FoodKnight: A mobile educational game and analyses of obesity awareness in children

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Abstract
One of the main contributing factors to child obesity is the absence of education and knowledge children have towards certain foods when they are making food choices. In most cases, children will pick energy-dense food over foods with more nutritional value and do not understand the consequences of their decisions. Our proposed solution to help overcome this problem is an educational gaming application called FoodKnight. Games have the ability to engage children more than traditional teaching methods used in schools, and capitalising on this exciting approach would be beneficial for children. FoodKnight incorporates stealth learning to disguise the teaching of healthy food choices while playing a game; a step-counter is also included to encourage the user to be active. The overall feedback FoodKnight received from 38 participants regarding the initial prototype was positive. Minor issues found with the game were addressed and implemented in an update. FoodKnight has been implemented in the Android mobile platform to increase accessibility.

Keywords
child obesity, educational gaming application, food choices, health informatics, mobile development, software development, stealth learning

Introduction
Child obesity is of great concern in the public health sector of New Zealand and also around the world. It has been reported by the World Health Organization (WHO) that the number of overweight and obese young children increased globally from 32 million in 1990 to 41 million in 2016. In addition, the number of overweight and obese children could reach 70 million globally if the...
current trend continues. Combating this issue early in a child’s life will surely be very beneficial; no intervention means overweight and obese children will remain this way as they mature to an adolescent and finally into adulthood. Recent statistics from the American National Centre for Health indicated that in America, 80 per cent of obese children will remain obese into adulthood.

Obesity affects not only the child’s health, but also their education and the quality of their life. Effects associated with obesity include more frequent bouts of obstructive sleep apnoea (stopping breathing when sleeping), musculoskeletal disorders (pain in joints, ligaments, tendons, nerves, and muscle structures that support the body), and asthma. Psychological problems also play a part in obesity as they can cause poor self-esteem in a child, which can ultimately lead to depression. Obesity puts children at great risk as they are more susceptible to inheriting health and mental problems during their childhood and later on in life. Obesity that is carried through to adulthood creates a greater risk of establishing long-term health problems like diabetes, heart disease, chronic pain, mental illness, and some cancers, which is why intervention measures should be put in place early in a child’s life.

One of the contributing factors to child obesity is a lack of education for children when it comes to making the right food choices and a lack of understanding of the consequences of those choices. For example, distinguishing a healthy food option, such as a piece of fruit or vegetable, over food that is energy-dense and high in sugar, fat, and salt, and understanding the benefits of the healthy alternative are critical for a young child. As food preferences can be established early in their life, consuming unhealthy foods in childhood can also result in poor food choices later on in life; trying to break that habit can be difficult for any child. It is also important for children to make the right food choices, selecting healthier options rather than high-energy food with no nutritional value. For example, in New Zealand, currently there are programmes throughout schools, as reported by Education Review Office (ERO), to teach children about food, nutrition, and physical activity. This report assessed the current status of food, nutrition, and physical activity in schools and early childhood services.

One potential approach used in schools, which has shown recent success for teaching children about the severity and consequences of obesity, is high interactive video games or mobile platform games. Games are very appealing and in this digital age have great power to engage children’s attention. In addition, they have the potential to improve children’s learning abilities such as thinking skills (critical thinking) and decision-making. More importantly, games have been found to have positive effects on students’ cognitive, physical, and social development and to engage students more effectively than the traditional method of teacher–student interaction. This is due to the immersive qualities of games, for instance, a game provides clear goals which can be customised. This means the goals of a game can be pursued by the student without expecting any award or questioning why. This allows students to work at their own pace while their full attention is captivated by the game. Compared to the traditional teaching method, where a student can fall behind or become bored as they have no control over what they learn, the speed they are taught at may be too fast for the student to process. Video games have the ability to stimulate the release of dopamine in the brain while playing. This is important as dopamine is a precursor chemical for memory storage, which means video games chemically prepare the brain to learn.

Effective learning methods in gaming usually incorporate self-efficacy (the belief an individual has in their ability to achieve a goal) and offer a reward system such as points, levels, abilities, and weapons to the player at positive decision points to encourage the player to keep playing. Goal setting (having a well-defined goal which allows for learning) is another vital feature available in games which motivates players to achieve the predefined set of goals. Inquiry-based learning (experimentation, discovery, and choices made by the player) encourages the player to experiment. For instance, what happens when I touch this? These are all great learning methods which can be
implemented into games. All these features trigger the adoption of interactive games for learning, especially for children and adolescents.

This research intends to design and implement an educational mobile gaming application in Android called FoodKnight to help educate children about healthy food decisions. Based on the preliminary data analyses conducted on collected data and reviewing of the existing apps in the literature, the findings suggest the target population of the game to be children aged 5–12 years. Our motivation is purely social as child obesity is a growing concern, and trying to educate children through a different medium may be beneficial and make it easier to reach our target audience. We will use the stealth learning method as a way to engage children and try teaching them about food choices when playing the game. Stealth learning is when non-traditional tools like games are used to disguise learning objectives to promote fun while learning. Students could think they are just playing a game, but they are also learning at the same time; hence, students are unaware they are learning, which is an unexpected benefit. The methodology followed to design and implement the mobile app game is based on a mixed research approach in which both quantitative and qualitative methods have been utilised. We critically analysed the existing mobile games apps that targeted a similar population and then designed and implemented our game using Android Studio version 3.4.1 with a My Bitnami Parse API database which is hosted on Amazon Web Servers. This research answers the following research question:

How could stealth learning be used to develop a mobile game for raising obesity awareness among kids?

FoodKnight’s unique proposition from the existing mobile games applications is that it allows users to compare step counts with their peers, which can provide opportunities for learning and encourage complex skills in students such as decision-making.

The article is structured as follows: section ‘Literature review’ covers similar gaming applications to give an overview of what has been developed so far related to obesity. In section ‘Proposed game solution – “FoodKnight”’, FoodKnight, the proposed solution, is discussed thoroughly, including key functionalities. In the same section, the data analysis results, based on the survey feedback received from the first prototype, are discussed. Conclusions and future works are highlighted in section ‘Conclusion and future work’.

**Literature review**

A report issued by ERO (New Zealand) collected information from 202 early learning services, 46 primary schools, and 29 secondary schools in New Zealand to educate children about food. Out of the 46 primary schools evaluated, 12 schools were not doing very well at promoting a positive attitude to health, nutrition, and physical activity. One of the challenges they faced was that teachers lacked confidence and the capability to provide a curriculum which promoted healthy lifestyles. A second report that discussed the effective practices of food, nutrition, and physical activity in schools was released. This report found schools that engaged students based on interest, compared to traditional curriculum methods of teaching in the classroom, responded and performed well to those programmes. Children were interested in colour-blending, so teachers used this opportunity to explore this interest by blending different coloured vegetables and fruits to create healthy smoothies which also gave the opportunity to educate children about healthy food choices.

Mayo discussed the potential of games in providing extensive education such as scale, compelling, and brain chemistry, among others. Games have a large audience and have the potential to
reach many people. People already play a lot of games, in some cases up to 8 h a day; now with smartphones, they have the ability to play almost at anytime and anywhere. In addition, games are interesting to many people and have the ability to draw people in. When playing a video game, the brain stimulates a chemical change which helps encourage learning. Finally, games are better than a lecture; a study showed the effectiveness of using video games with an improvement of 30 per cent and upwards compared to the traditional lecture method. Despite the advantages of games in education, they can become addictive in other potential arenas.

**Child obesity applications and games**

*Child Obesity & Healthy eating Habits for Fat Kids.* The Child Obesity & Healthy eating Habits for Fat Kids app is not a game, but more an informative app for parents which was developed by a nutritionist/dietician. This app helps parents with overweight or obese children to learn about healthy eating habits which they can develop for their children to lose weight. The app contains abundant information about child obesity, which can be beneficial for the user, such as symptoms, causes, complications of obesity, treatment, risk factors, and tips to prevent obesity. It also highlights the healthy foods obese children should be eating and the bad foods they should be avoiding. This app is currently only available on the android platform and has an average rating of 4.4 stars out of 5.

*Healthy Eating with Diana.* Healthy Eating with Diana is an app made by the Mútua General de Catalunya Foundation, a non-profit health insurance organisation based in the Catalan region of Spain. Like FoodKnight, the app appears to have social rather than business aims. The app is free to download, and the page on Google Play Store clearly states that the app contains no in-app purchases and no advertisements of any kind. This app is constrained to landscape orientation, which makes sense because this sort of app seems to work best in this format. The simple, wide, colourful illustrations work well on smartphone screens. This appears to be one of a series of apps intended to promote healthy habits and lifestyle choices to children. These images work well as illustrations, but there is a surprising lack of animation in the app. There are some activities, such as sorting foods into the food pyramid, that are very clearly linked to the social aims of the app. Other activities, such as the jigsaw puzzles, simply feature images related to healthy eating. Before each activity, there is an alert explaining the objective of the activity, but there are very few instructions related to the controls of the activities as these are very intuitive.

*Healthy Hero Pro.* Healthy Hero Pro is a gaming app where you play as a Superhero and control your flight to collect fruits and vegetables while avoiding hazards. These hazards include different types of junk foods and, if collected, cause the Superhero to lose a life. Your score increases as you collect all the healthy foods. Other important elements in the game are water and milk collectables, which help give the Superhero special powers for a short period of time. The aim of the game is to try to score while travelling the longest distance as much as possible. This game can
help players differentiate between healthy and junk foods. The current rating of the app is 4.6 out of 5 on the Google Play Store.15

**Fit the Fat 2.** Fit the Fat 2 is a gaming app where you play as the main character who is obese, with the aim of losing weight and getting fit. Fit the Fat 2 has potential to benefit the player by educating about the contributing factors of obesity and ways they can be combated. This is achieved through exercise activity in the game, deciding what to eat, and the amount of rest to have. At the start of the game, the subject weighs 507 lbs, and through exercise, eating the right type of foods/drinks, and having enough rest, his weight starts to decrease. Not doing these things results in an increase in weight, which is the opposite goal of the game. Another feature of the game is that it incorporates Google Fit, so when you exercise in real life, the main character also loses weight. This app is available on Android and iOS devices. The current rating of the app is 3.8 out of 5 on the Google Play Store.16

**Platformer games**

**Celeste.** Celeste is a single-player, mountain-climbing platformer game developed by Matt Makes Games studio.17 This game tells the story of a young woman named Madeline who is struggling with inner demons, and climbing the mountain is her ultimate achievement. For Madeline to conquer the mountain, the player must navigate through hundreds of platform levels filled with hazards such as spike pits and monsters. Jumping, mid-air dashes, and wall climbing are abilities the player can utilise to avoid these hazards and navigate through each level. There are secret rooms and collectables at each level, which encourages the player to experiment and test their limits. Collectables like strawberries are obtained by performing acrobatics or solving puzzles; these collectables unlock a bonus ending and levels in the game depending on how many are collected.18 Celeste is only available on gaming platforms like PC, PlayStation, Xbox, and Nintendo. The reviews for this game have been overwhelmingly positive and received an average aggregated rating of 91.25 out of 100 for all four platforms.19

**Super Mario Bros (original version 1985).** Super Mario Bros was developed by Nintendo in 1985 and has been cited as one of the best games of all time.20 This is a platform video game where you control Mario or Luigi (if playing multiplayer) who is trying to rescue Princess Toadstool. He/they must traverse through Mushroom Kingdom, which contains side-scrolling stages, and must avoid hazards such as enemies and pits. Various power-ups are included in the game which can aid Mario/Luigi through the levels. The game features coins which the player can collect to gain another life. After collecting 100 coins, a green spotted orange mushroom hidden in bricks, once collected, can replenish a life. Mario can lose lives by getting hit by enemies, falling in a pit, or running out of time; the game ends once all lives have been used. Mario’s primary attack is jumping on top of enemies.21 The first level is known as World 1-1 and was created by Shigeru Miyamoto. This level was a different form of tutorial which contained everything a player needed to naturally understand what they were doing in the game, allowing the user to understand the
mechanics of the game. This game is currently available on Nintendo Entertainment Systems platforms.

*TowerFall Ascension.* TowerFall is a two-dimensional platformer shooter that uses simple bright-coloured pixel art, reminiscent of the images created by 8-bit computers and early gaming consoles. Pixel art like this is an effective and popular aesthetic that appeals to the games’ target market. Creating this sort of game is less demanding in terms of technology and time than the process of creating a more realistic game. Design choices like these allow a small team with limited resources to create a complete and enjoyable game. TowerFall features a range of playable characters that are designed and coloured in a way that makes it easy for players to quickly identify them during fast-paced game play. This character design also means the game reproduces effectively on a small screen. The game has no online multiplayer functionality; the creator has stated that the nature of the game as a fast-paced two-dimensional shooter means that even a small variation in latency would be highly detrimental to game play, and this makes online multiplayer functionality impractical. Given the limitations of current technology, an effective online game may need to adjust the speed of game play or the nature of player interactions to account for the practical concerns of playing online.

**Other games**

*Duolingo.* Duolingo is the fourth most popular free application in the category of family games for children aged 6–8 years on Google Play Store. The goal of Duolingo is to help users translate text or learn more languages for free and save time; there are many other language options in the application. The design helps users to pass lessons and translate texts and documents. Duolingo has four versions that have appeared on web, Android, Windows Phone and iOS. It is simple, colourful, intuitive, and easy to use. This app has a range of interesting rewards and micro achievements that create feelings of progress and achievement. The version has a timed practice section for players to be awarded 30 s with 20 questions if a correct answer is given in the game. In the practice section, players will practise their quick reflexes and gain more knowledge before playing the level of the game. This application expresses itself as primarily concerned with education, but whether this is honestly effective marketing is not clear. By the end of the game, the user is able to learn another language and can also help translate text when it is in another language. Duolingo has achieved an average rating of 4.7 comments for the app (Google, 2019). This is a paid application, so not all features are available on the free version as it is time-locked.

*PJ Masks.* PJ Masks Moonlight Heroes was developed by Entertainment One (eOne, 2017) as a fun jigsaw game for children aged 6–7 years. This game is a bit boring (just avoiding obstacles), but the colours used are very eye-catching. Currently, there is only one version for children because the game developer wants to get attention from children to download and experience the game. Each main character in the game will have different levels of play with challenges for players of all levels. In the end, the player will see the scores he earned in each game. The PJ Masks Moonlight
Heroes game has achieved a 4.3 rating (eOne, 2018), and the percentage of users downloading the experience is also very high because the game looks cute for children. Most users are happy to play this game, but sometimes teenagers find it a bit boring because it is too colourful.

Roblox. Roblox is a multiplayer online platform that allows users to design their own games and play various types of games created by other users. Roblox is the most popular free app in the family game category for children aged 6–8 years in the Google Play Store with nearly 8 million ratings, ranking an average of 4.6 stars over the years since release. Users can download Roblox on Android, iOS, Xbox One, and Kindle platforms to experience an online collaboration platform that allows players to access millions of other popular three-dimensional online games on Google Play. Roblox is clearly a very successful game in terms of building audiences because it allows users to create their own games and financial growth, but its social impact may not be positive. Users under the age of 13 years are restricted from communicating with a selection of pre-written phrases to avoid inappropriate language. However, despite the efforts of Roblox management, a large part of the community seems willing to avoid censoring and is bringing old content into Roblox games. Roblox may be another example of the sophistication of video games where users are forced to continue to play regularly due to concerns that the resources and time they have invested will be wasted if they stop, instead of continuing to enjoy real fun (Fahey, 2019).

Discussion

The Platformer games reviewed - TowerFall, Celeste, and Super Mario Bros – allow players to progress through levels and to move to new worlds with new pickups, new hazards, new enemies, and new mechanics. This creates variety, keeps the player engaged, and gives more opportunities to explore, experiment, and discover which are important if the game is adequately embracing inquiry-based learning. Platformers contain little or no information and focus purely on entertainment rather than education or a social message. Super Mario Bros is a particularly interesting example. The first stage of the game is called ‘World 1-1’, which provides users a chance to familiarise themselves with the controls and the movement of the character. This will help the average user as they are able to pick up and play the game without the need for any extra information. In regard to the child obesity application, there are a number of good features included: ‘Healthy Heroes’ and ‘Fit the Fat 2’ used a form of stealth learning in their games, ‘Child Obesity & Healthy eating Habits for Fat Kids’ contains an abundance of information about child obesity, and ‘Healthy Eating with Diana’ contains no adverts. The majority of the applications reviewed demonstrate an effective use of colour and highly competent character design. It is important that users are able to quickly and easily recognise characters and other important elements of the game when they are presented on smartphone screens.

One main drawback with the majority of the applications reviewed is the prominence of advertising and the nature of these advertisements. For example, Fit the Fat 2 uses Google’s ad services, which selects advertisements based on a user’s search history rather than any criteria related to the application. This means an advertisement could be unrelated or even contradictory to the message and aims of the application. Another concern is balance; ‘Child Obesity & Healthy eating Habits for Fat Kids’ provides a great deal of useful information, but it is not a game. Another drawback we experienced was the nature of some games; ‘Healthy Heroes’ is designed to be endless, and these
tend to become repetitive as the environment does not change as the player merely chases a high score.

Based on games and applications reviewed, we will try and include all the applicable positive features mentioned above in our development of FoodKnight. The drawbacks discovered will be left out of FoodKnight as we found these to be an issue, and we want this educational gaming application to be the best possible. For example, we decided to exclude all advertising from the application to avoid any conflicting messages. A number of platformer games we researched make the player restart a level when they lose a life, so we decided to use a different approach as restarting a level can be frustrating especially for young players. We also added extra functionality to make FoodKnight unique from the applications we researched, such as a form of pedometer that allows users to compare steps counts with their peers.

Proposed game solution – ‘FoodKnight’

Child obesity is a prominent and growing concern worldwide for reasons already discussed in section ‘Introduction’. Preliminary research suggests that school health curricula, and similar conventional measures aimed at changing children’s behaviour, are not particularly effective. Innovative ideas and mediums may be required to reach children to promote health-related behavioural changes. Video games may be one such medium. Video games have positive connotations for many children and young people. Our research suggests a mobile gaming application would be an effective way to promote healthy eating and exercise to children. Broadly speaking, this application could be considered an ‘advergame’, which is a video game used for advertising. This can be a game created or sponsored to advertise a company, brand, product, or range of products.

Our app is intended to advertise healthy food and exercise in all possible forms rather than a specific brand or piece of exercise equipment. As per previous research, it is around the age of 8 years that children begin to understand the intention of advertising; children have a much harder time understanding the nature of ‘non-traditional and embedded forms of advertising, including advergames’ (Van Reijmersdal, 2011).29 Games like the one we have created have the potential to have a more significant influence on this audience because they are viewed as entertainment rather than advertising. Children who view these games as entertainment rather than advertising are less likely to apply any knowledge of persuasion they possess as ‘a critical defence while processing a persuasive message’ (Van Reijmersdal, 2011). The positive connotations video games have for children make them more persuasive.

This information suggests that advergames should be closely examined by local and international advertising regulatory bodies because they are a powerful tool for communication and persuasion. Pempek (2009)30 effectively documented how the same techniques that are used to promote companies, brands, and products through advergames can be used to promote healthy choices. Furthermore, if they are well made, these positive advergames can have significant, measurable, positive results on the behaviour of their audience. Operant conditioning, which is an approach that employs behaviour and consequences using a rewards and punishments system while playing a game,31 is prominent in video games. Figure 1 helps to explain our attempted use of a mild form of operant conditioning. If the player collects one of the various fruits and vegetables arranged throughout the stage, they are rewarded. This means their score increases by a set amount, their speed increases, and they can jump slightly higher. In contrast, if the player bumps into one of the enemies, they are punished. This means their speed decreases, and they cannot jump as high. Their avatar also becomes wider, making them a larger target, crudely representing weight gain. In Figures 1 to 4, the player’s score is on the right-hand side and their remaining lives are on the left-hand side. The player with three lives left in Figure 1 is much
Figure 1. Stage 1 is intended to be easy and to provide an opportunity for players to familiarise themselves with the controls, pickups, and standard enemy movement. Players can head straight to the exit or collect pickups to increase their score.

Figure 2. Stage 4 introduces ice; the blue blocks with a light blue stripe are covered in a simple material with the friction set to zero. The character can change direction, but the character cannot stop moving while on these tiles.

narrower than the player with no lives left in Figure 3. Perhaps, most importantly, when the player touches an enemy or a pizza spike, they lose a life. Once a player loses three lives, the counter on the left of the screen drops to zero, which means the next time they touch an enemy or a hazard the game is over. Giving the player multiple lives or chances is meant to make the game last longer and give the player more opportunities to learn. These enemies are sinister anthropomorphic walking representations of the products that our research indicates contribute the most significantly to childhood obesity, including sugary soft drinks, burgers, and pies, among others.
We created this app for the Android operating system using Android Studio, and the game is accessible via the Google Play Store. The game within the app was created in Unity, which is a cross-platform game engine. We also used the Bitnami Parse API which is targeted at mobile developers. Figure 5 depicts the navigation diagram of the proposed app. As this diagram shows, a user may play the game without registering or logging in which makes key content more accessible and increases the potential audience of the app. However, a user must register to complete a survey or create a step count. This diagram shows how registered and unregistered users will navigate through the app and available functionalities to each type of user.

Figure 3. Stage 7, the difficulty of this level varies depending on whether the player heads straight to the exit or attempts to collect all the pickups and get a higher score.

Figure 4. Stage 9 is short but comparatively challenging. It is intended to test the player’s decision-making and their understanding of how far and how high the character jumps. It is our intention that the average player may not successfully complete the entire game on their first attempt.
Character design

Creating a protagonist that can engage with your audience is a very important step in the process of developing games such as FoodKnight. The degree to which the audience engages with the main character will significantly influence their enjoyment of the game, the amount of time they spend playing the game, and the extent to which they are influenced by the message of the game. We
sketched and discussed several possible character designs before deciding on South the Star (full name ‘Southern Cross the Fourth’). Our research indicates stars are seen as a positive symbol almost universally. A star named South is ambiguous in terms of gender and is not linked to any one particular group. It is our intention that the player is able to project on to this character any ideas and personality traits they wish.

We aimed to provide a largely blank canvas and to allow the player’s imagination to provide the missing information. Having a non-human protagonist also made it much easier to address some of the issues related to childhood obesity with reduced potential for negative reactions. Our research indicates blue is the most popular colour globally, so the main character is predominately tiffany blue. This shade of blue is popular with children in our target demographic; it is particularly popular with girls aged between 2 and 10 years. This choice of colours means the main character is clearly distinct from the background, the pickups, and the enemies, which is important as it must be easy for the player to tell these elements apart on a small screen.

We put considerable effort into making sure the enemies looked as sinister and antagonistic as possible while ensuring they closely resemble the unhealthy food choices they represent. The three products – pies, burgers, and sugary soft drinks – contribute the most significantly to the problem of childhood obesity in New Zealand, and our research indicates they contribute significantly to the problem of childhood obesity globally.

To be effective, our application must reach a wide audience. As our target audience is young children, we must appeal not only to the children themselves but also to their parents, caregivers, and educators. One key element that we assume should help us appeal to these parties is our lack of commercial interest. We are motivated purely by a desire to have a positive social impact, and the lack of any ulterior motives will hopefully mean the application is considered trustworthy, educational, and beneficial. If our assumption proves to be correct, children may be allowed to play our game in locations such as classrooms and public libraries where they are not allowed to play more conventional commercial video games. These circumstances would give us unique opportunities to engage with our audience.

**Key functionalities**

*Play the game.* The most important function of our app is to allow users to play the game. The game is intended to be logical and intuitive. Our intention is that a user should be able to pick up the app and play the game without any extra instruction. The game requires only the on-screen joystick to play, although there is a jump button in case some users prefer this option. The game uses a conventional platformer layout with lives on the left-hand side and score on the right-hand side. The enemies are designed to very clearly look like enemies, and there is an interactive start screen where the user can move the character around and familiarise themselves with the controls before the game starts properly. However, a written tutorial is provided in case extra information is required. A user may play the game without logging in or registering, which was an important decision early in the development process.

*Register.* A user must register to access the app’s other functionality, but they are free to play as much as they wish anonymously. This is an important consideration given the young age of our target audience. A child should not register without their parent’s permission, and a parent may choose not to give a child permission to register. If a child is unable to register for any reason, we still want them to be able to play the game and hopefully to be positively influenced by its message and ideas. We have attempted to prevent children registering without the permission of their parent
or guardian by specifically asking for a parent’s email address during the registration process. This is also a practical consideration as young children may not have their own email address.

**Complete a survey.** Once registered, a user can complete a survey which is intended to help us improve the app and allow us to measure its possible influence on the attitudes of the user over time. This is important as our measurable organisational value (MOV) is focused on social impact. Ideally, a user will complete multiple surveys over an extended period. These surveys should show a marked improvement in the user’s attitudes towards healthy food and exercise as they play the game.

**Count steps.** Our app also allows people who have registered to use Android’s built-in pedometer to count approximately how many steps they take while the ‘Step Count’ activity is open on their phone. The step count on Android’s built-in pedometer resets when the phone is rebooted. Users can submit their step count and there is a leader board that shows the eight highest step counts that are currently stored on the server. This should motivate users to compete with their peers in the community of app users. Hopefully, this will also demonstrate the positive influence our app can have on a user’s attitude towards exercise as a user’s step counts increase over time.

**User feedback – survey results**

The first prototype of FoodKnight was released and two surveys were provided for user feedback. From the survey, we managed to obtain a total of 38 participants’ thoughts on FoodKnight. Our target audience for the initial prototype survey were children, adolescents, and adults, and most had some experience with mobile games. For children, adults including parents or family members filled out the survey and provided the feedback on their behalf. The target population of our survey can be divided into three categories: children who are the intended audience of FoodKnight, parents and guardians who will ultimately decide what their children are allowed to play, and information technology enthusiasts who were able to offer useful feedback based on their area of interest. We surveyed a diverse range of people from those three groups. One survey was included within the FoodKnight app for the registered users. This survey was basic and consisted of a few questions that covered the possible improvement of a user’s attitudes towards fruit and vegetables as they become more proficient at the game. This survey could be completed from anywhere using the application.

The second survey was a detailed questionnaire that included nine questions to try and understand users’ first impression, experience, and improvements we could tackle for future development of FoodKnight. Both surveys were created based on the intention of users to provide feedback on the prototype and any possible improvements that could be implemented. The survey was administered with the first release of the FoodKnight prototype. Participants were asked to first play the game and then fill out the survey within the game or fill out the detailed questionnaire feedback survey on a separate word document. This survey was completed in person, which encouraged more detailed responses. We received an overall response rate of 38 completed surveys: 20 of those feedback surveys filled out were of the detailed questionnaire and the rest coming from the survey within FoodKnight. All information was collected anonymously, and the user had to consent before participating in the survey. The feedback received gave us an insight into how the users felt about our first prototype and some changes we could make. Overall, the weighted average score FoodKnight received from users was 4.1 out of 5, which showed promising signs and encouraged our team.
We sorted the feedback into two categories – positive comments about the prototype and improvements; improvements was sub-categorised into short-term and long-term. Our main focus was on the short-term improvements due to the release date we set for FoodKnight. We used the data collected from the survey to determine what improvements we should make, and we were able to prioritise these possible improvements based on the number of times key words or phrases were repeated in the survey results. The two most common phrases related to short-term improvements were ‘small joystick’ and ‘no instructions’. The most prominent suggested short-term improvements were to increase the size of the joystick, add a tutorial about the game, add more levels, adjust the jumping mechanism, and adjust the name. Based on this feedback, all of these changes were implemented in the final design of FoodKnight. Increasing the size of the joystick and adding a tutorial became our top priorities based on the survey results. Some common long-term feedback will be discussed in the following section.

Limitations of FoodKnight

Numerous feedback suggestions were received for the FoodKnight prototype, but the main limitations we had to apply these suggestions were time and development skills. The common long-term feedback we received was to add the ability to neutralise the enemies, change colours on levels, earn lives, add some informative information about nutritious foods/obesity, save the level last achieved, and develop FoodKnight on the iOS platform. All these suggestions require extensive work, and with so little time we are unable to implement them in FoodKnight. These comments will not go ignored and have been categorised as long-term/future work, which will eventually be added to FoodKnight sometime in the near future. In addition, one possible expansion of this game is to use machine learning technology to make users intelligently learn from their experience while playing the game. This approach can be similar to recently used machine learning approaches in health informatics such as autism spectrum disorder.\textsuperscript{32–34}

Conclusion and future work

Our research indicates that school health curricula and similar conventional measures aimed at changing children’s attitudes and actions related to healthy eating are not particularly effective; hence, childhood obesity remains a growing concern. Therefore, innovative ideas may be required to reach children and promote health-related behaviour changes. Video games are a new medium that has been shown to effectively engage with this generation of children. Our proposed solution is to create a gaming application intended to promote health-related behavioural changes in a manner that is unique to this medium. FoodKnight encourages stealth learning by taking education out of the classroom and encouraging children to reach set goals at their own pace, in their own way, and at whatever time they choose. Like many video games we encountered in our research, FoodKnight encourages inquiry-based learning. The game does this by allowing children to experiment and discover in virtual spaces free from judgement, criticism, and negative consequences that can stifle a child’s experimentation in the real world. Video games allow users to adjust their own objectives and level of difficulty depending on whether a player is simply aiming to complete the game to set a high score or to finish the game in the fastest possible time. FoodKnight and South the Star are intended to engage with a young audience over an extended period, and the application has measures in place to encourage children to improve their health and fitness and to document these changes in a subtle and largely anonymous manner. Unlike many games that claim to have altruistic social objectives but are in truth beholden to some combination of sponsors, advertisers, politicians, and business objectives, FoodKnight’s sole objective is to encourage children to change their behaviour.
in a way that our research indicates will be beneficial to their long-term health and happiness. Initial data collected from the first prototype suggested a 4.1 out of 5 satisfaction level among the target population and revealed potential areas of improvement that we intend to address in updated versions of the game. In our first update, we changed the scoring, so each type of healthy food is now worth a different number of points. We could further enhance this change by including unhealthy foods that are worth a negative number of points and reduce the player’s score if collected.

In near future, we are going to enhance FoodKnight by including more intelligent features based on artificial intelligence techniques in which users will be able to learn from the experience of playing the game. FoodKnight if adopted by schools will contribute to raising awareness regarding obesity to kids as it employs an interactive learning approach encouraging high levels of engagement.

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