours like dietary intake and physical activity for children and adolescents (Rose et al., 2017). Interventions that appropriately incorporate gamification and behaviour change techniques (BCTs) may be even more effective (Edwards et al., 2016; Johnson et al., 2016). BCTs are the “observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour … a technique proposed to be an “active ingredient”” and include techniques such as feedback, goal setting, and social support (Michie et al., 2013). The BCT Taxonomy defines 93 different techniques and the taxonomy has been utilized to identify effective techniques for a variety of health behaviours, including diet, physical activity, and addiction; however, no known research has assessed which BCTs are most effective in nutrition mHealth interventions for children (Michie, Abraham, Whittington, McAteer, & Gupta, 2009; Michie et al., 2013; Michie et al., 2012).

Gamification involves the incorporation of gaming elements into traditionally non-gamified tasks, such as health promoting activities, and can harness a desire for competition, improve motivation, and increase engagement (Edwards et al., 2016). It is important to explore the current implementation of these strategies to understand how to appropriately utilize them in future interventions. A systematic review on serious games to improve knowledge or change behaviours in children with overweight or obesity identified six articles. Although this research is limited, these studies demonstrated that children find mHealth apps engaging and that they can significantly improve knowledge and incite positive behaviour change, indicating the need for further investigation on evidence-based gamified mHealth interventions for children (Dias, Domingues, Tibes, Zem-Mascarenhas, & Fonseca, 2018). By capitalizing on technology that is prevalent in the education system and owned by a large majority of the Canadian population, mHealth interventions can provide equitable, cost-effective access to health promotion interventions. Despite the poor diet quality and lack of food literacy skills in the Canadian population, minimal evidence-based mHealth interventions are publicly available to provide nutrition education for children (Edwards et al., 2016).

2.8 Review of Literature on mHealth Child Nutrition Interventions

Literature on evidence-based mHealth interventions with the aim of improving diet, assessing diet, or improving food literacy were reviewed to identify potential areas for intervention and enhance understanding of current best practice for mHealth child nutrition interventions. Articles were included in the literature search analysis if they met the following criteria:

1. Published after 2007 (within the last 10 years)
2. Published in English
3. Pediatric population (under the age of 18) is the target of the intervention
4. Utilized mHealth techniques to target nutrition

A search for relevant literature was conducted in the PubMed database. Multiple search strings utilizing Medical Subject Headings (MeSH) and Title/Abstract terms that incorporated the relevant criteria of pediatric population, mHealth, and nutrition were tested. A search string using the terms children, adolescent, diet, mobile app, mHealth, and cell phones was used as it resulted in the greatest number of relevant search results at 104 articles. Fourteen relevant articles were identified and assessed for their target population, target outcomes, BCTs, and gamification in the interventions. The results of these articles and their findings are summarized in Table 2-5.

Author	Country	Population	Study Design	Intervention	Control	Duration	Outcome(s)	Results
de Niet et al. (2012)	Netherlands	Children aged 7-12 enrolled in weight loss program	Randomized control trial	Short message service maintenance treatment	Treatment as usual	9 months	Nutrition behaviour change	Short message service maintenance treatment did not improve treatment outcomes for body mass index ($p = 0.85$), but seems to be a feasible method for treatment delivery.
Mameli et al. (2018)	Italy	Children aged 10-17 enrolled in weight loss program	Randomized control trial	Wristband and smartphone app	Treatment as usual	3 months	Nutrition behaviour change	Use of a mobile app and wristband was not superior to a traditional weight loss program for children with obesity ($p = 0.96$).
Nollen et al. (2014)	United States of America	Female ethnic minority children aged 9-14	Randomized control trial	Personal digital assistant program	Nutrition manuals	12 weeks	Nutrition behaviour change	Small to moderate effects were seen for increasing vegetable and fruit ($p = 0.08$) and reducing SSB consumption ($p = 0.09$) compared to control.
Pedersen, Gronhoj, and Thogersen (2016)	Denmark	Children aged 11-16	Randomized control trial	Texting program	Education as usual	11 weeks	Nutrition behaviour change	Participants who participated in the program by 50% or more significantly improved vegetable and fruit intake ($p = 0.007$)
Thompson et al. (2015)	United States of America	Children aged 9-11	Randomized control trial	Serious video game including action intentions	Serious video game with no intention setting	3 months	Nutrition behaviour change	Participants that created action intentions for increasing vegetable and fruit consumption maintained higher vegetable and fruit intake at long term follow-up ($p < 0.001$).

Costello, Deighton, Dyson, McKenna, and Jones (2017)	United Kingdom	Elite adolescent rugby athletes aged 16-18	Crossover design	Snap-n-Send mobile food record	24-hr food record	8 days	Dietary assessment	Snap-n-Send has a small mean bias for underreporting dietary intake (-0.75MJ/day; p = 0.004), but overall was a valid and reliable tool.
Nollen et al. (2013)	United States of America	Female ethnic minority children aged 8-15	Participatory action and pre-post assessment	Personal digital assistant program	N/A	2 weeks	Nutrition behaviour change & acceptability of the intervention	Participatory action research with participants helped to create an acceptable and useful intervention that lead to a significant increase in vegetable and fruit consumption from baseline (p = 0.05).
Wickham and Carbone (2018)	United States of America	Children aged 11-15	Participatory action and pre-post assessment	FuelUp&Go! In-person and online education program	N/A	6 sessions across 3 months	Food literacy skills	Attitudes towards reducing SSB consumption (p = 0.04) and increasing fruit consumption (p = 0.12) improved.
Baghaei, Nandigam, Casey, Direito, and Maddison (2016)	New Zealand	Children aged 9-13	Pre-post pilot assessment	Diabetic Mario educational video game	N/A	1 week	Food literacy skills & acceptability of the intervention	Scores on Health Knowledge Questionnaire improved from pre to post conditions, although not statistically significant (no p-value reported).
Schiel, Kaps, and Bieber (2012)	Germany	Children enrolled in weight loss program aged 10-16	Pre-post pilot assessment	Mobile intervention as part of a treatment program	N/A	4 days	Nutrition behaviour change & acceptability of the intervention	There were significant differences in self-reported physical activity (p < 0.001) and eating records (p = 0.09) compared to the mobile intervention, indicating mobile

								technology can better monitor participation in weight loss programs.
Aflague et al. (2015)	Guam	Children enrolled in summer camp age 3-10	Pilot usability assessment	Mobile food record	N/A	4 days	Dietary assessment & acceptability of the intervention	The mobile food record was acceptable and useable with 90% of participants successfully capturing their meals.
Panizza et al. (2017)	United States of America	Female children aged 9-13	Pilot assessment	Mobile food record to assess plate waste	N/A	3 days	Dietary assessment	>11% of food throughout the day was thrown in the trash. The mobile food record is an acceptable way to assess plate waste in this population.
Davison, Quigg, and Skidmore (2018)	New Zealand	Children aged 9-12	Exploratory mixed-method design	Electronic photo food diary	Written food diaries	8 days	Dietary assessment & acceptability of the intervention	The electronic food diary is suitable for use by children, provided greater accuracy and was easier to read based on qualitative feedback.
Woolford et al. (2011)	United States of America	Children enrolled in weight loss program aged 11-19	Qualitative focus groups	Discussion of text-based weight management intervention	N/A	90-120 minute focus groups	Acceptability of the intervention	Focus groups indicated that participants were interested in receiving text messages as part of their treatment program. Messages that provided ideas from peers or requested feedback were deemed acceptable and useful.

Table 2-5: *Summary of articles identified in mHealth literature search*

2.8.1 Target population.

Of the 14 identified articles that utilized mHealth interventions for child nutrition, six were for specific populations. Five of these studies targeted clinical populations (Baghaei et al., 2016; de Niet et al., 2012; Mameli et al., 2018; Schiel et al., 2012; Woolford et al., 2011) and the other targeted elite athletes (Costello et al., 2017). The remaining eight articles were for general child populations with no prior conditions, three of which only included females (Nollen et al., 2013; Nollen et al., 2014; Panizza et al., 2017). This indicates that approximately equal weight has been placed on studying the impacts of mHealth interventions for general and clinical populations.

2.8.2 Target outcomes.

There are many behaviours of interest when it comes to improving nutrition; therefore, assessing target outcomes elucidates which nutritional behaviours are currently being prioritized in the literature. Target behaviours focused on: nutrition behaviour change (n = 8), acceptability of the intervention (n = 5), dietary assessment (n = 4), and/or food literacy skills (n = 2; Table 2-5). Existing research has placed more emphasis on using mHealth to improve nutrition behaviours and assess diets with few interventions targeting food literacy skills.

2.8.3 Gamification.

Of the identified articles only four incorporated gamification techniques. Two of these articles were written by the same leading author, Nollen, with the earlier study focused on development and testing of the intervention and the later study being a formal pilot evaluation (Nollen et al., 2013; Nollen et al., 2014). No detailed description on the use gamification techniques was provided in either of these articles, although it was implied that the intervention used some form of gamification. Baghaei and colleagues (2016) created a Mario Brothers style intervention to teach children with diabetes about how nutrition can help manage their symptoms and blood sugar. Aside from the fact that the game was modelled after Mario Brothers, minimal description of specific gamification techniques was provided, and it is unclear which features of the traditional Mario Brothers game were ultimately included. Thompson and colleagues (2015) created a game to educate children on diet, with an emphasis on increasing vegetable and fruit consumption. A detailed description of the game is provided but again there is minimal discussion of the specific gamification techniques that were incorporated.

2.8.4 Behaviour change techniques.

The majority of articles (10/14) employed one or more BCT. The most common technique was feedback as five of the studies utilized a text-based feedback intervention or included feedback as part of dietary assessment (Costello et al., 2017; de Niet et al., 2012; Pedersen et al., 2016; Woolford et al., 2011). Other techniques included goal-setting, self-monitoring of behaviour, and reinforcement. Some studies employed external behaviour change techniques that were not part of the mHealth intervention, such as a group educational nutrition session (Pedersen et al., 2016), and motivational interviewing (de Niet et al., 2012). Only one study, Costello and colleagues (2017), used the BCT taxonomy to report the specific techniques used in the intervention, the use of BCTs in other studies had to be inferred based on the descriptions of the interventions (Michie et al., 2013).

2.8.5 Impact of mHealth interventions on outcomes.

Overall findings in the literature were positive, indicating that mHealth interventions can be an effective approach to improve nutrition quality, assess diet, and provide nutrition education for children. Although some studies did not report statistically significant results, when the cost-effectiveness of mHealth interventions and the relatively new nature of the field are considered, these initial findings are very promising. Authors suggested increasing the intensity of interventions (de Niet et al., 2012), and receiving feedback from users during the development phase to increase efficacy (Nollen et al., 2013). Another study found that the effectiveness of the intervention was based on level of engagement, demonstrating that engagement or adherence to an mHealth intervention is a critical mediating factor for enhancing overall outcomes (Pedersen et al., 2016). Studies that incorporated mHealth techniques as part of an existing treatment plan for overweight and obesity found that these tools are an easy and effective complement to increase adherence, reduce drop-out rates, and improve outcomes (de Niet et al., 2012). The use of mobile devices to track diet and physical activity, a large component of many weight loss treatment plans, significantly reduced self-report error since many adolescents over-report levels of physical activity and under estimate calories consumed (Schiel et al., 2012). Although the use of mHealth interventions for education were minimal, results indicate that this type of intervention can improve nutrition knowledge (Baghaei et al., 2016; Thompson et al., 2015).

2.8.6 Summary.

This review found that many literature gaps exist in the mHealth child nutrition field with minimal work focused on nutrition education. Existing evidence is promising, especially for the integration of mHealth interventions in existing overweight and obesity treatment programs; however, more work needs to be done to prove the efficacy of mHealth nutrition education interventions. Further research should incorporate qualitative and multi-method research strategies, along with feedback from target users throughout the intervention development process, to gain understanding of what children like and respond to in mobile interventions (Nollen et al., 2013; Woolford et al., 2011). Although many studies utilized BCTs, only one article used the taxonomy to report them (Costello et al., 2017; Michie et al., 2013). Reporting of BCTs using the taxonomy should be encouraged for all behavioural interventions to increase the replicability of studies and to identify effective techniques. Better reporting of gamification should also be encouraged in order to replicate effective interventions and identify the most engaging techniques (Schmidt-Kraepelin, Thiebes, Tran, & Sunyaev, 2018). This review has only assessed mHealth interventions from peer-reviewed literature. Currently, there is no peer-reviewed literature that has assessed the quality and content of publicly available mobile nutrition apps marketed to children. Food and nutrition apps, especially those that are gamified, are common and popular in the app marketplace. It is critical that public health professionals understand the content and quality of these apps since those that are high-quality and evidence-based have the potential to be leveraged to improve food literacy.

Given the lack of food literacy skills and nutrition knowledge in the Canadian population an important gap within the literature has been identified since only two mHealth interventions targeted food literacy skills. Furthermore, there are implementation problems with making evidence-based nutrition apps available as none of the mobile interventions discussed in this literature review are available in the Canadian app marketplace. By making nutrition interventions fun and engaging through the employment of mobile technology and gamification techniques, the food literacy skills of children may be enhanced, especially if these interventions are available for free or at low-cost to the public (Tate et al., 2013).

2.9 Summary

This review has identified the main nutritional problems for Canadian youth, namely inadequate intake of vegetables and fruits, fibre, and potassium, and excessive intake of sodium, sugar, and saturated fat (Health Canada, 2012a, 2018; Jessri et al., 2016; Tugault-Lafleur & Black, 2019). Food literacy was recognised as an important individual factor influencing dietary choices since it can serve as a barrier or a facilitator for making healthy eating decisions (Ronto et al., 2016; Thomas et al., 2019) Deficits in food literacy have also been identified with a recognition that nutrition knowledge can form the basis of healthy eating practices in children and adolescents and that adolescents perceive low nutrition knowledge as a barrier to healthy eating (Ronto et al., 2016). Despite low levels of food literacy, few evidence-based interventions have utilized mobile technology to improve these skills. No study has assessed the use of a mHealth intervention in a classroom setting despite evidence that cross-curricular and experiential interventions in schools can be effective for improving nutrition knowledge (Dudley et al., 2015). These research gaps indicate the need for mHealth interventions to improve food literacy in children that are evidence-based, high-quality, and widely available to the public.

Chapter Three: Objectives

There are many challenges associated with the development of a mHealth intervention. Interventions need to be grounded in existing, evidence-based research and practices while addressing relevant health concerns for the target population. mHealth interventions face the unique challenge of competition within the endlessly evolving app marketplace. For a novel mHealth intervention to be successful it should fill a unique niche within the market to be successful against industry competitors. Since mHealth interventions have many interacting components, the methodology and rationale for their development, evaluation, and implementation should be thoroughly outlined and guided by best practice. Therefore, the current research aims to:

1. Conduct an environmental scan of the Apple App Store and Google Play Store to identify and review the content of existing nutrition apps targeted to children and adolescents.
2. Describe the interdisciplinary development process used to create a novel mHealth nutrition education intervention, Foodbot Factory, including a description of the conceptual frameworks applied and an analysis of user testing data that was collected for each iteration of the intervention.

Chapter Four: Environmental Scan of the App Marketplace

Student Contributions: The design and methodology for this study was co-developed by me and my supervisor Dr. JoAnne Arcand. Apps were extracted from the app marketplace and analyzed by me and by co-supervised undergraduate students, Amina Mahmood and Amina Siddiqi. I completed the data analysis. Independent third reviews of the data were conducted by Hannah Froome and Tayyib Khan.

This research has been presented as poster presentations at both the Canadian Nutrition Society and American Society for Nutrition 2019 conferences.

Brown, J. M., Mahmood, A., Khan, M. T., & Arcand, J. (2019). Siri, can you tell me how to eat healthy? An analysis of nutrition content, behaviour change techniques and gamification used in mobile apps for children. *Applied Physiology, Nutrition, and Metabolism, 44*, S1-S54. doi:10.1139/apnm-2019-0152

Brown, J., Siddiqi, A., Froome, H., & Arcand, J. (2019). What's Cooking? A Content and Quality Analysis of Food Preparation Mobile Applications (P16-050-19). *Current Developments in Nutrition, 3*(Supplement_1). doi:10.1093/cdn/nzz050.P16-050-19

4.1 Introduction

Nutrition is a critical component of health and wellness across the lifespan. High-quality diets promote the healthy growth, development, and academic achievement of children (Basch, 2011; Haapala et al., 2015). Healthy diets during the developmental period also prevent the onset of non-communicable diseases that are associated with significant morbidity and mortality later in life, such as hypertension and type 2 diabetes (World Health Organization, 2013). In Canada, children under consume foods that are beneficial for their health such as vegetables and fruits, whole grain foods, and legumes, nuts, and seeds; they also consume too many high fat and/or high-sugar foods (Afshin et al., 2019; Tugault-Lafleur & Black, 2019). Since health behaviours, including dietary intake patterns, are often established in childhood and track into adulthood, early interventions to optimize the adoption of health-promoting behaviours among children are critical for preventing the development of non-communicable diseases in adulthood (Craigie et al., 2011).

Using mobile technology to deliver health interventions, known as mobile health (mHealth), is a promising way to engage children in dietary and nutrition education interventions. Access to mobile devices has increased rapidly with approximately 90% of the global population expected to own smartphones by 2020 (Carroll et al., 2017). In Canada, access to mobile devices in schools is also increasing, with 96% of students in Ontario being able to access technology in the classroom (Howell et al., 2017). Compared to traditional interventions, mHealth interventions are often more accessible because they are lower in cost and have additional opportunities to embed gamification and behaviour change techniques (BCTs) that enhance engagement and uptake of the intervention (Schoffman, Turner-McGrievy, Jones, & Wilcox, 2013; Tate et al., 2013). Furthermore, research has demonstrated an association between the use of gamification and positive outcomes for mHealth interventions (Edwards et al., 2016; Johnson et al., 2016; Schmidt-Kraepelin et al., 2018).

The two largest online app retailers are the Apple App Store and Google Play Store, representing the largest share of the app marketplace with each store containing millions of apps and thousands of individual users downloading new apps each day (Statista, 2018). Minimal information on the amount, quality, and content of existing marketplace apps is made available to the public, making it difficult to identify gaps and opportunities for new mHealth interventions. Despite the rise in mHealth nutrition apps, to date there are no known analyses of nutrition apps targeted children in the marketplace. Therefore, the objective of this study is to systematically identify and review mobile apps in the Apple App and Google Play Stores that focus on nutrition and are developed for children. This study will address the research question: what is the nutrition content and use of evidence-based engagement techniques in child nutrition mobile apps? Specific aims were to i) Summarize the core topics and content covered by apps developed for children that focus on nutrition; ii) Determine the proportion of nutrition apps that have incorporated BCTs and describe which BCTs were used; iii) Determine the proportion of nutrition apps that have used gamification techniques and describe which gamification techniques were used; and, iv) Determine the nutrition content and overall quality of a sub-set of identified "food prep" apps. Food prep apps required the user to cook, prepare, bake, and/or decorate virtual food items and contained the same BCTs and use of gamification, therefore, these apps were analyzed separately. It was hypothesized that on average nutrition apps targeted to children would not align well with existing dietary recommendations and make minimal use of evidence-based BCTs and gamification, approaches known to enhance engagement with mHealth interventions (Edwards et al., 2016).

4.2 Methods

This study was a cross-sectional environmental scan employing a systematic search strategy and standardized appraisal processes among mobile apps identified in the two most popular online app retailers, the Apple App Store and Google Play Store. Included apps contained nutrition content relevant for children, were appropriate for an audience <12 years of age, in English, accessible to any user, not affiliated with a brand or product, and updated in the past two years. Excluded apps included those where nutrition and food content is not relevant to dietary behaviours or education, e.g., restaurant time management games, food colouring books, word searches, recipe apps. Simple food tracking apps and those focused on chronic disease management were also excluded. During the search two types of apps were identified. The first were general child nutrition apps and outcome measures analyzed were the food and nutrition content based on food categories and key messages from the 2007 Canada's Food Guide (CFG), BCTs defined in the Behaviour Change Technique Taxonomy v1, and gamification techniques as outlined in the Taxonomy of Gamification Concepts for Health Apps (Health Canada, 2011; Michie et al., 2013; Schmidt-Kraepelin et al., 2018). The second type of apps identified were food prep apps and outcome measures assessed were food and nutrition content based on food categories and key messages from the 2007 CFG, and overall quality measured by the MARS - Mobile Application Rating Scale (Health Canada, 2011; Stoyanov et al., 2015).

4.2.1 Search Strategy.

In an app marketplace that is constantly changing, we employed a systematic search strategy to identify all relevant existing applications available on the app marketplace in May 2018 that provide nutrition content to children and adolescents. The search strategy methodology used in this study has been adapted from successful systematic searches conducted by Blàzquez Martin and colleagues (2018) and de la Vega & Miro (2014) which both used multiple keywords and terms to conduct their searches.

A search of all categories in the Canadian Apple App and Google Play Stores was conducted using 16 different search terms relating to childhood, nutrition, games, and education. Data extracted during the initial search were the app title, developer, and cost for each result. Apps were then subjected to two exclusion rounds before data collection.

4.2.2 Screening.

In a first round of screening, app titles and developers were evaluated which allowed for the removal of apps without nutrition content or those that were not relevant for children (i.e., a focus on sleep or physical activity, product promotions, etc.). App titles and developers were assessed by two independent reviewers. All reviewers met to discuss the exclusion criteria prior to review and any disagreements were resolved by a third independent reviewer.

In the second round of screening the detailed descriptions of the apps in the App Store and Play Store were assessed. Apps to be included for analysis met the inclusion and exclusion criteria shown in Table 4-1. These apps were independently assessed by two reviewers and disagreements were resolved by a third independent reviewer.

Inclusion Criteria	Exclusion Criteria

The app is not affiliated with a service provider or product	Service provider/retailer app
Information is relevant for children	Information not relevant for children
App contains content related to nutrition	No nutrition content
App is of an appropriate age rating for children	12+ or 17+ age rating in App Store Teen or Mature Rating in Play Store
App can be used by anyone, without referral	Specified population or user, e.g., app that you can only use with referral from a doctor
The nutrition content of the app goes beyond that of a simple diet record	Simple diet tracker, i.e., app contains no nutrition content beyond diet records
Nutrition and food content is relevant for children's dietary behaviours and/or nutrition education	Nutrition and food content is not relevant to dietary behaviours or education, e.g., restaurant time management games, food colouring books and word searches, recipe apps
The app has been updated or released within the last two years	No update after January 2016
App is in English	App is in a language other than English
	Other reasons for exclusion: removal from app marketplace, technical errors

Table 4-1: *Inclusion and exclusion criteria*

4.2.3 Nutrition apps outcome classification & assessment

The nutrition content and use of BCTs and gamification were assessed for general child nutrition apps. Nutrition content of apps was assessed by evaluating the presence or absence of foods using categories and key messages provided by CFG (Health Canada, 2011).

The Behaviour Change Technique Taxonomy v1 (Appendix A) developed in 2013 by a team of behaviour change experts consists of 93 hierarchically clustered techniques that are proven to elicit behaviour change in an individual (Michie et al., 2013). All reviewers were trained and certified in the Behaviour Change Taxonomy prior to conducting the analysis (University College London Centre for Behaviour Change, 2019).

Apps were also reviewed for the implementation of gamification techniques using the Taxonomy of Gamification Concepts for Health Apps (Schmidt-Kraepelin et al., 2018). This taxonomy was created in response to the growing use of gamification techniques in health interventions to help identify effective single game elements and their combinations. Currently, there is no training available for researchers in the Taxonomy of Gamification Concepts for Health Apps; therefore, all reviewers met and discussed the defined concepts to ensure a shared understanding for how the taxonomy would be used and interpreted.

4.2.4 Food prep apps outcome classification and assessment.

All food prep apps identified were gamified and contained similar BCTs, therefore these outcomes were not classified. Nutrition content was classified in the same way as the general child nutrition apps using categories from CFG (Health Canada, 2011). Additional analysis of the overall quality of food prep apps was conducted using the MARS scale, developed by Stoyanov and colleagues (2015) which assesses the quality of mHealth apps on four sub-scales of engagement, functionality, aesthetics, and information using a 5-point Likert scale from 1-5 with high scores indicating higher quality (Appendix C).

4.2.5 Data analysis.

Continuous data were analyzed and presented as means and standard deviations. Categorical data were analyzed and presented as frequencies and percentages. Between group comparisons for continuous data were conducted using unpaired t-tests and χ^2 tests were conducted for categorical data with a p-value of 0.05 considered significant. Since there is no publicly available data on the effectiveness or efficacy of each app to either incite behaviour change or educate children on nutrition, this analysis is primarily descriptive in nature.

4.3 Results

The cross-sectional systematic environmental scan search yielded 2,575 unique apps after merging the App Store and Play Store searches and removing duplicates. In Round 1 screening 1,368 apps were removed leaving n = 1,203 apps for Round 2 screening (inter-rater agreement = 64%). A total of 944 apps were excluded in Round 2 leaving n = 259 apps for data collection and analysis (inter-rater agreement = 94.3%). In total there were n = 125 general child nutrition apps and n = 134 food prep apps (Figure 4-1). Due to the dynamic nature of the app marketplace, 53 apps were evaluated by one reviewer as apps were removed from the marketplace during data collection. For apps that were evaluated by both reviewers (n = 269; 80.6%), inter-rater agreement was 93.2%.

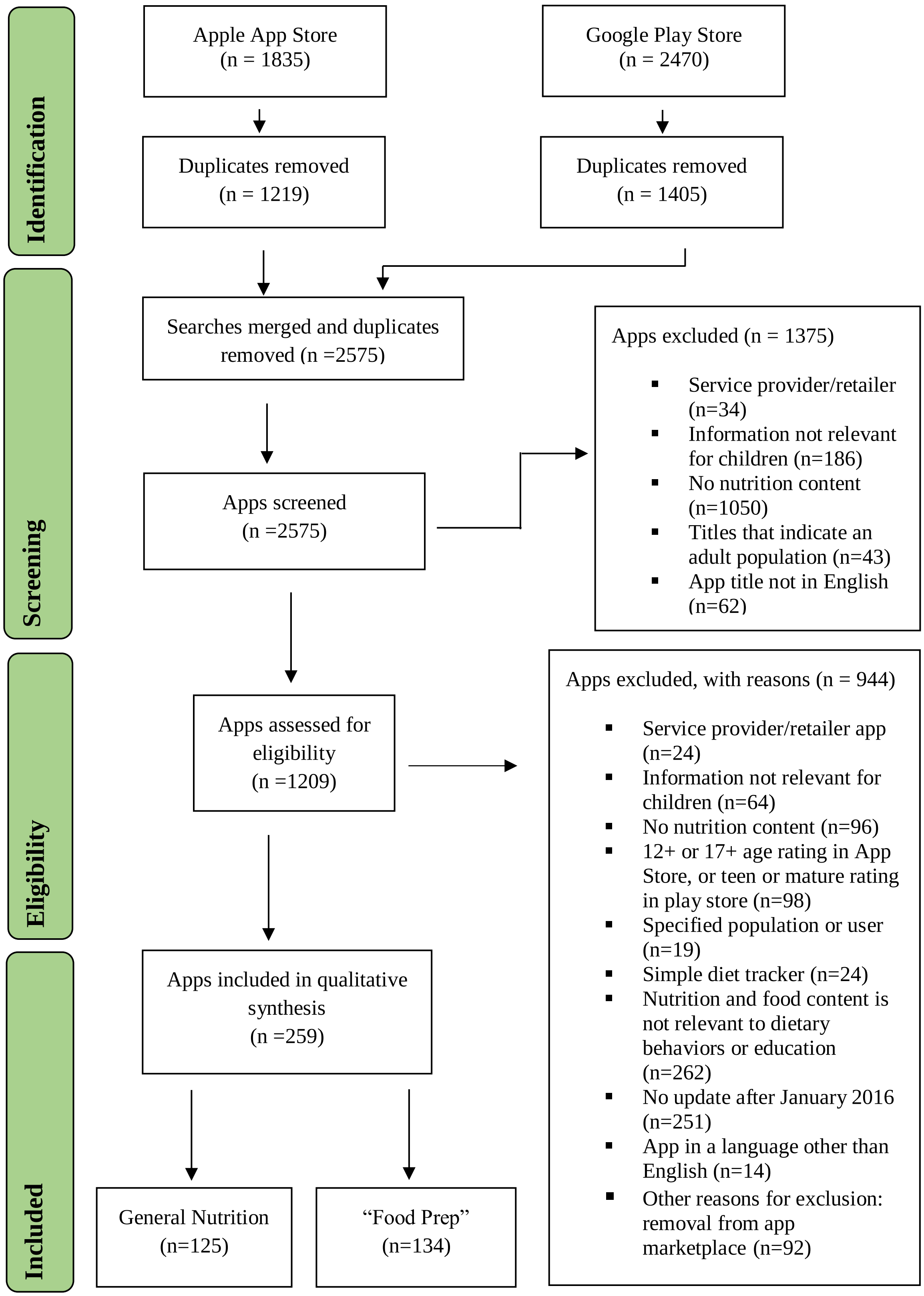

Figure 4-1: *Environmental scan flowchart*

4.3.1 Nutrition apps.

The majority of nutrition apps identified were categorized as didactic nutrition information apps (56.8%), wherein the app provides basic information on various nutrition topics. The rest of the apps were categorized as food games (21.6%), habit trackers (14.4%), other (4.8%), and food quizzes (2.4%; Figure 4-2). The majority of apps showed foods that are recommended by current dietary guidelines, with the most prevalent food items being vegetables (93.6%), fruits (92.0%), lean meats (78.4%), and milk products (72.0%). Foods that are not recommended by dietary guidelines, such as fast foods (24.0%), sugar sweetened-beverages (SSBs; 26.4%), and processed meats (28.0%), were not shown frequently in these apps (Figure 4-3 and Table 4-2). Fifty-six percent of apps explicitly included healthy eating messages.

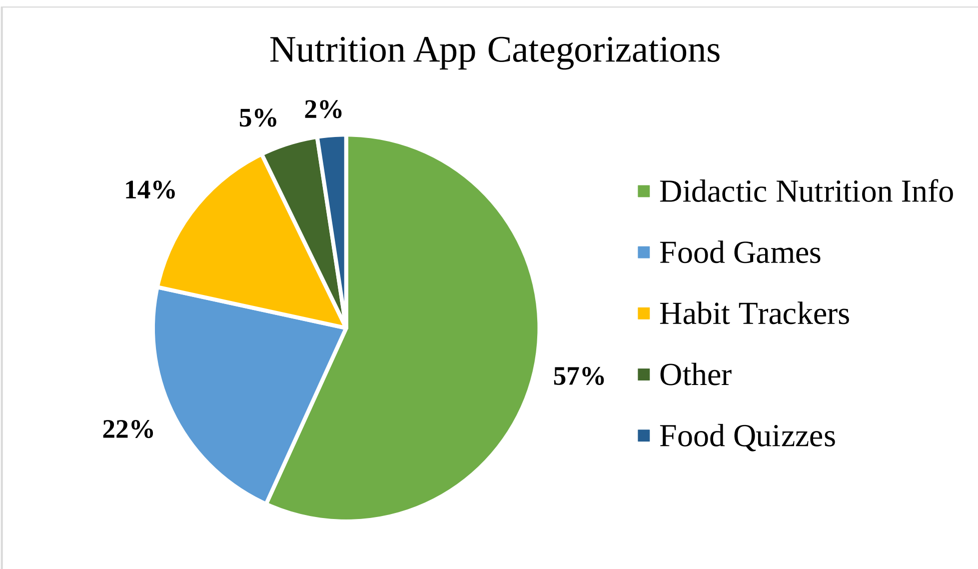

Figure 4-2: *Nutrition app categorizations*

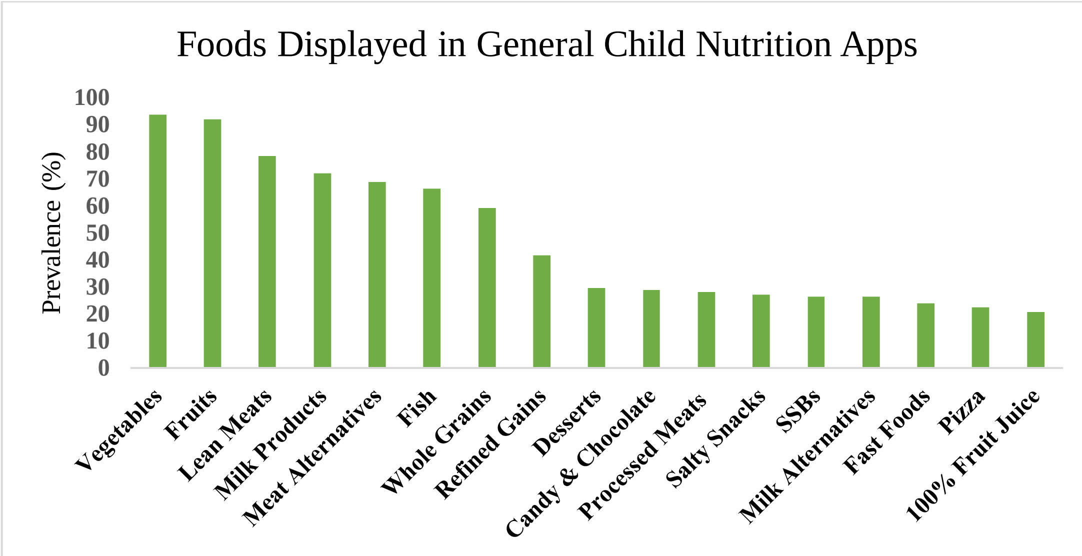

Figure 4-3: *Foods displayed in general child nutrition apps*

Food Displayed	General Child Nutrition Apps n(%)	Food Prep Apps n(%)
Vegetables	117 (93.6%)	62 (46.3%)
Fruits	115 (92.0%)	85 (63.4%)
Lean Meats	98 (78.4%)	77 (57.5%)
Milk Products	90 (72.0%	95 (70.9%)
Meat Alternatives	89 (68.8%)	21 (15.7%)
Fish	83 (66.4%)	21 (15.7%)
Whole Grains	74 (59.2%)	7 (5.2%)
Refined Grains	52 (41.6%)	99 (73.9%)
Baked Desserts and Pastries	37 (39.6%)	65 (48.5%)
Ice Cream, Candy, and Chocolate	36 (28.0%)	96 (71.6%)
Processed Meats	35 (28.0%)	46 (34.3%)
Salty Snacks	34 (27.2%)	26 (19.4%)
Sugar Sweetened Beverages	33 (26.4%)	50 (37.3%)
Milk Alternatives	33 (26.4%)	5 (3.7%)
Fast Foods	30 (24.0%)	27 (20.1%)
Pizza	28 (22.4%)	23 (17.2%)
100% Fruit Juice	26 (20.8%)	2 (1.5%)

Table 4-2: *Foods displayed in general child nutrition and food prep apps*

The use of BCTs in child nutrition apps was minimal with apps only implementing a mean of 2.2 $\pm$ 2.6 techniques; 15.2% of apps did not implement any BCTs. Of the 93 techniques identified in the BCT taxonomy only 24 were utilized across all apps, representing 10 of the 16 hierarchical categories (Figure 4-4 and Table 4-3). The most popular BCTs utilized were information about health consequences (73.6%), instruction on how to perform a behaviour (38.4%), and behavioural goal setting (13.6%).

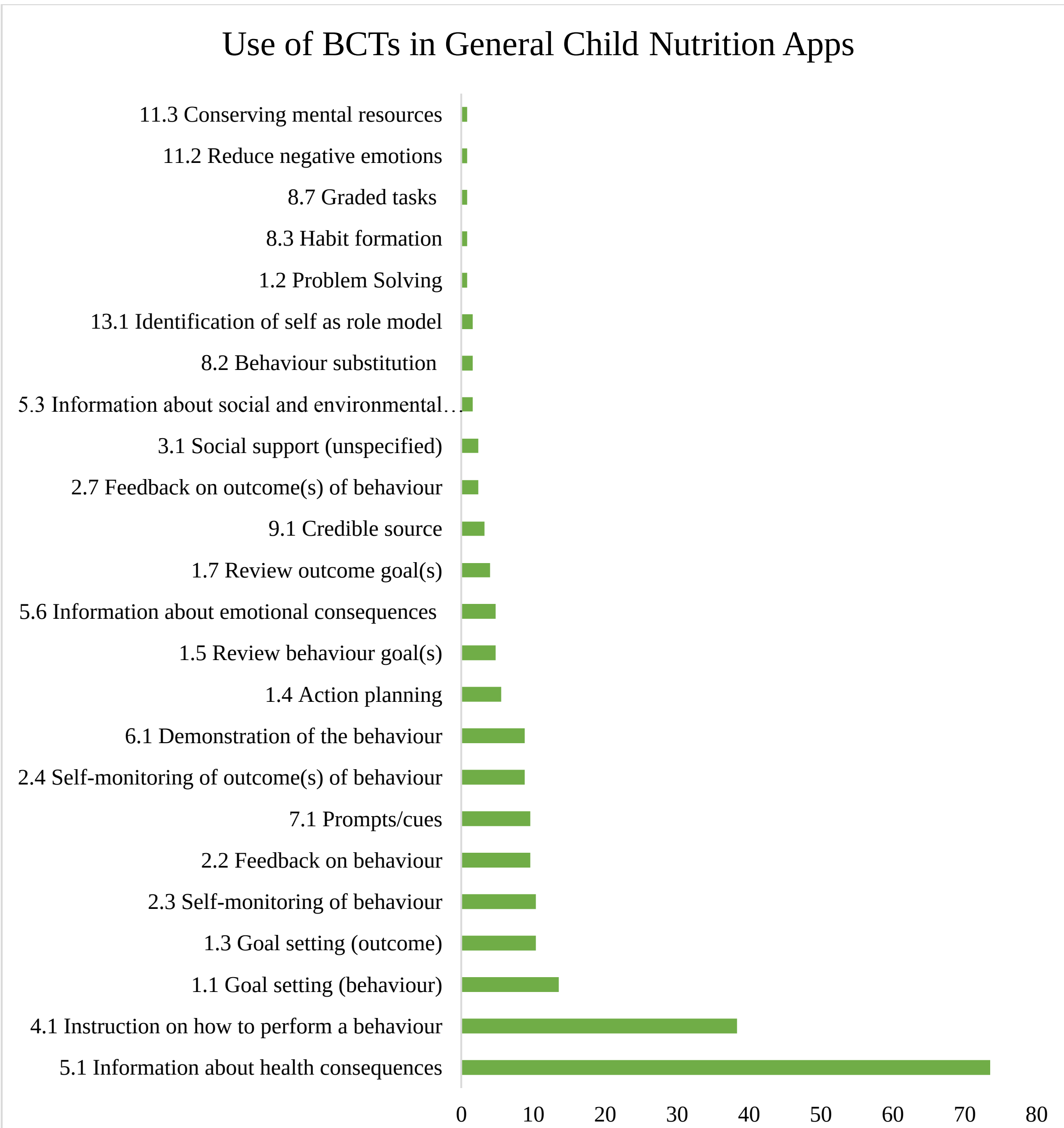

Figure 4-4: *Use of BCTs in general child nutrition apps*

BCT	Prevalence n (%)
1.1 Goal setting (behaviour)	17 (13.6%)
1.2 Problem solving	1 (0.8%)
1.3 Goal setting (outcome)	13 (10.4%)
1.4 Action planning	7 (5.6%)
1.5 Review behaviour goal(s)	6 (4.8%)
1.7 Review outcome goal(s)	5 (4.0%)
2.2 Feedback on behaviour	12 (9.6%)
2.3 Self-monitoring of behaviour	13 (10.4%)
2.4 Self-monitoring of outcome(s) of behaviour	11 (8.8%)
2.7 Feedback on outcome(s) of behaviour	3 (2.4%)
3.1 Social support (unspecified)	3 (2.4%)
4.1 Instruction on how to perform a behaviour	48 (38.4%)
5.1 Information about health consequences	92 (73.6%)
5.3 Information about social and environmental consequences	2 (1.6%)
5.6 Information about emotional consequences	6 (4.8%)
6.1 Demonstration of the behaviour	11 (8.8%)
7.1 Prompts/cues	12 (9.6%)
8.2 Behaviour substitution	2 (1.6%)
8.3 Habit formation	1 (0.8%)
8.7 Graded tasks	1 (0.8%)
9.1 Credible source	4 (3.2%)
11.2 Reduce negative emotions	1 (0.8%)
11.3 Conserving mental resources	1 (0.8%)
13.1 Identification of self as role model	2 (1.6%)

Table 4-3: *Use of BCTs in general child nutrition apps by app type*

Only 25% (n = 32) of apps utilized gamification techniques, the prevalence of the techniques that were utilized, as defined by the Gamification Taxonomy for Health Apps, is detailed in Table 4-4 (Schmidt-Kraepelin et al., 2018). The taxonomy has been slightly modified on the dimensions of user identity and persuasive intent; many apps did not have these components so a “no” option was added. The dimension of target group was also modified as all apps for health professionals were eliminated for the purpose of this review. The majority of apps were targeted to healthy individuals (96.9%) and the health behaviours within the games were usually independent of the gamification techniques implemented (90.6%). Most apps did not make use of collaboration (100%), competition (100%), goal setting (84.4%), user identity (78.1%), or rewards (56.2%). A total of 72 apps were available in the Google Play Store and estimates provided on downloads indicate that these apps have received an estimated average of $3.4M \pm 9.8M$ downloads each.

Dimension	n (%)
Gamification concept – to user communication	
Direct	6 (18.8%)
Mediated	26 (81.2%)
User Identity	
Virtual Character	3 (9.4%)
Self – Selected	4 (12.5%)
None	25 (78.1%)
Rewards	
Internal	14 (43.8.%)
Internal and External	0 (0%)
No	18 (56.2%)
Competition	
Direct	0 (0%)
Indirect	0 (0%)
No	32 (100%)
Target Group	
Patients	1 (3.1%)
Healthy Individuals	31 (96.9%)
Collaboration	
Cooperative	0 (0%)
Supportive only	0 (0%)
No	32 (100%)
Goal-Setting	
Self-set	0%
Externally-set	5 (15.6%)
No	27 (84.4%)
Narrative	
Continuous	7 (21.9%)
Episodical	25 (78.1%)
Reinforcement	

Positive	14 (43.8%)
Positive-Negative	18 (56.2%)
Level of Integration	
Independent	29 (90.6%)
Inherent	3 (9.4%)
Persuasive Intent	
Compliance change	1 (3.1%)
Behavior change	9 (28.1%)
Attitude change	1 (3.1%)
None	21 (67.7%)
User Advancement	
Presentation only	13 (40.6%)
Progressive	9 (28.1%)
No	10 (31.3%)

Table 4-4: *Use of gamification techniques in general child nutrition apps*

When comparing the nutrition content of gamified and non-gamified apps, gamified apps were significantly more likely to show high-sodium foods, defined as processed meats, pizza, salty snacks, and fast foods (56.2% vs. 28.0%; p = 0.004). Gamified apps were also more likely to display high-sugar foods, defined as desserts, chocolates/candies, and sugar-sweetened beverages, although this difference was not statistically significant (50.0% vs. 33.3%; p = 0.09). Gamified apps implemented a mean of 1.1 ± 1.2 BCTs, significantly less than the mean of 2.6 ± 2.9 BCTs implemented in non-gamified apps (p = 0.005).

4.3.2 Food prep apps.

Among food prep apps the most prevalent food items displayed in these apps were refined grain foods (73.9%), ice cream, chocolate, and candy (71.6%), and milk products (70.1%). The least prevalent food items displayed were whole grain foods (5.2%), milk alternatives (3.7%), and 100% fruit juice (1.5%; Figure 4-5 and Table 4-3). The prevalence of high-sugar foods (87.3%) was higher than that of high-sodium foods

(43.3%). The prevalence of fruits in food prep apps was high at 63.4%, however, fruits were often shown in the context of high-sugar foods; of the apps that displayed fruits (n = 85), only 9.4% featured fruits alone, with all remaining apps showing fruits in conjunction with high-sugar foods. Only 4.7% of food prep apps implemented healthy eating messages.

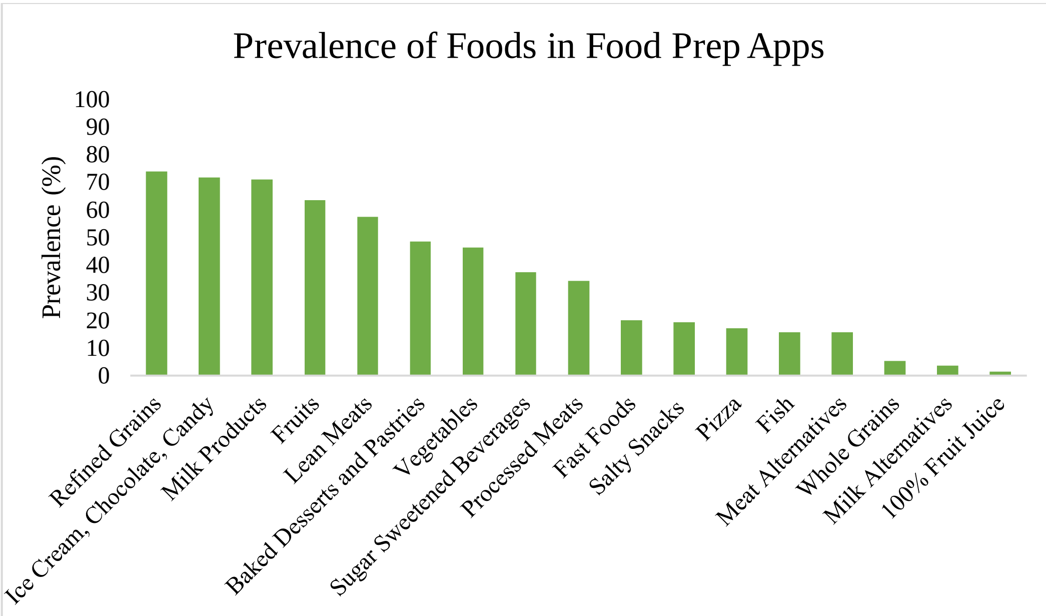

Figure 4-5: *Prevalence of foods in food prep apps*

App quality, as assessed by the MARS scale, indicated that the apps were slightly above average with a mean score of 3.5/5 overall. The mean for each subscale of the MARS was also average or slightly above average, with the highest quality subscale being Functionality at 3.9 $\pm$ 0.38, followed by Aesthetics at 3.7 $\pm$ 0.56, Information at 3.5 $\pm$ 0.85, and Engagement at 3.1 $\pm$ 0.53. Although the Information subscale mean was above average at 3.5, this average is likely inflated as many apps were only scored on one of the categories, the accuracy of their description in the app marketplace. The majority of apps did not contain goals (99.3%) or health information (97%) resulting in N/A scores for these categories in the Information subscale, which are not included in the subscale average. Furthermore, none of the food prep apps were trialed or tested in scientific literature, nor did any app come from a credible source such as the government, a non-governmental organization, or a university. Means for each category in the MARS can be viewed in Table 4-5. A total of 62 apps were available in the Google Play Store and estimates provided on downloads indicate that these apps have received an estimated average of $7.6M \pm 17.6M$ downloads each.

Category	Mean MARS Score
Entertainment	2.7 ± 1.0
Interest	3.1 ± 0.8
Customization	3.0 ± 0.6
Interactivity	3.1 ± 0.5
Target Group	3.8 ± 0.5
Performance	3.8 ± 0.6
Ease of Use	3.9 ± 0.4
Navigation	4.0 ± 0.4
Gestural Design	3.8 ± 0.5
Layout	3.9 ± 0.4
Graphics	3.6 ± 0.7
Visual Appeal	3.6 ± 0.7
Accuracy of App Description	3.9 ± 0.5
Goals	2 ± 0.0
Quality of Information	2.8 ± 0.5
Quantity of Information	2.3 ± 0.5
Visual Information	2.3 ± 0.6
Credibility	1 ± 0.0
Evidence-Based	N/A

Table 4-5: *Mean MARS category scores*

4.4 Discussion

This systematic environmental scan has identified publicly available apps in the Apple App and Google Play Stores that are targeted to children and contain nutrition content. From this scan, general child nutrition and food prep apps were identified and analyzed for their nutrition content using categories from the 2007 CFG (Health Canada, 2011). The use of BCTs and gamification in general child nutrition apps was also analyzed, and the overall quality of food prep apps was analyzed using the MARS scale (Michie et al., 2013; Schmidt-Kraepelin et al., 2018; Stoyanov et al., 2015).

Contrary to the initial hypothesis, general child nutrition apps frequently displayed foods that are recommended by dietary guidelines, such as vegetables (93.6%), fruits (92.0%), lean meats (78.4%), and whole grain foods (59.2%). Use of BCTs in general child nutrition apps was minimal with the average app implementing 2.2 techniques, lower than previous findings on the use of BCTs in health apps (Edwards et al., 2016). Only 25% of apps were gamified and gamified apps were significantly more likely to display high-sodium foods compared to non-gamified apps ($p = 0.004$). The low implementation of both BCTs and gamification aligned with the hypothesis that apps would make minimal use of these techniques.

Food prep apps displayed foods recommended by dietary guidelines like vegetables (46.2%), fruits (63.4%), lean meats (57.5%), and whole grain foods (5.2%) less frequently than general child nutrition apps. This subset of gamified apps frequently displayed high sugar (87.3%) and high sodium foods (43.3%) with only 4.7% of apps implementing healthy eating messages. Food prep apps were slightly above average in quality with a mean score of 3.5/5 as rated by the MARS scale, indicating that significantly more development effort has been placed into creating functional and aesthetically pleasing food prep apps, rather than ones that are evidence-based and aligned with dietary guidelines.

These results indicate that there is ample room for improvement in child nutrition apps for all of the factors that were assessed. The nutrition content of gamified apps is particularly troubling as they are significantly more likely to display foods that are not recommended by dietary guidelines compared to non-gamified apps. Furthermore, very few food prep apps included healthy eating messages, which have the potential to enhance the user's knowledge of healthy eating concepts, such as balance and variety, regardless of what food items are displayed. Future apps should aim to include a variety of foods, including ones that are recommended by dietary guidelines, and healthy eating messages to engage the user in a dialogue on what a high-quality diet looks like.

BCTs should also be better incorporated in nutrition mHealth apps as their use may better engage the child user and help them in achieving their health goals. Further research is warranted to better understand which combinations of BCTs are best utilized in nutrition health apps for children (Edwards et al., 2016). Only 25% of general child nutrition apps were gamified and these apps made minimal use of techniques such as collaboration, competition, and rewards, indicating that even when apps utilize gamification to enhance engagement, they are not implementing the breadth of available techniques. Developers should make use of the variety of evidence-based techniques that are available to enhance engagement and work to align the content of their apps with dietary guidelines.

A limitation to this study is that a search of this kind cannot be truly systematic due to the dynamic nature of the app marketplace and limited search and data extraction abilities (Bender, Yue, To, Deacken, & Jadad, 2013; de la Vega & Miro, 2014). However, the use of multiple search terms to identify child nutrition apps allowed this search to reach saturation and capture the most common child nutrition apps. Analysis was conducted by two reviewers with a third independent reviewer to resolve disagreements, ensuring rigorous data collection. Although paid apps were included in this study when free apps contained in-app purchases only the free content was analyzed as the use of in-app purchases is likely to be less accessible to our target audience of children and adolescents. This may have resulted in a slight underestimation of the use of BCTs in this set of mHealth apps as previous research has found that paid apps use slightly more BCTs compared to free apps and this finding may also apply to in-app purchases (Direito et al., 2014).

In summary, this research demonstrates that existing child nutrition apps do not make significant use of evidence-based techniques. Although general child nutrition apps frequently displayed foods recommended by dietary guidelines, food prep apps, which are more popular, did not. Given the popularity of these apps it is necessary for health care professionals and researchers to create and develop evidence-based child nutrition apps to ensure children have access to appropriate resources to help them improve their diet quality and food literacy skills. Nutrition and public health experts should be encouraged to collaborate with app developers to align the content of child nutrition apps with existing dietary guidelines. Future apps should aim to incorporate BCTs and gamification to enhance user engagement and provide children with fun and exciting resources that they can use to learn about healthy eating and nutrition.

Chapter Five: Development and Pre-Efficacy Testing of Foodbot Factory: A Nutrition Education mHealth Intervention

Student's Contributions: The development and evaluation of Foodbot Factory has been the central component of my MHSc thesis work. As part of this project, I was the student lead and project manager for an interdisciplinary team of dietitians, game developers, computer scientists, and educators. Foodbot Factory team members were Dr. JoAnne Arcand, Dr. Bill Kapralos, Dr. Ann LeSage, Robert Savaglio, Graham Watson, Campbell Hamilton, and Alain Sangalang. The concept for Foodbot Factory was co-developed by the entire team and the content was written by me, Rob Savaglio, and Dr. Arcand. The user testing methodology and questionnaires were developed and/or adapted by me and the team's creative app development lead, Rob. Data collection at user testing sessions was conducted by me, Rob, and Graham. I entered, analyzed and synthesized the data. In total, we conducted five iterative user testing sessions between March and December 2018, within classrooms of a local school board and at the Ontario Tech University summer camps.

This research has been presented orally at the Canadian Nutrition Society and the Canadian Obesity Summit. The presentation at the Canadian Obesity Summit was selected for the 2019 Oral Master's Presentation Award. The abstract submitted to the Canadian Nutrition Society was ranked among the top eight of all student abstract submissions and was awarded the George Beaton Award for Student Work in Public Health Nutrition.

Brown, J. M., Savaglio, R., Watson, G., Kapralos, B., & Arcand, J. (2019). *Developing Foodbot Factory: A case study on the importance of iterative development and usability testing for mHealth interventions*. Paper presented at the Canadian Obesity Summit, Ottawa, ON, Canada.

Brown, J. M., Savaglio, R., Watson, G., Kaplansky, A., LeSage, A., Kapralos, B., & Arcand, J. (2019). The making of Foodbot Factory: An evidence-based mHealth nutrition education app for children. *Applied Physiology, Nutrition, and Metabolism, 44,* S1-S54. doi:10.1139/apnm-2019-0152

5.1 Introduction

Poor diet quality is one of the leading risk factors for chronic disease development. Global Burden of Disease investigators have reported that morbidity and mortality risk from a low-quality diet now surpasses the risk associated with tobacco exposure. High intakes of sodium, and low intakes of whole grains, fruits and vegetables, were identified as the greatest dietary risk factors (Afshin et al., 2019). In Canada, up to 92% of children consume sodium in excess of the recommended level and the average child does not meet recommended servings for both whole grains and vegetables & fruits (Health Canada, 2018; Tugault-Lafleur & Black, 2019). These dietary risk factors are extremely relevant for children as they require high quality diets for growth, development, and academic success (Basch, 2011). Healthy eating behaviours are established during childhood, therefore, it is important to promote optimal adoption of healthy eating habits early in life that will continue into adulthood (Craigie et al., 2011).

Mobile health (mHealth) is a promising way to deliver innovative nutrition interventions and information to children to improve food literacy and enhance their overall diet. In Canada, children and adolescents have access to mobile devices at home and school. Recent estimates indicate that 47% of children aged 0-11 and 80% of teens aged 12-17 in Canada own a mobile device (eMarketer, 2016). This suggests that mHealth apps are accessible to this population, particularly when they are available for free (Tate et al., 2013). Despite the popularity of mobile devices, very few evidence-based mHealth nutrition apps for children exist (Brown, Mahmood, Khan, & Arcand, 2019). Furthermore, no app exists that can be integrated into the classroom setting to support educators in facilitating nutrition education (Dudley et al., 2015). The aim of this paper is to report on the iterative design, development, and testing of a mHealth nutrition app, *Foodbot Factory*. The app was designed to be used at home and in school to teach children about healthy eating and nutrition. *Foodbot Factory* is a mHealth app developed by an interdisciplinary team of health researchers, dietitians, educators, computer scientists, and game developers for children aged 9-12. The overarching research question driving the development and evaluation of *Foodbot Factory* has been: can a mobile health app improve children's food literacy and nutrition knowledge?

5.2 Methods

The app development and testing methodologies were guided by the Obesity-Related Behavioural Intervention Trials (ORBIT) model for developing behavioural interventions for the prevention and management of chronic diseases (Czajkowski et al., 2015). App development also followed the Integrate, DEsign, Assess, and Share (IDEAS) framework to direct the iterative development process for mHealth apps (Mummah, Robinson, King, Gardner, & Sutton, 2016). While the ORBIT model guided the design and evaluation of *Foodbot Factory*, the IDEAS framework provided more specific direction on the iterative development and testing. The IDEAS framework complements the ORBIT model by adding depth related to specific considerations for mHealth apps.

The ORBIT model focuses specifically on behaviour change for chronic illnesses (Czajkowski et al., 2015), including the development and pre-efficacy testing process for health interventions (Figure 5-1). This model is useful for complex intervention development as goals and milestones are established for each phase, and it encourages developers to revisit previous phases to improve the intervention based on new evidence. The ORBIT model promotes the integration of behavioural and social sciences research by requiring the design research phase to be informed by the latest research, ensuring that high-quality evidence is incorporated into the intervention. This research presents the development and evaluation of *Foodbot Factory* over three phases of the ORBIT model: *Discovery, Phase Ia: Define,* and *Phase Ib: Refine* (Czajkowski et al., 2015).

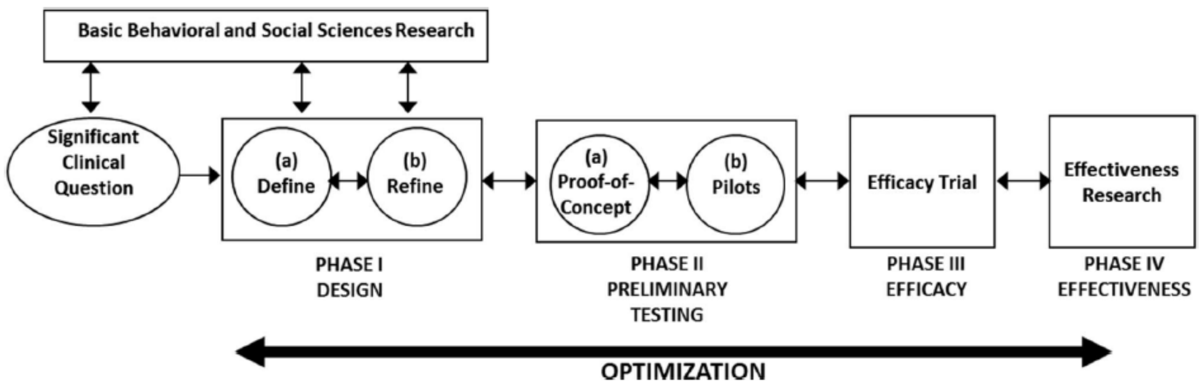

Figure 5-1: *ORBIT model (Czajkowski et al., 2015)*

5.2.1 Discovery

The *Discovery* phase of the ORBIT model is characterized by defining a "Significant Clinical Question", or in the case of this research, a Significant "Educational" Question (Czajkowski et al., 2015). The purpose of this phase is to define the central research questions and identify educational and behavioural strategies that provide effective and engaging nutrition education to children. This phase of development involved background research in behavioural sciences, educational pedagogy, mHealth app development, and nutritional sciences to identify important points for intervention and effective methods and techniques for delivery. An environmental scan of existing mHealth resources was conducted to form a baseline understanding of the learning tools available to children and teachers for nutrition education (Brown, Mahmood, et al., 2019).

5.2.2 Phase Ia: Define.

The overall goal of *Phase I: Design* is to identify the essential features of an intervention, which includes identifying the goals and structure and “tinkering” with the intervention to refine and improve upon it (Czajkowski et al., 2015). This phase required insights from the target audience, alignment with behavioural theory, and iterative development and testing of the app. As part of *Phase Ia: Define,* key stakeholders were consulted via an online survey to identify a priority age group and the nutrition content. Consultation enabled researchers to identify the needs of the target audience and isolate detailed, strategic learning objectives.

For the *Define* phase of the ORBIT model three key content components, nutrition content, gamification, and behaviour change techniques (BCTs), were outlined based on research conducted in the *Discovery* phase and feedback received from stakeholders (Czajkowski et al., 2015). The first component to define were the learning objectives and specific nutrition content included in the app. This was important, as there are many components of food literacy that could be addressed in a nutrition app (Thomas et al., 2019). Based on best practices gleaned from the literature review, it was decided that the second component included in *Foodbot Factory* would be gamification (the application of game design elements to engage and motivate users) to promote continuous engagement with the app (Johnson et al., 2016; Zichermann & Cunningham, 2011). Also based on the literature, the third component included were BCTs or “the observable, replicable, and irreducible components of an intervention designed to alter or redirect causal processes that regulate behavior” (Michie et al., 2013). Included BCTs were hypothesized to effectively improve knowledge gained through interacting with the app.

5.2.3 Phase Ib: Refine.

The purpose of *Phase Ib: Refine*, is to ensure that an intervention is strong and efficient. This was addressed by using a quasi-experimental convergent mixed-method design to collect user feedback while building and testing each iteration of *Foodbot Factory* (Alwashmi, Hawboldt, Davis, & Fetters, 2019; Czajkowski et al., 2015). The *Refine* phase utilized iterative user testing sessions with the target audience (Grade 4-6 students) in a classroom setting. The participants were recruited through established partnerships with the Durham Catholic District School Board and Ontario Tech University summer camps.

Throughout the iterative development process *Foodbot Factory* moved between *Phases Ia* and *Ib* with each iteration of the app. This required meeting milestone markers related to identifying how the app could promote learning and behaviour change and specifying the components that were doing so. As various aspects of *Foodbot Factory* were defined in *Phase Ia*, they were tested and refined through *Phase Ib,* user testing, and certain components of the app would subsequently be improved.

The user testing sessions assessed four metrics important for the success of *Foodbot Factory*: satisfaction, engagement, knowledge, and usability. Satisfaction refers to the user's subjective experience with *Foodbot Factory,* and the appropriateness and suitability of the platform and content for the target audience. Engagement refers to how the target audience interacted with the intervention, (i.e., found the app enjoyable, and want to play again). Knowledge refers to how well *Foodbot Factory* supported the target audience's acquisition of new knowledge about healthy eating. Usability refers to the technical aspects of the app, (i.e., easy to use, easy to navigate, and clear presentation of content).

To assess these metrics, user testing sessions collected three types of data through observation, qualitative interviews, and quantitative questionnaires. During gameplay, students were observed by game developers who collected information with a semi-structured form evaluating how the student engaged with the app and if they encountered any usability problems. Qualitative interviews consisted of 4-5 open-ended questions, designed to assess satisfaction and knowledge gained from playing *Foodbot Factory*. Interviews were conducted one-on-one with students after gameplay. The open-ended questions varied depending on which module students tested since a minimum of two questions directly assessed the knowledge gained through gameplay. Interviews were informal as they focused on obtaining feedback for the next iteration of the app, rather than formally evaluating learning and educational potential. Therefore, the interviews were not recorded, but the content expert took verbatim notes. After the interviews, students completed a quantitative questionnaire consisting of eight questions on a 5-point Likert scale. The questionnaire was modified from an existing game-engagement and usability questionnaire previously validated for adults as there was no available validated questionnaire to assess game engagement in children (Appendix D) (Brockmyer et al., 2009).

User testing sessions were approximately 20-30 minutes in duration. During this time, students used the app for 10 minutes, followed by interviews and questionnaires for another 10 minutes. Prior to using *Foodbot Factory*, the research team explained the purpose and nature of the research to students who provided assent for their data to be collected. Participating students also had parental consent to participate in the study. In total, five iterative user testing sessions were conducted. Four sessions were with Grade 4-6 students from the Durham Catholic District School Board and one session was with similarly aged children attending a science and technology summer camp at Ontario Tech University. The testing sessions received REB approval from both Ontario Tech University and the Durham Catholic District School Board (File Numbers: 14426 and 14879).

5.3 Results

5.3.1 Discovery

Literature reviews on the nutritional status of Canadian children and existing nutrition education interventions identified foods and nutrients of concern for this population and techniques that could be used to create a successful mHealth app. The average Canadian child has inadequate intake of fibre and excessive intake of saturated fat, sugar, and sodium; therefore, education on how these nutrients influence health and well-being is an important component of *Foodbot Factory* (Health Canada, 2012a). Furthermore, the average Canadian child does not consume the daily recommended amount of vegetable and fruit servings (mean servings/day = 4.3; recommendation = 5), acquires 30% of daily sugar calories from sugar sweetened beverages, and under consumes whole grain foods (mean servings/day = 1) making education on these foods a priority for the app (Langlois, Garriguet, Gonzalez, Sinclair, & Colapinto, 2019; Tugault-Lafleur & Black, 2019). Minimal literature exists on effective mHealth nutrition education apps for the child population, and no known research has utilized mHealth apps in the classroom (Dudley et al., 2015). Use of BCTs and gamification were identified as effective approaches to include in mHealth interventions (Johnson et al., 2016; Martin, Chater, & Lorencatto, 2013). An environmental scan of the app marketplace further supported the necessity of this type of work, identifying 259 mobile food apps targeted to children (Brown, Mahmood, et al., 2019; Brown, Siddiqi, Froome, & Arcand, 2019). However, very few were high-quality, with gamified apps being more likely to display high-sodium and high-sugar foods compared to non-gamified apps. These results identified many gaps in the public app marketplace, where food games are popular with children but are not aligned with existing dietary recommendations (Brown, Mahmood, et al., 2019; Brown, Siddiqi, et al., 2019).

The *Discovery* phase led to the creation of the significant educational question: "Can a mHealth nutrition education app improve nutrition knowledge in children aged 9-12?" This phase defined the focal point of intervention for *Foodbot Factory*, which is to improve users' nutrition knowledge with a focus on nutrients of public health concern (Health Canada, 2012a). The milestone for moving to *Phase I: Design,* in the ORBIT model involves isolating a promising educational strategy that warrants further inquiry and development. The research and literature reviews conducted in this phase indicated that gamified mHealth apps are an encouraging avenue to pursue for child nutrition education. These apps are engaging and can be distributed in an equitable manner (Tate et al., 2013). With the central research question and strategy chosen, the development of Foodbot Factory proceeded to *Phase I* (Czajkowski et al., 2015).

5.3.2 Phase Ia: Define the Basic Elements

During the *Define* phase, key stakeholders (n = 21) provided feedback on the target audience and learning objectives for the app. Among the dietitians and teachers surveyed, 81.0% ranked Grades 7-8 as first priority and 85.7% ranked Grades 5-6 as the second priority age group for a nutrition education app. It was decided to target students in Grades 4-6 (ages 9-12) for the app as we believed this age group would be more interested in a gamified nutrition app compared to older students. In addition to identifying the priority age level, 85.7% of stakeholders agreed that increasing water consumption and decreasing sugar-sweetened beverage consumption was important for this age group. While 57.1% of stakeholders agreed that understanding nutritional value was also important.

In alignment with stakeholder feedback, the app was designed to meet the revised 2018 Ontario Grade 4 Health Curriculum expectation that students should "identify the key nutrients (e.g., fat, carbohydrates, protein, vitamins, minerals) provided by foods and beverages, and describe their importance for growth, health, learning, and physical performance" (Ontario Ministry of Education, 2018). This expectation also aligns with the health curriculum expectations from other provinces, providing teachers across Canada with a mobile tool to aid nutrition education in the classroom (British Columbia Ministry of Education, 2016; Saskatchewan Ministry of Education, 2010).

The goal of *Foodbot Factory* is to improve nutrition knowledge, a component of food literacy that has been identified as a gap in Canadian youth's ability to make healthy eating choices (Ontario Food and Nutrition Strategy Group, 2017). While knowledge is often insufficient to initiate dietary behaviour change, it is necessary for individuals to change their behaviour and is associated with better diet quality in adolescents (Vaitkeviciute et al., 2015). As our target audience of 9-12-year-olds moves into adolescence, they will be able to exercise more autonomy in their eating decisions. It is hypothesized that the nutrition knowledge obtained from *Foodbot Factory* will empower student users to make healthier dietary choices. Therefore, the goal of this app is to provide the baseline knowledge required to make informed healthy eating choices.

5.3.2.1 Nutrition content.

Canada's Food Guide (CFG) is the leading government source of nutrition information for Canadians. Education on CFG is embedded in the Ontario Health curriculum and in the curriculum of other provinces (British Columbia Ministry of Education, 2016; Health Canada, 2019; Ontario Ministry of Education, 2018; Saskatchewan Ministry of Education, 2010). In 2019, an updated CFG was released. The *Foodbot Factory* team consulted with Health Canada's Office of Nutrition Policy and Promotion to ensure the app's content aligned with the new CFG recommendations. Foodbot Factory is structured into five modules, each focusing on a CFG food grouping and specific learning objectives. The learning objectives are based on the nutrients of concern relevant for each food grouping, their function within the body, and how intake of the nutrient relates to health outcomes. Each module also incorporates whole-food healthy eating messaging from CFG (Health Canada, 2019). The organization of each module's food grouping, nutrients of concern, and learning objectives are detailed in Table 5-1 (Appendix E).

Module (Food Grouping)	Nutrient(s) of Concern	Module Learning Objectives
1. Drinks	Sugar	1. Recall the best beverage choice for staying hydrated 2. Describe the health effects of different types of beverages 3. Recall different types of sugary drinks
2. Grain Foods	Fibre	1. Explain the nutritional differences between whole grain and refined grain products 2. Recall the components of the grain kernel and how grains are refined 3. Describe why consuming fibre is important for health

3. Vegetables & Fruits	Fibre, Vitamins, & Minerals	1. Recall the amount of vegetables and fruits that should be consumed with a meal 2. Explain why vegetables and fruits are a healthy choice 3. Describe which forms of vegetables and fruit are healthiest to consume (i.e., canned, frozen, juice)
4. Animal Protein Foods	Saturated Fat & Sodium	1. Recall that some fats are healthy (unsaturated fats) and unhealthy (saturated fats) 2. Describe the health effects of excess dietary saturated fat and sodium. 3. Explain why processed meats should be consumed less often 4. Describe why fish are a healthy choice
5. Plant Protein Foods	Protein & Fibre	1. Describe what foods are plant-protein foods, and why they are a healthy choice 2. Recall that plant-protein foods contain fibre

Table 5-1: *Foodbot Factory modules, nutrients of concern, and learning objectives*

5.3.2.2 Gamification.

Foodbot Factory, is set in a fictional town where the residents have nutrition robots, also known as Foodbots, to help them make dietary decisions. The storyline is driven by two nutrition scientists, Robbie and Rebecca, who guide the user on a healthy eating adventure that begins when one of the Foodbots breaks down. Throughout *Foodbot Factory*, the user learns the fundamentals of nutrition across five interactive modules, each with a unique focus on a food grouping and relevant nutrients of public health concern.

Gamification techniques were embedded in each module to enhance user interactions, engagement, and motivation to play. Every module contains four unique components: dialogue, gameplay, food quizzes, and food logs. Three of the five modules contain additional interactive dialogue allowing the user some choice in the content explored. The dialogue portion of each module is designed to educate users about nutrition while engaging them through humour. The dialogue is also rated as easy to read and appropriate for Grade 4 children, receiving a score of 88.9 using the Flesch Formula (Ley & Florio, 1996). Each module contains intermittent opportunities for gameplay that involve collecting or sorting a variety of food items. Gameplay varies across the five modules to avoid repetition and appeal to a variety of user preferences. Users have their knowledge tested via food quizzes at the end of each module. The food quizzes require the user to help characters in the app make healthy eating decisions. This interaction simulates how dietary decisions are made outside of *Foodbot Factory*, which may increase the user's confidence in the ability to make healthy dietary decisions. During the quizzes, if users select an incorrect response they have the opportunity to retry, ensuring exposure to the correct response. The final component of each module is a food log. The food log encourages the user to review fun nutritional facts about each of the foods introduced, reinforcing learning that occurred during the module.

The combination of engaging dialogue, gameplay, food quizzes, and the food log allows users to learn about different types of foods, providing them with the baseline nutrition information required to make healthy eating decisions. Each module incorporates the core tenets of CFG which emphasizes balance and eating a variety of healthy foods each day that align with an individual's lifestyle and culture (Health Canada, 2019). A game flow diagram illustrating the progression of the Drinks module demonstrates the interplay between dialogue content and interactive gamified components (Figure 5-2).

Figure 5-2: *Foodbot Factory game flow diagram for Drinks module*

The Taxonomy of Gamification Concepts for Health Apps allows for the identification of specific gamification characteristics within an mHealth app. Those characteristics included in *Foodbot Factory* are highlighted in Table 5-2 (Schmidt-Kraepelin et al., 2018). Since *Foodbot Factory* is focused on education, rather than behaviour change like most mHealth apps, the taxonomy has been modified to include a "No" option for the characteristics of user identity and goal-setting.

Foodbot Factory uses multiple gamification characteristics as defined by this taxonomy (Schmidt-Kraepelin et al., 2018). The app utilizes mediated communication where information is delivered through a guided storyline. There is no virtual character or self-selected identity, as the user is led through the storyline by the main characters, Robbie and Rebecca. Rewards received in the game are internal, i.e. only within the game, there is no competition with other players or opportunity to collaborate with others. The app is targeted to healthy individuals as there is no specific content directed to children who have a chronic disease. Since *Foodbot Factory* is focused on nutrition education, the content helps users meet specific learning objectives and there is no health goal-setting component e.g. setting a goal for daily water intake. *Foodbot Factory's* narrative is episodical as the app is divided into distinct learning modules. Users receive positive and negative reinforcement during gameplay. Negative reinforcement occurs during gamified components when users do not sort or catch the correct foods or when a question in the food quiz is answered incorrectly. After an incorrect response, users have the opportunity to complete the questions again.

The use of *Foodbot Factory* is independent of its health and learning objectives as the health-related knowledge gained in the app could be accomplished without gamification. The persuasive intent of *Foodbot Factory* is to positively change user’s attitudes and knowledge regarding healthy eating. There is no presentation of how the user advances through the game since the modules can be played in any order.

<table>
<tr><td>Dimension</td><td colspan="4">Characteristics</td></tr>
<tr><td>Gamification concept-to-user communication</td><td colspan="2">Direct</td><td colspan="2">Mediated</td></tr>
<tr><td>User identity</td><td>Virtual character</td><td colspan="2">Self-selected</td><td>No</td></tr>
<tr><td>Rewards</td><td>Internal</td><td colspan="2">Internal and external</td><td>No</td></tr>
<tr><td>Competition</td><td>Direct</td><td colspan="2">Indirect</td><td>No</td></tr>
<tr><td>Target Group</td><td>Patients</td><td colspan="2">Healthy individuals</td><td>Health professionals</td></tr>
<tr><td>Collaboration</td><td>Cooperative</td><td colspan="2">Supportive only</td><td>No</td></tr>
<tr><td>Goal-Setting</td><td>Self-set</td><td colspan="2">Externally-set</td><td>No</td></tr>
<tr><td>Narrative</td><td colspan="2">Continuous</td><td colspan="2">Episodical</td></tr>
<tr><td>Reinforcement</td><td colspan="2">Positive</td><td colspan="2">Positive-negative</td></tr>
<tr><td>Level of integration</td><td colspan="2">Independent</td><td colspan="2">Inherent</td></tr>
<tr><td>Persuasive intent</td><td>Compliance change</td><td colspan="2">Behavior change</td><td>Attitude change</td></tr>
<tr><td>User advancement</td><td>Presentation only</td><td colspan="2">Progressive</td><td>No</td></tr>
</table>

Table 5-2: *Foodbot Factory gamification characteristics (Schmidt-Kraepelin et al., 2018)*

5.3.2.3 Behaviour change techniques.

The BCT Taxonomy of 93 techniques is hierarchically organized into overarching categories (Michie et al., 2013). Although the goals of *Foodbot Factory* are to educate users about healthy eating and nutrients of public health concern, BCTs are a way to illustrate how the knowledge gained can be applied to actual dietary decisions. The hope is that through the *Foodbot Factory* app, users will be better informed about nutrition which will provide a foundation for making healthy eating decisions.

The main BCT categories integrated throughout *Foodbot Factory* are Feedback & Monitoring, Social Support, Shaping Knowledge, Natural Consequences, and Reward and Threat (Michie et al., 2013). In total, Foodbot Factory utilizes seven BCTs across the game. The BCTs included in each module are detailed in Table 5-3. In each module users have the opportunity to test their knowledge and help game characters make dietary decisions, with users receiving feedback on the accuracy of those decisions. Users also learn about the natural health consequences that occur as a result of the consumption of certain foods and nutrients. At the end of each module, users are rewarded by unlocking new food items in the food log, where they can review additional nutrition information.

Module	BCTs Implemented
Drinks	2.2 Feedback on behaviour 4.1 Instruction on how to perform the behaviour 4.2 Information about antecedents 5.1 Information about health consequences 10.3 Non-specific reward
Grain Foods	2.2 Feedback on behaviour 4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences 10.3 Non-specific reward
Veggies & Fruits	2.2 Feedback on behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behaviour 4.2 Information about antecedents 5.1 Information about health consequences 10.3 Non-specific reward
Plant Protein Foods	2.2 Feedback on behaviour 4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences 6.1 Demonstration of behaviour 10.3 Non-specific reward

Animal Protein Foods	2.2 Feedback on behaviour 4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences 10.3 Non-specific reward

Table 5-3: BCTs implemented in Foodbot Factory (Michie et al., 2013)

70a5.3.3 Phase Ib: Refine for Strength and Efficiency

5.3.3.1 Session 1: Drinks and Grain Foods.

The first user testing session occurred with students in Grade 5 (n = 12) and Grade 6 (n = 18). At this time point, the research team only utilized the quantitative questionnaire, and took unstructured observational notes. All other sessions utilized the three types of data collection previously described.

From this testing session, it was observed that Grade 6 students progressed through the app at a faster rate than Grade 5 students. However, Grade 6 students seemed less engaged and interested in the intervention compared to Grade 5 students. It was also observed that there was confusion and frustration in navigating the gameplay portion of the module as students had difficulty controlling the movement of the robot. Female students appeared to be more interested in the nutrition and healthy eating content of the app compared to males and were more likely to state that they would play the game again.

Quantitative survey results confirmed our observations demonstrating that 10% of students disagreed with the statement “the app was fun” and 13% disagreed with “the goals of the app were clear” (Figures 5-3 and 5-4). A large portion of students (46.6%) also disagreed with the statement “the robot was easy to control” (Figure 5-5 and Table 5-4). Based on the feedback received the aims for the next iteration of the app were to include more explicit tutorial instructions, increase the use of gamification to enhance engagement, and clearly state the goals of the modules.

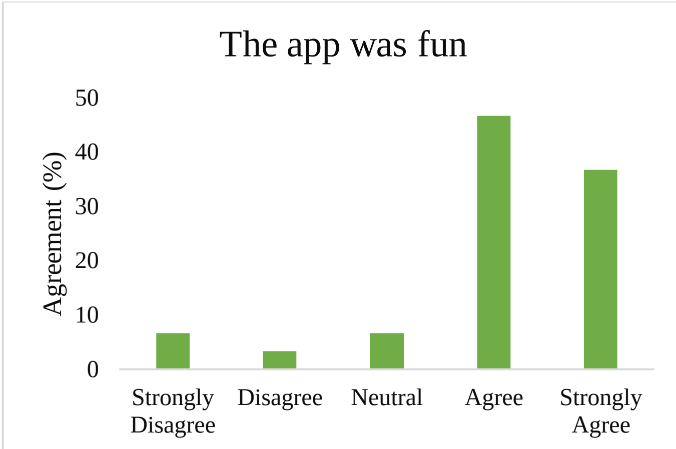

Figure 5-3: *S1 "The app was fun"*

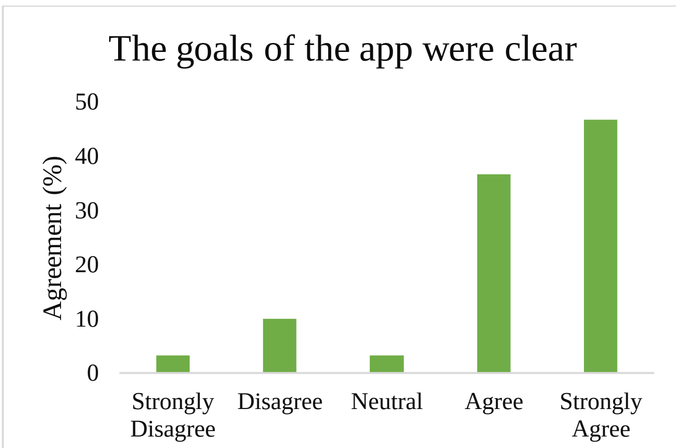

Figure 5-4: *S1 "The goals of the app were clear"*

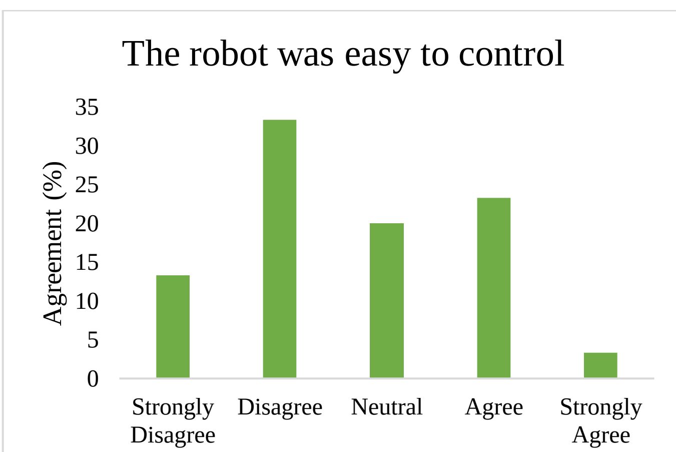

Figure 5-5: *S1 "The robot was easy to control"*

5.3.3.2 Session 2: Drinks.

The next iteration of *Foodbot Factory* was tested with Grade 4 students (n = 20; 50% male). During this and all subsequent sessions, all three types of data were collected: observational, qualitative, and quantitative. Observational data revealed that students were relatively engaged with the dialogue in the module. The majority of students (70%) demonstrated high interest in reading the healthy eating content based on observations of their engagement with the dialogue, while 26.5% of students skipped some or most of the dialogue (Table 5-4). 21.1% of students (n = 4) showed visual frustration or confusion during game play e.g. appearing confused or asking for helping. Students who were confused were also observed skipping quickly through dialogue, indicating that they felt the module had too much reading. The students' frustrations may have related to them skipping instructional portions of the app.

	Above Average Reading Interest n (%)	Skipping Most of the Dialogue n (%)
Session 2 (n = 20)	14 (70%)	2 (10.5%)
Session 3 (n = 14)	7 (51.3%)	2 (14.3%)
Session 4 (n = 21)	13 (60%)	2 (9.5%)
Session 5 (n = 17)	13 (75%)	2 (13.3%)

Table 5-4: *Summary of observational data for Sessions 2-5*

Qualitative interviews assessed user satisfaction and the knowledge gained from *Foodbot Factory*. When students were asked to identify their favourite part of the game, 30% identified the app characters and their humour, 25% favoured the "food quiz" gamified component of the module, and 15% identified learning about nutrition. When prompted to select the drink they would like to have if they were thirsty, given the options of water, milk, and pop that were shown in the Drinks module, 90% chose water with students stating: *"Water is needed to stay hydrated."* and *"Water, because if you're thirsty you can stay hydrated."* Some additional comments from students were *"60% of your body is water."* and *"I learned even more about having pop less."* The qualitative interviews demonstrated that students were able to take away key healthy eating messages as they recalled and explained why water is the best beverage choice for health and hydration.

Quantitative questionnaires further assessed engagement and usability. For this iteration, the team was interested in improving the clarity of the goals of the app and students perceived enjoyment of it. This iteration was successful in improving both metrics with 68.4% and 80% of students strongly agreeing with these statements respectively. Quantitative data for all testing sessions of the Drinks module summarizing the percentage of students who agreed or strongly agreed with the statements is shown in Table 5-5.

	Strongly Disagree and Disagree n (%)	Neutral n (%)	Strongly Agree and Agree n (%)
The app was fun			
Session 1 (n = 30)	3 (10%)	2 (6.7%)	25 (83.4%)
Session 2 (n = 20)	1 (5.3%)	0 (0%)	18 (94.7%)
Session 3 (n = 14)	0 (0%)	1 (7.1%)	13 (92.9%)
Session 4 (n =21)	0 (0%)	2 (9.5%)	19 (90.4%)
The goals of the app were clear			
Session 1	4 (13.3%)	1 (3.3%)	25 (83.4%)
Session 2	1 (5%)	0 (0%)	19 (95.0%)
Session 3	1 (7.1%)	1 (7.1%)	12 (85.7%)
Session 4	0 (0%)	1 (4.8%)	20 (95.2%)

Table 5-5: *Summary of quantitative data for Sessions 1-4 (Drinks)*

5.3.3.3 Session 3: Drinks.

The next iteration of the *Foodbot Factory* Drinks module was tested with Grade 4 students (n =14; 82.4% male). The major modification to this iteration was the addition of two gamified "food catches" to enhance engagement between the dialogue content. The team hypothesized that this would increase engagement and interest in the app. However, observational data contradicted the hypothesis as more students skipped some or most of the dialogue (34.3%) compared to Session 2 (Table 5-4). Fewer students showed visual frustration or confusion and the confusion was related to the "food catch" portion of the game, where students did not understand what to catch because they had skipped through the added tutorial.

Results from qualitative interviews also differed from Session 2 with 36% of students stating that the "food catch" was their favourite part of the game and 27% stating the "food quizzes" was their favourite part. Students were also less likely to provide the correct answer when prompted to choose which drink they would like to have if they were thirsty, with 57% stating water and 36% stating milk. However, students who replied milk were able to express their knowledge of water during the interview; one student stated "*Water is the better choice."* and another stated *"You should have water after you exercise."* The high response of milk may reflect students' taste preference for milk over water, or baseline knowledge from parents and care providers, rather than a lack of knowledge on the importance of water for health and hydration. Quantitative results were similar from Session 2. Most students continued to agree or strongly agree with the statements the app was fun (92%) and the goals of the app were clear (85.7%; Table 5-5).

5.3.3.4 Session 4: Drinks and Grain Foods.

The next testing of *Foodbot Factory* occurred with summer camp students at Ontario Tech University (n = 21; 65.2% male). The Drinks module was unmodified from Session 3. The Grain Foods module was modified to include a new interactive component where students could choose to learn about different parts of the grain kernel, as well as play a "food sort" mini-game to increase variety between the gamified portions of each module. It was hypothesized that students would show increased engagement with the different interactive components included, particularly in the Grain Foods module.

Observations during gameplay were similar to previous sessions with 60% of students showing high reading interest and 9.5% skipping most of the dialogue (Table 5-4). Some students appeared to disengage with the game after playing more than one module, which may explain why observational data showed slight declines in engagement compared to Sessions 2 and 3 where only one app module was tested. Students seemed to connect with the characters and humorous dialogue content in the app, with two students commenting after gameplay *"That was really fun!"*. In this testing session no students showed any visual frustration or confusion, indicating that the usability of the game and clarity of instructions had improved.

Qualitative interviews revealed that knowledge gained through *Foodbot Factory* improved from previous sessions. All students (100%) replied that water is the best for quenching thirst, with students recognizing that *"You need it [water] to survive and stay hydrated."* and *"60% of the body is made of water."* Students also conveyed knowledge of milk and sugary drinks with some sharing that *"Milk has calcium and Vitamin D and makes bones grow bigger and stronger."* and *"Pop is a treat like chocolate. You get cavities from the sugar."* For the Grains Foods module, 70% of students recalled that whole grain bread has more fibre than white bread with students stating *"Whole grain* *bread has more fibre and is better for you than white bread because of fibre."* and *"White bread has less fibre because they remove the bran and the germ."* These interviews demonstrated that, on average, students were able to fulfill the learning objectives for both the Drinks and Grain Foods modules.

Quantitative results showed considerable improvements on two key metrics of concern. 90.4% of students agreed with the statement "the app was fun" and 95.2% agreed "the goals of the app were clear" (Table 5-5). Although observational data suggests that students may disengage when playing multiple modules in one sitting, this self-reported quantitative data confirms that students found the game engaging and useable.

5.3.3.5 Session 5: Veggies & Fruits and Protein Foods.

The last user testing session for *Foodbot Factory* occurred with Grade 4 students (n = 17; 54.5% male). In this session students either tested the first iteration of the Veggies and Fruits module or the Protein Foods module. Based on the iterative feedback received in previous sessions, these modules included multiple interactive components. For example, students could select the vegetables and fruits to learn about, cook pasta, and there was added variation between the "food sort" and "food catch" mini-games.

Observational data showed similar levels of engagement to previous user testing sessions, with 75% of students showing high reading interest and 13.3% of students skipping through the dialogue (Table 5-4). Qualitative interviews with students who played the Veggies & Fruits module (n = 8) revealed that 75% of students were able to recall a key healthy eating message, with one student stating *"They have lots of vitamins and minerals"* and another stating *"Most of the stuff [nutrients] helps your body and when you eat it, it helps your body work."* Only 55% of students who played the Protein

Foods module (n = 9) were able to recall a key healthy eating message. The first iteration of the Protein Foods module was ambitious, as it included content on the benefits of plant-based protein foods, and the health effects of sodium, saturated, and unsaturated fats. Based on this feedback, the module was divided into Animal Protein Foods and Plant Protein Foods to enhance the clarity of healthy eating messages and improve students' ability to meet the learning objectives.

Quantitative results confirmed that *Foodbot Factory* is an engaging and useable intervention for the target audience with 87.5% of students agreeing that "the app was fun" and 94.1% agreeing that "the goals of the app were clear." Additionally, 70.6% of students agreed that "the app was easy to use" and "the words in the app were easy to read." A total of 70.8% of students agreed with the statement "I want to keep playing", indicating that *Foodbot Factory* is an engaging and acceptable way for students to learn about food, nutrition, and healthy eating (Figures 5-6 to 5-9 and Table 5-6).

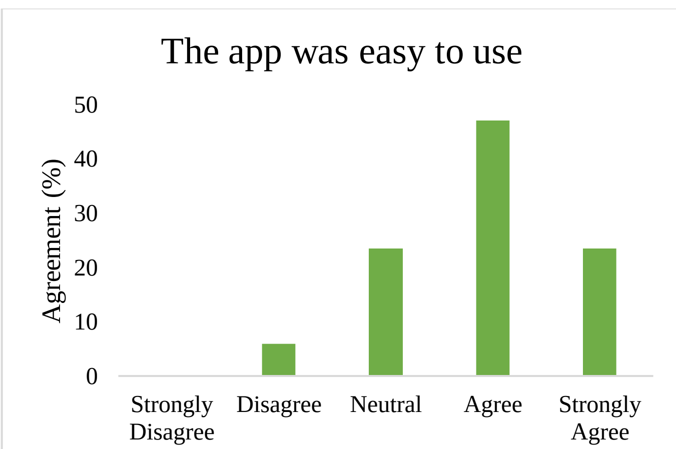

Figure 5-6: *S5 "The app was easy to use"*

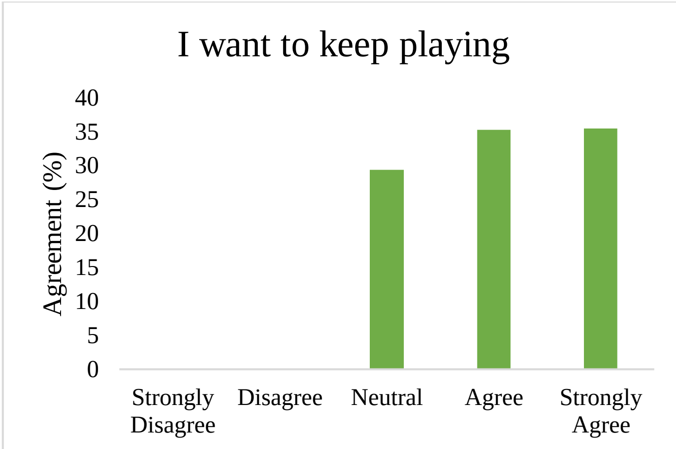

Figure 5-7: *S5 "I want to keep playing"*

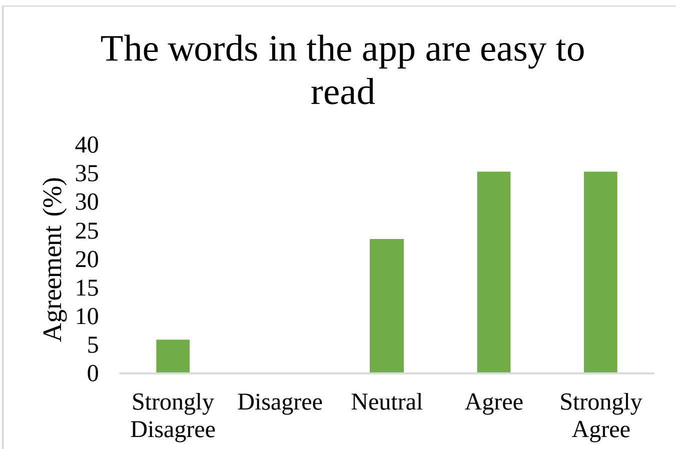

Figure 5-8: *S5 "The words in the app are easy to read"*

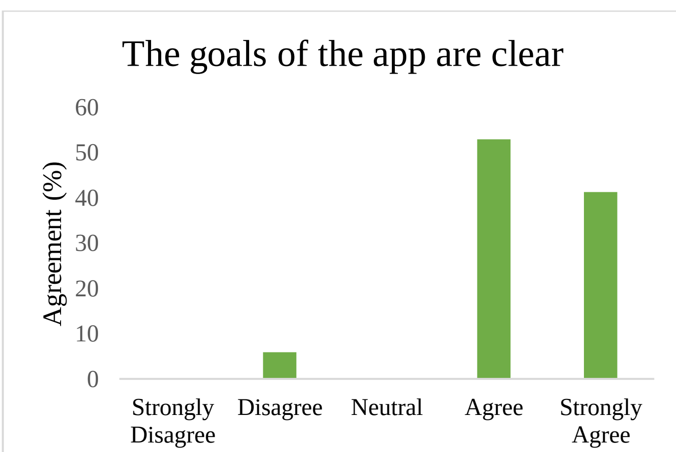

Figure 5-9: *S5 "The goals of the app are clear*"

	Strongly Disagree and Disagree n(%)	Neutral n(%)	Strongly Agree and Agree n(%)
The app was easy to use n(%)	1 (5.9%)	4 (23.5%)	12 (70.6%)
I want to keep playing	0 (0%)	5 (29.4%)	12 (70.6%)
The words in the app are easy to read	1 (5.9%)	4 (23.5%)	12 (70.6%)
The goals of the app are clear	1 (5.9%)	0 (0%)	15 (94.1%)
The app was fun	0 (0%)	2 (12.5%)	14 (87.5%)

Table 5-6: *Quantitative user testing results (Session 5)*

5.3.3.6 Sub-group analyses.

Differences in engagement between male and female students were noted from Session 1, and it was hypothesized that female students were more engaged than male students. Between Session 2 and 3 reduced engagement with the app was also noticed and Session 3 included the highest proportion of male students (82.4%). Quantitative survey results between students who self-identified as male or female were compared using one-tailed unpaired t-tests (n = 87; 60% male). Female students were significantly more likely than male students to agree that they wanted to keep playing ($p = 0.03$). Female students were also more likely to agree that the app was fun ($p = 0.11$) and less likely to agree that they were bored ($p = 0.09$) compared to male students although these differences were not statistically significant (Table 5-7). To address the differences in engagement between male and female students, the research team made significant efforts to enhance overall engagement with each iteration of *Foodbot Factory* by further incorporating games and humour to better appeal to male students. A voiceover has also been added to the app which may enhance engagement and make the content more accessible. Although female students do show higher levels of engagement compared to male students, males are still likely to find the app fun and are able to learn through gameplay as evidenced by qualitative feedback.

Question	Strongly Disagree and Disagree n (%)	Neutral n (%)	Strongly Agree and Agree n (%)
"I want to keep playing"			
Female	1 (3%)	5 (14%)	29 (83%)
Male	3 (6%)	12 (23%)	37 (71%)
"The app was fun"			
Female	1 (3%)	0 (0%)	33 (97%)
Male	3 (6%)	4 (8%)	45 (86%)
"I was bored"			
Female	28 (82%)	5 (15%)	1 (3%)
Male	39 (75%)	11 (21%)	2 (4%)

Table 5-7: *Quantitative engagement results between female and male students*

5.4 Discussion

The iterative development and evaluation of *Foodbot Factory* has led to the creation of an evidence-based and engaging mHealth app to help Canadian children learn about healthy eating and nutrition. The development of this app was led by experts in public health, dietetics, computer science, game development, and education, ensuring that the app is aligned with the latest dietary recommendations for Canadians and current advances in gaming and teaching technology. This development process was unique since the content of *Foodbot Factory* was informed by teachers, to ensure the app can be utilized in the classroom, and in consultation with Health Canada's Office of Nutrition Policy and Promotion, the government office responsible for generating and disseminating dietary recommendations. Utilizing an interdisciplinary team, consisting of faculty members and graduate students representing the faculties of Education, Information Technology, and Health Sciences, allowed for the creation of a novel mHealth app that successfully engages children in nutrition education. The knowledge gained from playing *Foodbot Factory* can assist children in making healthier dietary decisions, appreciating that there are many factors that influence eating in childhood that are beyond the control of a young individual, e.g. socioeconomic status, parental influence, neighbourhood food environment (Story et al., 2008). *Foodbot Factory's* alignment with CFG makes it an educational resource that can be utilized in schools and homes across Canada.

The multi-method user testing data demonstrate that the majority of *Foodbot Factory's* target audience find the app engaging and useable, providing evidence that this intervention can help Canadian children learn about nutrition. *Foodbot Factory* has completed *Phase I: Design* in the ORBIT model and is currently being evaluated in a randomized control trial as part of *Phase 2: Preliminary Evaluation* (Czajkowski et al., 2015). The strengths of the iterative development and testing approach is that multiple testing sessions allowed the research team to improve engagement and usability of the app, as evidenced in the user testing results. The research team successfully utilized the data collected to improve each iteration of *Foodbot Factory*. A limitation of the research project is that evaluative testing was conducted with students that may be of a higher socio-economic status than the broader Canadian population since students were recruited from a relatively affluent suburban area and a university-based summer camp. Testing results suggest that students may disengage after playing multiple modules during testing sessions, and that female students may be more engaged than male students. To address these limitations, *Foodbot Factory* can be played in a flexible format, providing users a choice in the number of modules played in a given session. The app contains multiple gamified components that vary through each module to appeal to a variety of learning and gameplay preferences.

This research demonstrates that *Foodbot Factory* is a viable and engaging app that has potential to improve the nutrition knowledge of Canadian children. The app aligns with the latest dietary recommendations for Canadians and Ontario educational curriculum, providing a tool for children to learn about healthy eating and nutrition at home and in the classroom. Future work with *Foodbot Factory* includes a randomized trial measuring its impact on nutrition knowledge and development of a knowledge translation strategy to ensure maximal reach and adoption among the intended audience.

Chapter 6: Discussion

This research has centered on the development and pre-efficacy evaluation of a novel mHealth nutrition education app for children, Foodbot Factory. A systematic environmental scan of the app marketplace was conducted to evaluate the content and techniques utilized in mobile nutrition apps that are targeted to children. Additionally, an iterative approach was utilized to design and develop the Foodbot Factory mobile app, with each iteration being informed by data collected from the target audience across five user testing sessions.

6.1 Overview of Findings

Nutrition is a critical component of a healthy lifestyle. Diet is the leading modifiable risk factor for morbidity and mortality associated with the development of non-communicable diseases (NCDs) such as hypertension, obesity, type 2 diabetes, and some forms of cancer (Afshin et al., 2019). Furthermore, high-quality diets in childhood promote healthy growth, development, and academic success (Basch, 2011). Early dietary and nutrition education interventions can help set children up for success throughout the lifespan. Dietary patterns are often established in childhood, so when children have access to early interventions they are more likely to continue consuming high-quality diets into adulthood, thus preventing the development of diet-related NCDs (Craigie et al., 2011).

The actual dietary intakes of the average Canadian child may promote, rather than prevent, the development of diet-related NCDs. On average, Canadian children under consume beneficial foods like vegetables and fruits, whole grain foods, and legumes, nuts, and seeds, while consuming excess amounts of high-sugar and/or high-fat foods (Tugault-Lafleur & Black, 2019). Furthermore, 23-31% of daily calories come from “other” foods that are often high in sugar, sodium, and/or saturated fat that are not recommended by dietary guidelines (Jessri et al., 2016). Consequently, the average Canadian child over consumes nutrients that are linked to the development of diet-related NCDs, namely sugar, sodium, and saturated fat, and under consumes nutrients that can prevent the development of these NCDs, namely potassium and fibre (Health Canada, 2012a). Children and adolescents require access to interventions and opportunities to improve food literacy and dietary intake in order to prevent the development of NCDs.

Mobile health (mHealth) apps are promising opportunities to engage children with healthy eating interventions. In Canada, children increasingly have their own mobile devices and are able to access them at school and at home (eMarketer, 2016; Howell et al., 2017). Compared to traditional interventions, mHealth has the unique ability to enhance users’ motivation and engagement with an intervention by appropriately incorporating evidence-based behaviour change and gamification techniques (Edwards et al., 2016). Given the increasing availability of mobile devices in Canada, when mHealth interventions are available to the public for free or at a low-cost they are more affordable and accessible for Canadians. mHealth interventions also reduce barriers in accessing high-quality nutrition education interventions for the 18.9% of Canadians living in rural areas of the country (Statistics Canada, 2012; Tate et al., 2013).

Despite the increasing popularity of mobile devices and mHealth apps in society, minimal research has been conducted on the use of mHealth interventions to improve children’s diet quality or food literacy. A search of the literature identified 14 peer-reviewed articles and only two articles assessed interventions targeting food literacy skills, indicating significant knowledge gaps in how researchers can create and implement effective mHealth interventions for children in this area (Baghaei et al., 2016; Wickham

& Carbone, 2018). Schools are a promising avenue to implement nutrition education interventions; however, no known study has aligned a nutrition mHealth intervention for children with existing curriculum requirements (Dudley et al., 2015). Apart from interventions created by health researchers, there are many publicly available mHealth apps on the marketplace (Statista, 2018). Systematic searches have explored the content and quality of publicly available mHealth apps, focused on various topic areas, but no published study has assessed nutrition mHealth apps targeted to children.

Therefore, this thesis sought to add to the literature in this area with two different approaches. The first, was to conduct a systematic cross-sectional environmental scan of the app marketplace to identify and evaluate publicly available child nutrition mHealth apps. The second, was to develop a novel gamified mHealth app, Foodbot Factory, that would be targeted to children to improve their nutrition knowledge, an aspect of food literacy skills (Thomas et al., 2019). Foodbot Factory was designed for use at school and at home and was developed by an interdisciplinary team to ensure the app would be aligned with best practices in the disciplines of dietetics, education, game development, and public health. From the beginning of development, Foodbot Factory integrated both gamification and behaviour change techniques (BCTs) to enhance users' engagement and motivation to interact with the app (Edwards et al., 2016).

The cross-sectional environmental scan of publicly available nutrition apps marketed to children revealed significant gaps in the app marketplace for high-quality and evidence-based child nutrition apps, indicating the need for stronger mHealth interventions in this area. For the purposes of this research, outcomes of interest were nutrition content, based on foods and recommendations from the 2007 Canada's Food Guide (CFG), and the use of both gamification and BCTs (Health Canada, 2011; Michie et al., 2013; Schmidt-Kraepelin et al., 2018). A systematic search strategy was implemented to identify nutrition apps targeted to children in the Apple App and Google Play Stores using multiple search terms related to nutrition, healthy eating, and food. In total, n = 259 nutrition apps targeted to children were identified. During the screening process, a sub-set of “food prep” apps were identified (n = 134). These apps require the user to cook, prepare, bake, and/or decorate virtual food items and contained similar BCTs and gamification techniques: therefore, these apps were not included in the group analysis for these outcomes. Food prep apps were analyzed separately for their nutrition content and quality as assessed by the Mobile Application Rating Scale, or MARS (Stoyanov et al., 2015).

General child nutrition apps (n = 125) frequently showed healthy foods that are recommended by dietary guidelines such as vegetables (93.6%), fruits (92.0%), and meat alternatives (68.8%). However, these apps did not make significant use of BCTs ($\bar{X} = 2.2 \pm 2.6$) nor gamification techniques with only 25% of apps being gamified (n = 32). Gamified apps were significantly more likely to show high-sodium foods compared to non-gamified apps (59% vs. 22% p = 0.004).

Food prep apps (n = 134) showed unhealthy foods like high-sugar (87.3%), and refined grain foods (73.8%), more frequently than healthy foods like fruits (63.4%), vegetables (46.2%), and meat alternatives (15.7%). These apps were slightly above average in quality with a mean rating of 3.5/5 on the MARS scale, indicating that app developers have invested more time into the aesthetics and functionality of food prep apps rather than the nutrition content. Data on the number of downloads for apps available in the Google Play Store demonstrates that the average food prep app receives substantially more downloads ($\bar{X} \cong 7.6M \pm 17.6M$) compared to the average general child nutrition app ($\bar{X} \cong 3.4 \pm 9.8M$). This indicates that children may be more inclined to play and engage with gamified apps, compared to non-gamified apps, and highlights a significant gap for children who lack access to fun and evidence-based mHealth nutrition apps that align with existing dietary recommendations.

The development and evaluation of Foodbot Factory fills this gap by creating a high-quality, engaging, and evidence-based app for children to play and learn about healthy eating and nutrition. The app is also aligned with Ontario Curriculum requirements, allowing teachers to utilize Foodbot Factory as a tool to support nutrition education in the classroom setting. The ORBIT model and IDEAS framework were both utilized to guide the development of the mHealth intervention (Czajkowski et al., 2015; Mummah et al., 2016). Foodbot Factory has completed *Phase I: Design* of the ORBIT model and is ready for further testing and evaluation (Czajkowski et al., 2015).

To create an effective and fun intervention, this research required an interdisciplinary team to support the development and creation of a novel mHealth nutrition app for children. mHealth is inherently an interdisciplinary field, and the utilization of a team of experts from dietetics, game development, education, and public health, has made the development of Foodbot Factory unique and rigorous by applying the leading concepts and approaches from all relevant disciplines. In contrast, the development of many other mHealth interventions are outsourced to external developers which may limit communication and reduce the opportunity to collaborate across disciplines. As part of this process, we partnered with a local school board to assist us in evaluating the app with our target audience and Health Canada's Office of Nutrition Policy and Promotion to ensure the content of the app would align with the latest dietary recommendations for Canadians seen in the 2019 CFG (Health Canada, 2019). The initial concept and content for the first prototype of Foodbot Factory was tested in March 2018 with a partnered school board. In total, five iterations of Foodbot Factory were rigorously user tested ensuring that the final product would be a satisfying, useable, and engaging tool for the target audience to learn about nutrition.

Each user testing session took a multi-method approach to collect data on engagement, satisfaction, knowledge, and usability of Foodbot Factory. This approach utilized semi-structured observation, informal qualitative interviews, and quantitative questionnaires. Data was collected by content experts and game developers to ensure that all relevant metrics were captured. This data collection approach is aligned with current recommendations for utilizing mixed-methods user testing approaches and is more comprehensive than previous approaches, enabling the team to significantly improve upon each iteration of Foodbot Factory (Alwashmi et al., 2019; Kliemann, Croker, Johnson, & Beeken, 2019; Nollen et al., 2013).

Foodbot Factory has evolved dramatically throughout the iterative development process, with the final product now meticulously evaluated with the target audience and in line with their learning needs for healthy eating and nutrition. In Session 1, difficulties with the usability of the game controls were observed and students would become disengaged with the amount of dialogue and healthy eating content in the app. For Sessions 2 & 3, more gamified components were incorporated and dialogue was reduced to enhance engagement. This improved overall engagement with the app; however, in Session 3, which was primarily male (82.4%), a reduction in engagement was noticed. When comparing data on engagement between female and male students, female students were significantly more likely to report that they would want to keep playing Foodbot

Factory ($p = 0.03$) and were less likely to report that they were bored ($p = 0.09$). The interdisciplinary team worked to improve engagement for a variety of learning preferences, including gamified components, opportunities to learn and test knowledge, and incorporating humour that would appeal to the target audience throughout the iterative development process. Although, female students may show higher engagement with Foodbot Factory overall, there are components within each module of the app that can appeal to many learning preferences.

Session 4 data continued to demonstrate that students find the app engaging and usable and that they can gain knowledge on healthy eating and nutrition from playing Foodbot Factory. After gameplay, 100% of students were able to recall that water is the best beverage for hydration and 70% recalled that whole grain bread contains more fibre than white bread. In Session 5, students continued to qualitatively and quantitatively report that the game was engaging, useable, and acceptable. Of students who played the Veggies & Fruits module, 75% were able to recall a key healthy eating message, however, only 55% of students who played the Protein Foods module were able to do so. The first iteration of the Protein Foods module was ambitious, educating users on the benefits of plant protein foods, the health effects of sodium, and the differences between unsaturated and saturated fats. Based on this iterative feedback, the module has been divided into Animal and Plant Protein Foods, to clarify and break up the learning objectives for the different types of protein foods.

The multi-method user testing approach allowed for significant improvements to be made to the final Foodbot Factory product, which is now ready for public release and further evaluation. This is the first research study to create an mHealth child nutrition app that can be utilized both at school and at home, providing ample opportunities for the intervention to be leveraged by the public to improve nutrition knowledge. The app is aligned with both Ontario Grade 4 Health curriculum learning objectives and the 2019 CFG, providing a necessary tool for modern day teachers, parents, and most importantly children, to learn about healthy eating and nutrition.

6.2 Future Directions

The environmental scan of the app marketplace identified significant gaps in the availability of high-quality evidence-based child nutrition apps. General child nutrition apps (n = 125) frequently showed foods recommended by dietary guidelines; however, they made minimal use of evidence-based BCTs and gamification techniques that could enhance engagement and motivation. Food prep apps, which receive an average of 7.6M downloads, frequently expose users to high-sugar and high-sodium foods that are not recommended by dietary guidelines. The popularity of these apps highlights a public health problem as children are clearly interested in playing games with food and nutrition content, but existing apps are not aligned with the basic evidence-based principles of healthy eating.

There are many challenges associated with conducting this type of environmental scan research as the app marketplace is a dynamic environment that changes rapidly, thus no search of the app marketplace can be truly systematic. Furthermore, search results and data extraction abilities are limited, requiring more efforts on researchers to collect this data in a rigorous fashion (de la Vega & Miro, 2014). This environmental scan research has many strengths compared to other methods implemented. First, 16 search terms were utilized to ensure that all relevant apps were captured, whereas other “systematic” searches have only utilized one (Reusche, Buchanan, Kozlow, & Vercler, 2016). All data was collected by two independent reviewers with a third to resolve disagreements ensuring all data was of high-quality and that every component within each app was captured. Future systematic searches of the app marketplace should employ similar methods to ensure all apps are captured and that the data collection is completed in a rigorous and reliable fashion. Researchers should also be encouraged to establish guidelines, similar to those seen in the PRISMA statement, for this emerging field to ensure that those conducting this type of research are presenting rigorous and high-quality data (Shamseer et al., 2015). Given the dynamicity of this field, the marketplace should be monitored over time to assess how the content and techniques utilized in mHealth apps changes over time and as utilization of mHealth apps continues to rise.

Foodbot Factory has successfully filled a gap in the app marketplace for a high-quality and evidence-based nutrition game for children. This app also supports the implementation of CFG as there are no specific resources available for educators or children at this time (Health Canada, 2019). There have been many strengths to the approach the interdisciplinary development team has taken, which was a true ongoing collaboration, that existed throughout the duration of app creation and testing. The research and development of Foodbot Factory lies at the intersection of multiple disciplines, education, computer science, and public health nutrition, creating an intervention that contains the best practices from each and that can be utilized by children in the context of gameplay at home and learning at school. Each member of our team brought unique perspectives and insights to the app. While at times it was difficult to merge the priorities of each discipline, for example making the game simultaneously fun and educational, we successfully worked together to define the most important elements and create them within Foodbot Factory. The multi-method approach used to evaluate and iteratively develop Foodbot Factory allowed the team to significantly improve upon each iteration from the perspectives of nutrition and gaming. Health researchers looking to create mHealth interventions should take an iterative approach and create strong partnerships with their developers and stakeholders to ensure that their apps truly meet the needs of the target audience and incorporate best practices from health and technology research.

The development of evidence-based mHealth interventions by academics come with challenges. A key issue within the field of mHealth is how researchers can create competitive and sustainable interventions. More often than not, health researchers lack the funding that industry or government groups have access to, including resources and staff support to continuously create new content and updates for their apps. Although the Foodbot Factory team has created a competitive product that fills a significant gap in the app marketplace, a challenge moving forward will be to secure funding to launch and maintain the app. Foodbot Factory will soon be evaluated in a randomized trial to test whether the app can help children learn about healthy eating and nutrition compared to a control app. This data will provide support for future funding applications to assist with the maintenance of Foodbot Factory after its public release. mHealth researchers should consider the sustainability of their interventions from the beginning of development and funding bodies should be open to providing long-term resources to support the maintenance of highly needed evidence-based health apps that are available to the public.

6.3 Conclusions

This research has produced novel findings on the content of existing child nutrition apps, a significant public health concern given the popularity of these apps and their misalignment with existing dietary guidelines. To fill this gap, Foodbot Factory, a novel nutrition education mHealth intervention, was created by an interdisciplinary team of health researchers, educators, and game developers at Ontario Tech University. Foodbot Factory was rigorously evaluated with student users with a multi-method iterative development approach, allowing improvements to be made to each iteration aligned with the target audience's learning needs and preferences. The content of the app meets Ontario curriculum requirements and aligns with the 2019 CFG, fulfilling an important need for teachers and students to have a fun and engaging tool to learn about healthy eating and nutrition. Currently, Foodbot Factory is being evaluated in a randomized trial and preparations are underway for public release, where the app will be available on the marketplace for children all across Canada to download, learn, and play for free.

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Appendixes

Appendix A: Behaviour Change Taxonomy (Michie et al., 2013)

Page	Grouping and BCTs
1	**1. Goals and planning**
	1.1. Goal setting (behavior) 1.2. Problem solving 1.3. Goal setting (outcome) 1.4. Action planning 1.5. Review behavior goal(s) 1.6. Discrepancy between current behavior and goal 1.7. Review outcome goal(s) 1.8. Behavioral contract 1.9. Commitment
3	**2. Feedback and monitoring**
	2.1. Monitoring of behavior by others without feedback 2.2. Feedback on behaviour 2.3. Self-monitoring of behaviour 2.4. Self-monitoring of outcome(s) of behaviour 2.5. Monitoring of outcome(s) of behavior without feedback 2.6. Biofeedback 2.7. Feedback on outcome(s) of behavior
5	**3. Social support**
	3.1. Social support (unspecified) 3.2. Social support (practical) 3.3. Social support (emotional)
6	**4. Shaping knowledge**
	4.1. Instruction on how to perform the behavior 4.2. Information about Antecedents 4.3. Re-attribution 4.4. Behavioral experiments
7	**5. Natural consequences**
	5.1. Information about health consequences 5.2. Salience of consequences 5.3. Information about social and environmental consequences 5.4. Monitoring of emotional consequences 5.5. Anticipated regret 5.6. Information about emotional consequences
8	**6. Comparison of behaviour**
	6.1. Demonstration of the behavior 6.2. Social comparison 6.3. Information about others' approval
9	**7. Associations**
	7.1. Prompts/cues 7.2. Cue signalling reward 7.3. Reduce prompts/cues 7.4. Remove access to the reward 7.5. Remove aversive stimulus 7.6. Satiation 7.7. Exposure 7.8. Associative learning
10	**8. Repetition and substitution**
	8.1. Behavioral practice/rehearsal 8.2. Behavior substitution 8.3. Habit formation 8.4. Habit reversal 8.5. Overcorrection 8.6. Generalisation of target behavior 8.7. Graded tasks
11	**9. Comparison of outcomes**
	9.1. Credible source 9.2. Pros and cons 9.3. Comparative imagining of future outcomes
12	**10. Reward and threat**
	10.1. Material incentive (behavior) 10.2. Material reward (behavior) 10.3. Non-specific reward 10.4. Social reward 10.5. Social incentive 10.6. Non-specific incentive 10.7. Self-incentive 10.8. Incentive (outcome) 10.9. Self-reward 10.10. Reward (outcome) 10.11. Future punishment
15	**11. Regulation**
	11.1. Pharmacological support 11.2. Reduce negative emotions 11.3. Conserving mental resources 11.4. Paradoxical instructions
16	**12. Antecedents**
	12.1. Restructuring the physical environment 12.2. Restructuring the social environment 12.3. Avoidance/reducing exposure to cues for the behavior 12.4. Distraction 12.5. Adding objects to the environment 12.6. Body changes
17	**13. Identity**
	13.1. Identification of self as role model 13.2. Framing/reframing 13.3. Incompatible beliefs 13.4. Valued self-identify 13.5. Identity associated with changed behavior
18	**14. Scheduled consequences**
	14.1. Behavior cost 14.2. Punishment 14.3. Remove reward 14.4. Reward approximation 14.5. Rewarding completion 14.6. Situation-specific reward 14.7. Reward incompatible behavior 14.8. Reward alternative behavior 14.9. Reduce reward frequency 14.10. Remove punishment
19	**15. Self-belief**
	15.1. Verbal persuasion about capability 15.2. Mental rehearsal of successful performance 15.3. Focus on past success 15.4. Self-talk
19	**16. Covert learning**
	16.1. Imaginary punishment 16.2. Imaginary reward 16.3. Vicarious consequences

<u>Appendix B: Taxonomy of Gamification Concepts for Health Apps (Schmidt-Kraepelin et al., 2018)</u>

<table>
<tr><th>Dimension</th><th colspan="6">Characteristics</th></tr>
<tr><td>Gamification concept-to-user communication</td><td colspan="3">Direct</td><td colspan="3">Mediated</td></tr>
<tr><td>User identity</td><td colspan="3">Virtual character</td><td colspan="3">Self-selected</td></tr>
<tr><td>Rewards</td><td colspan="2">Internal</td><td colspan="2">Internal and external</td><td colspan="2">No</td></tr>
<tr><td>Competition</td><td colspan="2">Direct</td><td colspan="2">Indirect</td><td colspan="2">No</td></tr>
<tr><td>Target group</td><td colspan="2">Patients</td><td colspan="2">Healthy individuals</td><td colspan="2">Health professionals</td></tr>
<tr><td>Collaboration</td><td colspan="2">Cooperative</td><td colspan="2">Supportive only</td><td colspan="2">No</td></tr>
<tr><td>Goal-setting</td><td colspan="3">Self-set</td><td colspan="3">Externally set</td></tr>
<tr><td>Narrative</td><td colspan="3">Continuous</td><td colspan="3">Episodical</td></tr>
<tr><td>Reinforcement</td><td colspan="3">Positive</td><td colspan="3">Positive-negative</td></tr>
<tr><td>Level of integration</td><td colspan="3">Independent</td><td colspan="3">Inherent</td></tr>
<tr><td>Persuasive intent</td><td colspan="2">Compliance change</td><td colspan="2">Behavior change</td><td colspan="2">Attitude change</td></tr>
<tr><td>User advancement</td><td colspan="2">Presentation only</td><td colspan="2">Progressive</td><td colspan="2">No</td></tr>
</table>

Appendix C: Mobile Application Rating Scale (Stoyanov et al., 2015)

SECTION A

Engagement – fun, interesting, customisable, interactive (e.g. sends alerts, messages, reminders, feedback, enables sharing), well-targeted to audience

1. Entertainment: Is the app fun/entertaining to use? Does it use any strategies to increase engagement through entertainment (e.g. through gamification)?

1 Dull, not fun or entertaining at all
2 Mostly boring
3 OK, fun enough to entertain user for a brief time (< 5 minutes)
4 Moderately fun and entertaining, would entertain user for some time (5-10 minutes total)
5 Highly entertaining and fun, would stimulate repeat use

2. Interest: Is the app interesting to use? Does it use any strategies to increase engagement by presenting its content in an interesting way?

1 Not interesting at all
2 Mostly uninteresting
3 OK, neither interesting nor uninteresting; would engage user for a brief time (< 5 minutes)
4 Moderately interesting; would engage user for some time (5-10 minutes total)
5 Very interesting, would engage user in repeat use

3. Customisation: Does it provide/retain all necessary settings/preferences for apps features (e.g. sound, content, notifications, etc.)?

1 Does not allow any customisation or requires setting to be input every time
2 Allows insufficient customisation limiting functions
3 Allows basic customisation to function adequately
4 Allows numerous options for customisation
5 Allows complete tailoring to the individual's characteristics/preferences, retains all settings

4. Interactivity: Does it allow user input, provide feedback, contain prompts (reminders, sharing options, notifications, etc.)? Note: these functions need to be customisable and not overwhelming in order to be perfect.

1 No interactive features and/or no response to user interaction
2 Insufficient interactivity, or feedback, or user input options, limiting functions
3 Basic interactive features to function adequately
4 Offers a variety of interactive features/feedback/user input options
5 Very high level of responsiveness through interactive features/feedback/user input options

5. Target group: Is the app content (visual information, language, design) appropriate for your target audience?

1 Completely inappropriate/unclear/confusing
2 Mostly inappropriate/unclear/confusing
3 Acceptable but not targeted. May be inappropriate/unclear/confusing
4 Well-targeted, with negligible issues
5 Perfectly targeted, no issues found

A. Engagement mean score =

<u>SECTION B</u>

Functionality – app functioning, easy to learn, navigation, flow logic, and gestural design of app

6. Performance: How accurately/fast do the app features (functions) and components (buttons/menus) work?

1 App is broken; no/insufficient/inaccurate response (e.g. crashes/bugs/broken features, etc.)
2 Some functions work, but lagging or contains major technical problems
3 App works overall. Some technical problems need fixing/Slow at times
4 Mostly functional with minor/negligible problems
5 Perfect/timely response; no technical bugs found/contains a ‘loading time left’ indicator

7. Ease of use: How easy is it to learn how to use the app; how clear are the menu labels/icons and instructions?

1 No/limited instructions; menu labels/icons are confusing; complicated
2 Useable after a lot of time/effort
3 Useable after some time/effort
4 Easy to learn how to use the app (or has clear instructions)
5 Able to use app immediately; intuitive; simple

8. Navigation: Is moving between screens logical/accurate/appropriate/ uninterrupted; are all necessary screen links present?

1 Different sections within the app seem logically disconnected and random/confusing/navigation is difficult
2 Usable after a lot of time/effort
3 Usable after some time/effort
4 Easy to use or missing a negligible link

5 Perfectly logical, easy, clear and intuitive screen flow throughout, or offers shortcuts

9. Gestural design: Are interactions (taps/swipes/pinches/scrolls) consistent and intuitive across
all components/screens?

1 Completely inconsistent/confusing
2 Often inconsistent/confusing
3 OK with some inconsistencies/confusing elements
4 Mostly consistent/intuitive with negligible problems
5 Perfectly consistent and intuitive

B. Functionality mean score = ____________

<u>SECTION C</u>

Aesthetics – graphic design, overall visual appeal, colour scheme, and stylistic consistency

10. Layout: Is arrangement and size of buttons/icons/menus/content on the screen appropriate or
zoomable if needed?

1 Very bad design, cluttered, some options impossible to select/locate/see/read device display not optimised
2 Bad design, random, unclear, some options difficult to select/locate/see/read
3 Satisfactory, few problems with selecting/locating/seeing/reading items or with minor screensize problems
4 Mostly clear, able to select/locate/see/read items
5 Professional, simple, clear, orderly, logically organised, device display optimised. Every design component has a purpose

11. Graphics: How high is the quality/resolution of graphics used for buttons/icons/menus/content?

1 Graphics appear amateur, very poor visual design - disproportionate, completely stylistically inconsistent
2 Low quality/low resolution graphics; low quality visual design – disproportionate, stylistically inconsistent
3 Moderate quality graphics and visual design (generally consistent in style)
4 High quality/resolution graphics and visual design – mostly proportionate, stylistically consistent
5 Very high quality/resolution graphics and visual design - proportionate, stylistically consistent throughout

12. Visual appeal: How good does the app look?

1 No visual appeal, unpleasant to look at, poorly designed, clashing/mismatched colours
2 Little visual appeal – poorly designed, bad use of colour, visually boring
3 Some visual appeal – average, neither pleasant, nor unpleasant

4 High level of visual appeal – seamless graphics – consistent and professionally designed

5 As above + very attractive, memorable, stands out; use of colour enhances app features/menus

C. Aesthetics mean score = ______________

<u>SECTION D</u>

Information – Contains high quality information (e.g. text, feedback, measures, references) from a credible source. Select N/A if the app component is irrelevant.

13. Accuracy of app description (in app store): Does app contain what is described?

1 Misleading. App does not contain the described components/functions. Or has no description

2 Inaccurate. App contains very few of the described components/functions

3 OK. App contains some of the described components/functions

4 Accurate. App contains most of the described components/functions

5 Highly accurate description of the app components/functions

14. Goals: Does app have specific, measurable and achievable goals (specified in app store description or within the app itself)?

N/A Description does not list goals, or app goals are irrelevant to research goal (e.g. using a game for educational purposes)

1 App has no chance of achieving its stated goals

2 Description lists some goals, but app has very little chance of achieving them

3 OK. App has clear goals, which may be achievable.

4 App has clearly specified goals, which are measurable and achievable

5 App has specific and measurable goals, which are highly likely to be achieved

15. Quality of information: Is app content correct, well written, and relevant to the goal/topic of the app?

N/A There is no information within the app

1 Irrelevant/inappropriate/incoherent/incorrect

2 Poor. Barely relevant/appropriate/coherent/may be incorrect

3 Moderately relevant/appropriate/coherent/and appears correct

4 Relevant/appropriate/coherent/correct

5 Highly relevant, appropriate, coherent, and correct

16. Quantity of information: Is the extent coverage within the scope of the app; and comprehensive but concise?

N/A There is no information within the app

1 Minimal or overwhelming

2 Insufficient or possibly overwhelming
3 OK but not comprehensive or concise
4 Offers a broad range of information, has some gaps or unnecessary detail; or has no links to more information and resources
5 Comprehensive and concise; contains links to more information and resources

17. Visual information: Is visual explanation of concepts – through charts/graphs/images/videos, etc. – clear, logical, correct?

N/A There is no visual information within the app (e.g. it only contains audio, or text)
1 Completely unclear/confusing/wrong or necessary but missing
2 Mostly unclear/confusing/wrong
3 OK but often unclear/confusing/wrong
4 Mostly clear/logical/correct with negligible issues
5 Perfectly clear/logical/correct

18. Credibility: Does the app come from a legitimate source (specified in app store description or within the app itself)?

1 Source identified but legitimacy/trustworthiness of source is questionable (e.g. commercial business with vested interest)
2 Appears to come from a legitimate source, but it cannot be verified (e.g. has no webpage)
3 Developed by small NGO/institution (hospital/centre, etc.) /specialised commercial business, funding body
4 Developed by government, university or as above but larger in scale
5 Developed using nationally competitive government or research funding (e.g. Australian Research Council, NHMRC)

19. Evidence base: Has the app been trialled/tested; must be verified by evidence (in published scientific literature)?

N/A The app has not been trialled/tested
1 The evidence suggests the app does not work
2 App has been trialled (e.g., acceptability, usability, satisfaction ratings) and has partially positive outcomes in studies that are not randomised controlled trials (RCTs), or there is little or no contradictory evidence.
3 App has been trialled (e.g., acceptability, usability, satisfaction ratings) and has positive outcomes in studies that are not RCTs, and there is no contradictory evidence.
4 App has been trialled and outcome tested in 1-2 RCTs indicating positive results
5 App has been trialled and outcome tested in > 3 high quality RCTs indicating positive results

D. Information mean score = _____________ *

* Exclude questions rated as “N/A” from the mean score calculation.

<u>Appendix D: User Testing Data Collection Tools</u>

Semi-Structured Observation Form

Grade and Gender: ____

Reading Interest: 1 2 3 4 5

Skipping through any dialogue? None Some Most

Any visual frustration or confusion? Yes No

When/Where? ____

Tapping random answers? Yes No

Notes: ____
____
____
____

Qualitative Interview (Example from Grain Foods Module)

Gender: M F

1. What was your favourite part of the game?

2. Was there anything in the game you found confusing?

3. In the game you learned about the grain kernel, can you tell me the 3 different parts of the grain kernel?

4. Can you tell me a bit about the differences between whole grain bread and white bread? (Prompt to discuss nutritional differences if they only discuss grain components)

Quantitative Questionnaire

For each question below, tell us how you found the app, where:
1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree

	Strongly Disagree	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**
1. The app was easy to use.	1	2	3	4	5

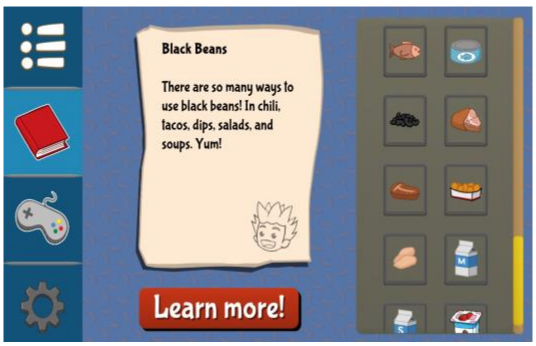
2. The app was too hard.	1	2	3	4	5
3. I was bored.	1	2	3	4	5
4. I want to keep playing.	1	2	3	4	5
5. The game was too repetitive.	1	2	3	4	5
6. The game was fun.	1	2	3	4	5
7. I found the game too easy.	1	2	3	4	5
8. The words in the app were easy to read.	1	2	3	4	5

Appendix E: Foodbot Factory Game Build

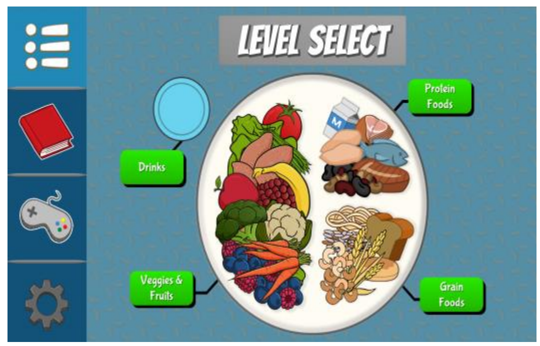
Introduction and Menu

Start Screen

Mini Game Selection



Food Log



Module Selection Menu

Module 1: Drinks

Learning Objectives

1. Recall the best beverage choice for staying hydrated
2. Describe the health effects of different types of beverages
3. Recall different types of sugary drinks

CFG Messages Included:

- Water is the best choice to stay healthy and hydrated.
- Make water your drink of choice instead of sugary drinks.
- Sugary drinks can cause cavities, diabetes and obesity.
- Low-fat dairy and unsweetened soy milk are healthy options.

User Flow Diagram

Sample Screenshots

Sample Dialogue

Drinks Quiz

Drinks “Food Drop” game

Module 2: Grain Foods

Learning Objectives

1. Explain the nutritional differences between whole grain and refined grain products
2. Recall the components of the grain kernel and how grains are refined
3. Describe why consuming fibre is important for health

CFG Messages Included

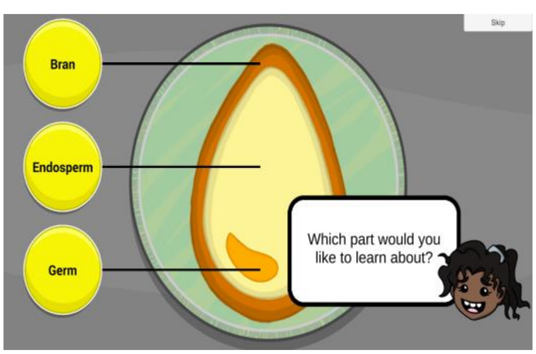
- Choose whole grain foods more often than refined grain foods
- Whole grain foods contain more fibre, vitamins, and minerals than refined grain foods
- Fibre helps you feel full, keeps your digestive system healthy and prevents heart disease and cancer

User Flow Diagram

Screenshots

Sample Dialogue

Refined & Whole Grain “Food Sort”



Interaction: Grain Kernel

Grain Foods Quiz

Module 3: Veggies and Fruit

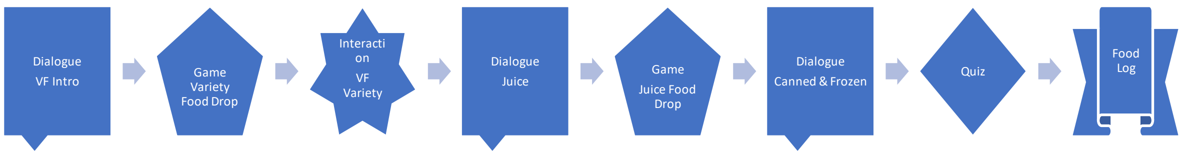
Learning Objectives

1. Recall the amount of vegetables and fruits that should be consumed with a meal
2. Explain why vegetables and fruits are a healthy choice
3. Describe which forms of vegetables and fruit are healthiest to consume (i.e., canned, frozen, juice).

CFG Messages Included

- ½ of your plate should consist of vegetables and fruits
- Vegetables and fruits are a good source of fibre, vitamins, and minerals
- Consume a variety of vegetables and fruits daily that are different colours, textures, and shapes
- Canned vegetables and fruits may contain added sodium and/or sugar but are still healthy choices
- Whole vegetables and fruits are a healthier choice than juices because they contain less sugar and more fibre

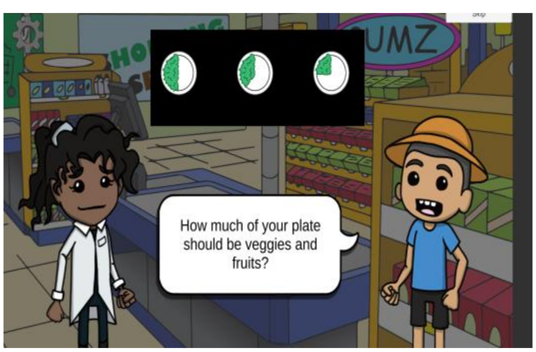
User Flow Diagram



Screenshots

Sample Dialogue

Interaction: Variety



Veggies and Fruit Food Quiz

Veggies and Fruit Variety “Food Drop”

Module 4: Plant Protein Foods

Learning Objectives

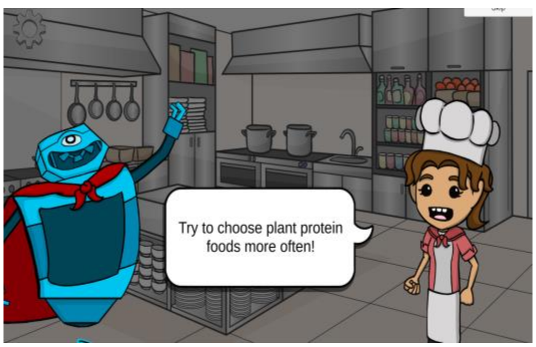
1. Describe what foods are plant-protein foods, and why they are a healthy choice
2. Recall that plant-protein foods contain fibre

CFG Messages Included

- Choose plant proteins most often
- Plant proteins are the only protein source that also contains fibre

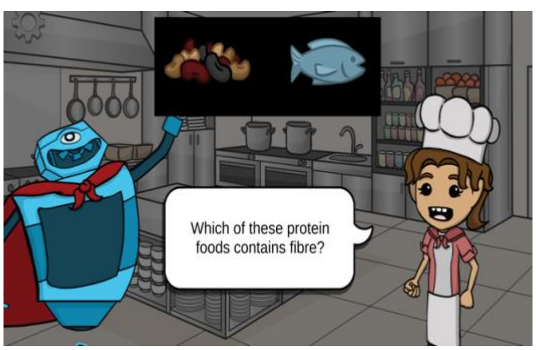
User Flow Diagram

Screenshots



Sample Dialogue

Interaction: Cooking with Plant Protein Foods



Plant Protein Foods Quiz

Module 5: Animal Protein Foods

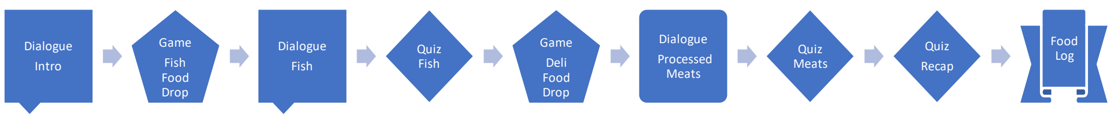
Learning Objectives

1. Recall that some fats are healthy (unsaturated fats) and unhealthy (saturated fats)
2. Describe the health effects of excess dietary saturated fat and sodium.
3. Explain why processed meats should be consumed less often
4. Describe why fish are a healthy choice

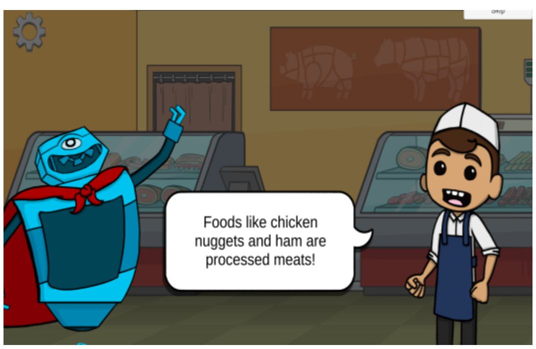
CFG Messages Included

- Processed meats are high in sodium and less healthy saturated fats and should only be eaten occasionally and in smaller portions
- High sodium consumption can lead to health consequences like heart disease
- Fish are a good source of protein and healthy unsaturated fat

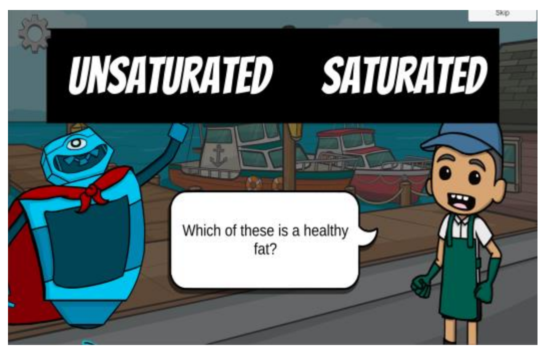
User Flow Diagram



Screenshots

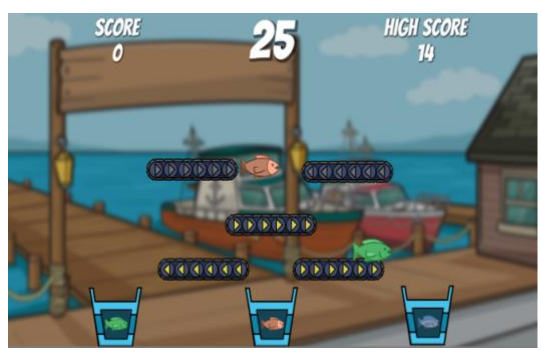


Sample Dialogue



Food Quiz

Processed Meat “Food Sort”



Fish “Food Sort”

Appendix F: REB Notices of Approval

Change Request Approval Notice - REB File #14426 (received February 14, 2018)

researchethics@uoit.ca

Mon 3/19/2018 7:24 PM

To: Janette Hughes <Janette.Hughes@uoit.ca>;

Cc: Jacqueline Brown <Jacqueline.Brown@uoit.ca>; Rileigh Rodych (Research/Project Coordinator) <rileigh.rodych@uoit.net>; researchethics@uoit.ca <researchethics@uoit.ca>;

Date:
To:
From:
File # & Title:

Status: Current Expiry:

March 19, 2018

Janette Hughes

Shirley Van Nuland, REB Chair

14426 - There's an App for That: Designing, Developing, Implementing and Researching Educational Apps

CHANGE REQUEST APPROVED (received February 14, 2018) August 01, 2018

Notwithstanding this approval, you are required to obtain/submit, to UOIT's Research Ethics Board, any relevant approvals/permissions required, prior to commencement of this project.

The University of Ontario, Institute of Technology Research Ethics Board (REB) has reviewed and approved the change request related to the research proposal cited above. This request has been reviewed to ensure compliance with the Tri- Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2 (2014)) and the UOIT Research Ethics Policy and Procedures. You are required to adhere to the protocol as last reviewed and approved by the REB.

Continuing Review Requirements (all forms are accessible from the IRIS research portal):

Renewal Request Form: All approved projects are subject to an annual renewal process. Projects must be renewed or closed by the expiry date indicated above ("Current Expiry"). Projects not renewed 30 days post expiry date will be automatically suspended by the REB;

projects not renewed 60 days post expiry date will be automatically closed by the REB. Once your file has been formally closed, a new submission will be required to open a new file.

Change Request Form: Any changes or modifications (e.g. adding a Co-PI or a change in methodology) must be approved by the REB through the completion of a change request form before implemented.
Adverse or Unexpected Events Form: Events must be reported to the REB within 72 hours after the event occurred with an indication of how these events affect (in the view of the Principal Investigator) the safety of the participants and the continuation of the protocol (i.e. un-anticipated or un-mi140gated physical, social or psychological harm to a participant).

Research Project Completion Form: This form must be completed when the research study is concluded.

Always quote your REB file number (**14426**) on future correspondence. We wish you success with your study.

Dr. Shirley Van Nuland REB Chair shirley.vannuland@uoit.ca

Janice Moseley Research Ethics Officer researchethics@uoit.ca

NOTE: If you are a student researcher, your supervisor has been copied on this message.

Approval Notice - REB File #14879

researchethics@uoit.ca

Fri 6/29/2018 1:54 PM

To:JoAnne Arcand <JoAnne.Arcand@uoit.ca>;

Cc:Khan Tayyib (Research/Project Coordinator) <Mohammed.khan11@uoit.net>; Jacqueline Brown <Jacqueline.Brown@uoit.ca>; researchethics@uoit.ca <researchethics@uoit.ca>;

Date:
To:
From:
File # & Title: ***Status: Current Expiry:***

June 29, 2018
JoAnne Arcand
Shirley Van Nuland, REB Chair
14879 - A pilot study for assessing nutrition and physical activity apps among children

APPROVED
June 01, 2019

Notwithstanding this approval, you are required to obtain/submit, to UOIT's Research Ethics Board, any relevant approvals/permissions required, prior to commencement of this project.

The University of Ontario, Institute of Technology Research Ethics Board (REB) has reviewed and approved the research proposal cited above. This application has been reviewed to ensure compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2 (2014)) and the UOIT Research Ethics Policy and Procedures. You are required to adhere to the protocol as last reviewed and approved by the REB.

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Research Project Completion Form: This form must be completed when the research study is concluded. Always quote your REB file number (**14879**) on future correspondence. We wish you success with your study.

Dr. Shirley Van Nuland REB Chair shirley.vannuland@uoit.ca

Janice Moseley Research Ethics Officer researchethics@uoit.ca

NOTE: If you are a student researcher, your supervisor has been copied on this message.

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