



# DIGITAL SERIOUS GAMES FOR PROMOTING HEALTHY EATING HABITS IN CHILDREN: A CASE STUDY IN BRUNEI DARUSSALAM

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## ABSTRACT

*Obesity, childhood or otherwise, remains a deeply concerning health matter in the modern world, but especially in Brunei Darussalam. As such, this research endeavours to identify and implement a serious game aimed at helping children acquire healthy eating habits as a potentially innovative solution to trim down obesity. The practical aspect of this study involves the digitisation and testing of an existing educational board game centred on healthy diets, known as All You Can Eat (AYCE), on Bruneian children. This digital transition enhances the game's accessibility from its traditional physical counterpart, making it more readily and widely available in keeping with rising gadget usage. Furthermore, AYCE has been culturally adapted in relation to the food menu and language support to suit the local Malay context. The outcomes of these tests are vital for further validating the concept of serious games and their need within the context of health. The findings from this research can also apply to various other serious games extending well beyond healthy eating habits. In addition to the field of study, ensuring the relevance for future health-related serious games, inspiring not just educators and medical practitioners but game designers alike. This would create more multidisciplinary collaboration, all towards applying serious games for the purposes of first educating and then subsequently improving the health of everyone involved.*

**Keywords:** Serious games, obesity, Brunei, *All You Can Eat (AYCE)*, healthy diet

## INTRODUCTION

Obesity among young children is an increasingly concerning issue, even going so far as to be labelled a drastic global public health issue (Hussin and Ikram 2022; Kusumah and Kurniawan 2024). This concern is made worse by how obesity is largely a preventable affliction which, unless addressed early, would persist into adolescence and adulthood by which time the negative impacts would have already taken hold of their lives and the damage would become permanent. Brunei is not exempt from this worrying trend either, as highlighted countless times by its Ministry of Health. In fact, the sultanate has had headlines that call for the urgent need to reduce the numbers of obese individuals; at one point in 2016, the statistics revealed that 50% of elementary school children were either obese or overweight. This has been the reality for over two decades now and with slight improvement to show for it. Interestingly, the level of dietary knowledge amongst young children is still generally not well understood, which could significantly affect their daily eating habits and eventually lead to choices that will shape their bodies and health for the worse in the long term. The gap becomes more pronounced, especially when the Bruneian context is taken into account, and when paired with the need for digital intervention through mediums such as serious games, which are entertainment platforms designed to engage students in acquiring and exploring new knowledge. Their capacity for promoting new behaviours and modifying existing ones make this untapped prospect significant within the region of Southeast Asia, where unhealthy lifestyle choices that increase the likelihood of developing obesity, such as frequency of eating and being picky eaters, are more ingrained (*The Scoop* 2018; Hussin and Ikram 2022; *The Star* 2024).

The motivation behind this research is to explore the potential of the serious game *All You Can Eat (AYCE)* in raising awareness of healthy eating habits among Bruneian children. This study investigates how *AYCE* engages children's interest, serves as a learning tool for healthy eating, and how children behave during gameplay. To answer these questions, this study utilises playtesting, which includes pre-play and post-play assessments to determine whether students' knowledge increases through *AYCE*. Additionally, satisfaction surveys were distributed to gauge student interest in *AYCE*. The observation assessment of the children's behaviour was conducted by the researchers as they played the game. In the bigger picture, this research also aims to identify more serious games that can help children acquire healthy eating habits. This will be achieved by first digitising *AYCE*, an already existing educational board game concerning healthy

diets. Based on the results of a previous informal pilot study in Taiwan with a physical version of *AYCE*, it has been verified that the format and gameplay of the serious game could well stimulate children's interest in healthy diets.

The now-digital format will make it more readily available and accessible compared to the traditional physical board game. Additionally, *AYCE* has been redesigned to adapt to the local culture of Brunei Darussalam by incorporating Malay, the primary language used, and featuring more types of cuisine familiar to the region of Southeast Asia. The results from these tests are not only imperative in helping the researchers further validate the concept of serious games about health, but they can also be applied to a variety of serious games related to a myriad of general health topics, and thus are not solely confined to healthy eating habits. Conducting this study would provide enormous benefits for children who are overweight or have problems with obesity. The digital online serious game will be adaptable to various educational environments without the limits of location or hardware. Both teachers and parents alike could use *AYCE* as a much-needed tool to supplement efforts in educating their children on healthy eating habits. Such a study would help other researchers from intersecting disciplines better understand the needs of children. From a theoretical perspective, these advancements would enable technologies, particularly games, to provide social support for health-related issues. Individuals and communities can benefit from improved health and well-being because the project enhances their overall quality of life. As such, the practicality and usefulness of digital technology as a platform would be further demonstrated by its ability to accommodate a wide array of health issues.

## LITERATURE REVIEW

### Childhood Obesity in Brunei

Childhood obesity is a global health concern, with its prevalence having more than doubled since 1975 (Zapata et al. 2025). Based on a World Health Organization (WHO 2012) report, approximately 170 million children under 18 are overweight. Childhood obesity increases the risk of medical conditions both during childhood and later in life, such as diabetes, heart disease, high blood pressure, and more. Research by Farella et al. (2025) highlights that childhood obesity also poses a complex challenge to bone health, influenced by a combination of endocrine, metabolic, and mechanical factors. Obesity is not only an effect on physical health, but it also affects mental well-being, leading to low self-esteem and social challenges (Asadabadi and Karami 2025). Prevention and early intervention help support healthier physical and psychological growth and development in children with obesity.

Talip et al. (2017) investigated the eating habits of Bruneian primary school children. The study found diverse perceptions of healthy eating. Children categorised foods as healthy or unhealthy, though few emphasised fruits and vegetables. Parents generally viewed healthy eating as consuming quality foods rich in vitamins and minerals. The study shows that a lack of healthy eating is one of the leading causes of childhood obesity. This issue has been raising national attention. The *Borneo Bulletin*, an independent newspaper covering Brunei Darussalam, Sabah, and Sarawak, reported that the Brunei minister stressed the urgent need to address childhood obesity in Brunei in a message for World Obesity Day 2024 (*Borneo Bulletin* 2024). In 2025, the *Borneo Bulletin* (2025) also reported that Brunei had the highest obesity rate in Southeast Asia.

## Serious Games

As reported in the 2023 PricewaterhouseCoopers' global entertainment and media outlook, the global video game industry has been shown to have experienced significant and continuous growth in its market value, from USD227 billion up to an estimated value of USD321 billion by 2027. This impressive growth indicates the industry's potential towards engaging an increasingly broad and diverse audience. The COVID-19 pandemic, an arguably major driver of this expansion, has led many people to seek cognitive stimulation, comfort, and social interaction through video games (Barr and Copeland-Stewart 2022). This observation becomes even more staggering from the worldwide 39% rise in the overall time spent playing video games as of June 2020 (Jaeger 2020). Ultimately, this upsurge in popularity has highlighted the numerous advantages associated with video gaming.

Games are known to provide specific functions. For example, games that have been designed for educational purposes are referred to as serious games (Gee 2011), whereas those meant for entertainment are more widely known as commercial games. Serious games can take the form of physical or video games, aiming to improve performance and knowledge. Commercial games primarily provide enjoyable experiences (Ratan and Ritterfeld 2009; Becker and Gopin 2016; Liu and Wills 2022). It is worth noting that commercial games can also offer educational value, as learning opportunities can nevertheless arise while in the midst of play engagement. Therein lies the conundrum, because serious games need to walk the fine line of incorporating both fun factor as well as effective learning, lest they lose their appeal or end up being yet another commercial game (Inamori and Lellis-Santos 2024). Gee (2009a) strongly advocates for games and believes that they make for highly effective tools for learning. He proposed that well-designed video games inherently encourage deep and effective learning due to the immersion of players within simulated virtual environments. These experiences enable players to gain knowledge and skills that may be challenging to otherwise acquire or pursue in the real world. Video games provide a structured framework with specific goals whereby players can assess their progress and instantly receive feedback on their successes or failures. Through this feedback, players may feel empowered to identify and correct errors in their understanding. Such an iterative nature of gameplay allows players to practice and apply their skills in various situations within the virtual world, further enhancing the learning and skill development process.

Additionally, video games have been known to serve as models that stand in for complex phenomena in simplified ways, which aid players in breaking down and comprehending concepts that could otherwise be abstract. Players can then grasp and apply their knowledge across different scenarios precisely by connecting concrete experiences within the game with real-world counterparts and operations. This includes social contexts, where players can explore and interact with a diverse group of social cliques and identities, fostering a deeper and safer understanding of the perspectives of those around them (Gee 2009b). However, it is essential to acknowledge that video games can run the risk of perpetuating negative stereotypes, especially if they inaccurately or damagingly portray certain groups (DeVane and Squire 2008; Latorre 2015).

## Serious Health Games for Children

When it comes specifically to the development of children, serious games have a strong foothold. BBC Bitesize, a comprehensive media educational platform offering a plethora of learning materials in the United Kingdom, covers and makes use of various digital tools, which include videos, films, music, radio, computer resources, and, naturally, video games, to facilitate engaging and interactive learning experiences. The platform has been catering to students across England, Scotland, Wales, and Northern Ireland, providing educational sessions tailored to the

respective curricula of each region. Another well-known serious game example is DragonBox, which has been implemented in schools as an alternative to the traditional classroom instructions and exams, most notably in the field of mathematics. An illustrative study was carried out by scholars from Worcester Polytechnic Institute in Massachusetts, US, focusing specifically on DragonBox Algebra 12+ (now known as Kahoot! Algebra 2 by DragonBox) and exploring how the game could enrich students' mathematical performance during the COVID-19 pandemic (D'Arcy 2023). The findings demonstrated that 253 students in Georgia were able to improve their ability to solve mathematical problems and achieve higher levels of mathematical proficiency through the direct use of DragonBox. In fact, such games have garnered significant attention, having been cited in various research studies, most notably during the pandemic, as they have offered valuable support for addressing the concerning educational needs of children. With the recent shift to online learning becoming a necessity due to the pandemic, many children have had to acclimate to an entirely new schooling environment and regimen that generally lacked in-person interactions. Despite that, DragonBox has emerged as a fruitful platform for children to continue their education engagingly and enjoyably. These games present an innovative approach to learning, enabling children to improve their math skills while relishing the interactive gameplay they offer.

The general consensus of serious health games for children is that they hold significant potential to improve the health of said users in fun and engaging ways. However, they remain underutilised on a larger scale despite being introduced more frequently in recent years. Massaro et al. (2023) emphasised that the elementary education period is crucial in predicting whether a child will develop obesity as they age. They observed the rising popularity and demand of educational games in school settings and noted the similarity in approaches, suggesting that serious games be used similarly, only this time addressing obesity and for overall health gains. This was not unlike how Liu et al. (2022) and Liu (2023) demonstrated the idea of using a synergy of digital interventions in both fostering understanding of senior dementia among children and identifying the suitable time for seeking diagnoses based on warning signs. Hassan et al. (2012), one of the earliest precursors working in this field, acknowledged the increasing trend of serious games as a means to better one's health, mainly as a way to complement the proven traditional weight loss methods like exercising and eating right. However, they also noted the significant drawbacks in existing serious games, such as the at-the-time widely known Nintendo Wii Fit, which comes with many sports games. Their cloud-based exergaming alternative called Treasure Hunting is a potential all-inclusive serious game that can bypass the mobility restrictions associated with such games, such as having to set up bulky equipment or worrying about running out of power halfway through an exercise. Although it did encounter a range of logistical issues, especially with connectivity and an insufficient push for more physical activity, its influences can nevertheless be noticed in the *AYCE* implementation, particularly in the digitisation process, albeit with a separate, though not standalone, aim of raising nutrition knowledge. Kusumah and Kurniawan (2024) provided another example of a serious game entitled Bone & Friend, a food-themed adventure game that was designed to encourage players to collect only the healthy choices and avoid junk foods, which were depicted as enemies that could hurt them.

In the subsequent years, Dias et al. (2017; 2018) conducted two comprehensive reviews on the usage of serious games within the context of addressing health concerns, namely obesity. Although these games' effectiveness in achieving their goals of increased dietary knowledge and motivation to partake in exergaming has been noted in these studies, a few limitations must be acknowledged. These primarily include the limited trials conducted with the aforementioned serious games, which were only exposed to small sample sizes that could not be representative of the larger population. Additionally, each study typically focused on a different serious game, often without follow-up sessions, making the exposure and testing phases even more brief.

Therefore, it is not the case that serious games lack potential in health interventions, but rather that attempts to prove their effectiveness could still be improved. While the current study does not attempt to circumvent these shortcomings by way of its sampling and approach in playtesting, it is, however, the first in a series of ongoing studies that seek to replicate its hopeful findings on children of ASEAN member states, starting with Brunei and Malaysia, and eventually expanding internationally to address the sample size concerns.

One of the more recent reviews of serious health games, expressly evaluating their advantages and disadvantages as still unfamiliar and unconventional alternatives, is by Porri et al. (2024), whose findings shed light on how the efficacy of serious games has yet to be fully gauged, despite their potential being highlighted numerous times over the years. The paper was written in response to the aftereffects of COVID-19, namely the increased sedentary lifestyles resulting from self-isolation and quarantine protocols, where a shift to more digital-based learning was necessitated, and technology-assisted healthcare was more prevalent. Video games in general were even cited as a promising avenue to venture into, potentially offering a groundbreaking solution to obesity prevention and reduction. This idea has been suggested in the past, but it is now more relevant than ever.

Overall, the literature indicates that serious games can enhance children's engagement, promote healthy behaviours, and improve health literacy. However, most studies focus on general or Western contexts, with limited attention to Brunei. Consequently, there is a lack of empirical research examining how serious games can be effectively applied to children's health education in the Bruneian context, particularly in promoting healthy eating habits. Addressing this gap, this study investigates how culturally adapted serious games can be used to raise awareness and encourage healthier dietary practices among Bruneian children, highlighting the potential significance of digital game-based interventions for childhood nutrition education.

## RESEARCH DESIGN AND METHODOLOGY

This study has been divided into two experiments: an observation assessment, which is reserved for researchers, and playtest sessions for children. The observation assessment is a tool designed for researchers to measure the children's behavioural and emotional responses as they participate in the playtesting activities. On the other hand, the playtest involved exposing multiple groups of anonymous elementary school children to the educational game *AYCE*. Each participant was interviewed twice: once before playing the game and once after. This two-stage process enabled the researchers to evaluate whether the children gained any knowledge about healthy diets from *AYCE*. Before the game testing, informed consent forms, namely parental consent forms and participants' individual consent forms, were distributed to the parents and guardians of the children to ensure that their involvement was voluntary and informed.

The game testing was conducted in three stages:

1. Stage 1: The children completed a brief survey to assess their knowledge of diet and nutrition before being subjected to the game stimulus.
2. Stage 2: The children engaged in playing *AYCE* for approximately 20 minutes.
3. Stage 3: The children provided feedback on the game and revised their earlier answers.

This portion of the study only involved children currently attending elementary school, specifically those in Years 5 to 6, with an age range between 10 years old and 12 years old. A total of 40 participants took part, of which were divided into groups of two to four leading to

the competitive and multiplayer format of the game, although it should be noted that one can still play the game by oneself. The *AYCE* was and always has been specifically designed for children and their level of understanding, justifying their role as the primary target of this study. The children first answered the provided questions using paper-based forms, after which the research team converted the collected data into digital formats to facilitate the data analysis process.

The designed test questions were split into two sections and sessions: pre-play and post-play. The pre-play session took place before starting the activity, wherein participants were presented with a set of open-ended questions related to their healthy eating habits to gauge their familiarity with the subject matter. These inquiries can be found in Appendix A in greater detail, amounting to nine questions altogether. Alternatively, the post-play session took place after the participants engaged in the activity, where they completed a post-play survey which was adapted from and expanded on Brooke's System Usability Scale (Brooke 2013), specifically tailored for testing games. The post-play survey consisted of eighteen multiple-choice questions that adopted a five-point Likert scale to explore two main themes: game practicality and motivation. Additionally, participants had the opportunity to revisit the healthy eating section after having experienced the game, allowing them to review their initial responses and make any desired additions or corrections. Furthermore, participants were encouraged to provide open comments in the survey, offering valuable qualitative feedback on their gaming experience and how it influenced their understanding of eating habits and other related topics.

The design of the observation assessment used in this study took inspiration from the BASC-3 Behavioural and Emotional Screening System (BASC-3 BESS), a widely recognised, reliable, and structured approach to assessing the behavioural and emotional strengths and challenges of individuals in the child and adolescent age range, spanning from preschool to high school. However, since this study primarily focuses on behaviour within the context of gaming, adjustments were made to tailor it for this specific platform.

The assessment now encompasses three distinct categories: attitude, strategies, and motivation/engagement. The attitude category focuses on meticulously observing and evaluating the children's behaviour, interactions, and emotional responses. This approach tries to derive valuable insights as to their social and emotional functioning across a number of activities. The strategies category involves assessing the children's capabilities on matters of planning, problem-solving, and decision-making. Examining their strategic approaches in different situations can yield essential information about their cognitive and executive functioning. The motivation/engagement category is designed to understand the children's level of motivation and their engagement with their community, even as the observation is ongoing in the background. In total, the observation assessment posed 52 questions, which collectively provide a comprehensive understanding of the children's behavioural and emotional responses while they actively participated in the assessment.

## **RESEARCH TOOLS (GAME): ALL YOU CAN EAT**

In this study, a digital game called *AYCE* was developed by the game developer, designer, artist, and researchers. In this game, players embark on a virtual journey worldwide, experiencing cuisines from various countries. The *AYCE* game was built on previous research about engaging children in health education (Liu et al. 2025). It investigated parents' and children's views on healthy eating. Parents shared their thoughts on their child's diet, and children gave feedback after watching a game demo video. The results show that the *AYCE* game helped them learn about nutrition and different food cultures. Parents supported using educational games. Overall, the game shows promise as a fun way to teach children about healthy eating.

## Game Concept and Objective

The game was designed based on Brunei’s Ministry of Health’s recommendations for a healthy plate around 2020, as shown in Figure 1. The game and related research were already underway by late 2020. However, the healthy plate design in the game can be updated in response to changes in the environment or public health situations. For example, an increase in diabetes cases may influence future updates to the dietary guidelines. The objective of the game is to eat as much as possible while adhering to a balanced diet, especially for children. Game mechanics such as the Plate Board and Balanced Diet Formula are used to educate players about healthy eating habits. In terms of reliability, the *AYCE* research game serves as an educational tool. It helps researchers understand player behaviour while also functioning as an interactive and enjoyable way to promote healthy eating. The *AYCE* continues to expand and update its content based on the latest guidelines from the WHO and the Ministry of Health Brunei. Currently, there are no other games designed to help children understand healthy eating, according to the Ministry of Health Brunei.

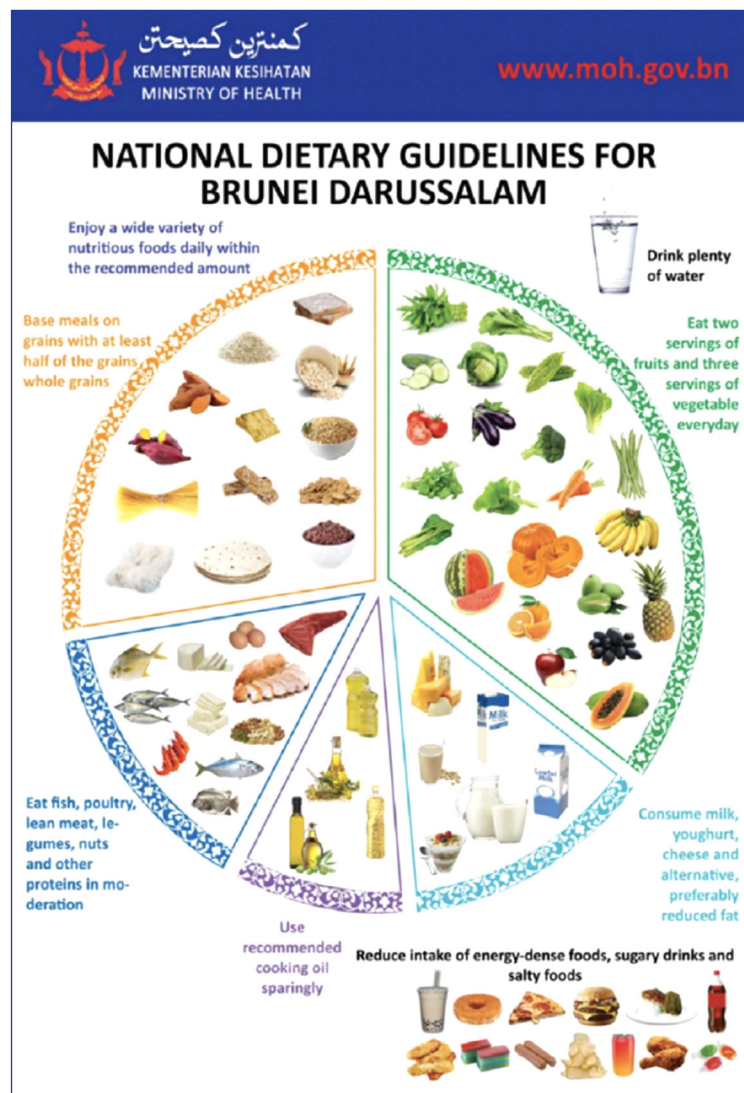


Figure 1: National dietary guidelines for Brunei Darussalam.

Source: As retrieved from <https://sites.google.com/monash.edu/global-insights-to-success/career-pathway/working-overseas/brunei/working-as-a-nutrition-professional-in-brunei> on 2 January 2026.

## The AYCE Game Design

The *AYCE* is a preexisting serious game that was purposefully redesigned to educate players about healthy eating habits (as shown in Figure 2). The game incorporates various components like cuisine cards, bonus cards, and tokens. More specifically, *AYCE* features a total of 95 cuisine cards, with specific cards allocated for breakfast (36), lunch (31), and dinner (28). Bonus cards provide special abilities to enhance the gameplay, while tokens represent different types of food, categorised into six food groups: whole grains; oils, fats, nuts, and seeds; legumes, fish, eggs, meat, and their derivatives; dairy products; vegetables; and fruits.

The *AYCE*'s core game loop follows a turn-based format, starting with the hungriest player and continuing in a clockwise manner. This ensures that each player has the opportunity to strategically manage their Plate Board and make choices that align with their goals in the game. Each player has several actions they can choose from during their turn:

1. **Cuisine Card Action:** The player selects up to three cuisine cards, following the specific order of breakfast, lunch, and dinner, the corresponding tokens of which must be placed on their Plate Board. However, players cannot acquire a cuisine card if it exceeds the token limit on their Plate Board.
2. **Token Action:** The player can take up to seven tokens of any colour from their Plate Board. This action allows them to adjust the composition of their Plate Board and manage their available tokens.
3. **Balanced Diet Action:** The player can remove 14 tokens from their Plate Board that fulfil the requirements of the Balanced Diet Formula.

In addition, they can take one bonus card. If the bonus card is of the one-time use variety, it will be immediately consumed, and its effects will be applied. The *AYCE* includes several key game elements, namely:

1. **Cuisine cards:** Collecting a cuisine card is the equivalent of eating a meal. There are three decks (breakfast, lunch, and dinner), and players must eat their meals in that specified order unless instructed otherwise. In the top right corner of every cuisine card is a number indicating how much it will fill the player's stomach. If the player finds that they are unable to collect a particular cuisine card, then it is most likely because their stomach is full.
2. **Tokens:** Tokens are objects to be collected to win. There are six token types in total: fruits, vegetables, dairy, oil, meat, and carbohydrates. Each type requires a certain number of tokens to be collected, and only by meeting all of these requirements will the player be able to balance their diets. Every dish is made up of various combinations of tokens, displayed at the bottom left of each cuisine card.
3. **Plate:** The plate is how players keep track of how many tokens they currently have, as well as how many they still need. If a token is instead stored at the bottom of the plate, that is an indication that the player already has enough of that specific token, and they must digest it or risk having their points deducted.
4. **Stomach:** The stomach shows players exactly how much their stomach can store. When nearing full capacity, players should digest.
5. **Bonus cards:** Every time players achieve a balanced diet, they are entitled to either a "permanent" or "one-time" bonus card. A permanent bonus card lasts until the game ends, while a one-time bonus card must be used immediately, or it will vanish.

The game can end in one of two ways, i.e., (1) completion of the Balanced Diet Formula, whereby if a player successfully completes the Balanced Diet Formula three times, the game concludes, and (2) depletion of cuisine card decks, whereby if any of the cuisine card decks are fully depleted, the game also comes to an end. To determine the final score, players sum up the numbers on their cuisine cards. However, for each token remaining on their Plate Board, one point is subtracted from their score. The player with the highest score at the end of the game is declared the winner. In the event of a tie, players with the same score will both be considered winners.



Figure 2: The AYCE.

Source: As retrieved from <https://www.youtube.com/watch?v=ZA0hh4L0pg> on 2 January 2026.

## RESULTS

In this study, 40 participants (27 boys and 13 girls) were involved. Of these, 25 children were 10 years old, 11 children were 11 years old, and 4 children were 12 years old, as illustrated in Table 1. In this section, the insights from the pre-play and post-play surveys are fully outlined to highlight the differences in responses as a result of playing AYCE between the two stages.

Table 1: Participants' demographic information

Code	Gender	Age (years old)	Code	Gender	Age (years old)
01	Boy	10	21	Boy	11
02	Boy	11	22	Girl	10
03	Boy	10	23	Girl	10
04	Boy	12	24	Boy	11
05	Girl	10	25	Girl	10

(continued on next page)

Table 1: (continued)

Code	Gender	Age (years old)	Code	Gender	Age (years old)
06	Boy	10	26	Girl	10
07	Boy	12	27	Girl	10
08	Boy	11	28	Girl	11
09	Boy	11	29	Boy	10
10	Boy	10	30	Boy	10
11	Girl	10	31	Boy	10
12	Boy	12	32	Boy	10
13	Boy	11	33	Boy	10
14	Boy	11	34	Boy	10
15	Boy	11	35	Boy	10
16	Boy	11	36	Boy	11
17	Girl	10	37	Girl	12
18	Girl	10	38	Boy	10
19	Girl	10	39	Boy	10
20	Girl	10	40	Boy	10

## Playtest

The playtesting process consisted of two main sessions: pre-play and post-play. The pre-play session can be further categorised into two parts: one focusing on the participants’ eating habits, and the other on their knowledge about healthy eating. The post-play assessments were conducted to determine whether children’s knowledge increased through *AYCE*.

In the pre-play study on healthy eating habits, out of the 40 children surveyed, 40% (16) definitely did not consider themselves as someone who eats healthy food, whereas 30% (12) did (as shown in Figure 3). Two children (5%) answered “rarely”, 15% (6) answered “sometimes”, and 10% (4) did not provide an answer. When asked a similarly worded question, this instance on the manner and frequency in which they consume healthy food, 42% (17) reported that they did not consistently eat healthy food, while only 18% (7) children disclosed that they did. Additionally, 28% (11) chose “sometimes” as their response and 12% (5) indicated “rarely”. For the pre-play healthy eating knowledge questions, among the surveyed children, 23 demonstrated knowledge of vegetables across the 6 categories, while 21 correctly identified fruits. Fourteen children correctly identified protein, 11 recognised meat, six identified dairy, and 2 mentioned oil. However, only one child correctly acknowledged grains. None of the children were able to answer all the food category questions correctly, as shown in Table 2. Although the children could indeed provide answers that encompass the six food categories, their responses were only partially accurate, thus, suggesting a gap in their dietary knowledge. For example, 10 children mentioned carbohydrates, 5 pointed out vitamins, and 3 referred to fats.

The children also mentioned various specific foods in their responses. Three children (7.5%) mentioned chicken, 4 (10.0%) mentioned fish, 3 (7.5%) mentioned rice, 3 (7.5%) mentioned noodles, 4 (10.0%) mentioned bread, and 3 (7.5%) mentioned toast. Additionally, 5 children (12.5%) brought up desserts or sweets, 3 (7.5%) mentioned calcium, and 2 (5.0%) referred to caffeine. Two children (5.0%) made remarks about junk food, while 3 (7.5%) talked about fast food in general. Three children (7.5%) discussed healthy choices, whereas 2 (5.0%) mentioned unhealthy choices. Lastly, one child (2.5%) mentioned halal and non-halal foods.

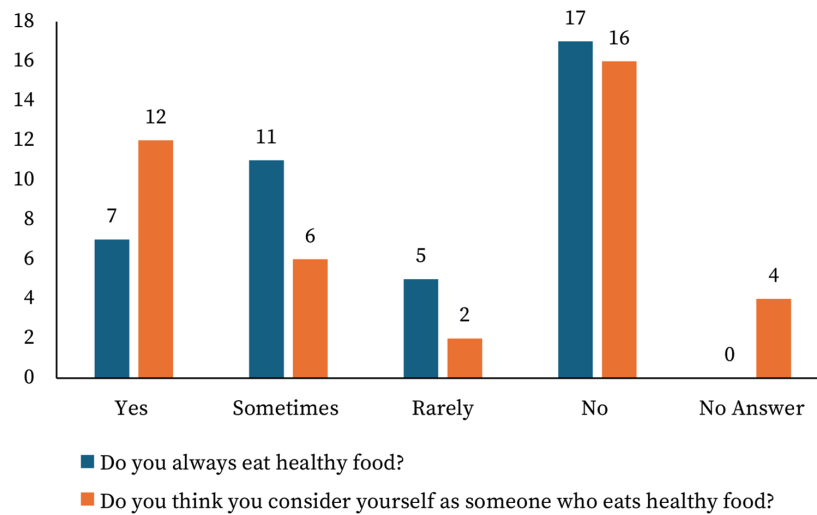


Figure 3: Children's self-perceived eating habits and healthy food intake opinions.

Table 2: Children's responses on the six food categories

Theme	Responses (Number of children)	Theme	Responses (Number of children)
Categories	Vegetables (23)	Others	Dessert/sweet (5)
	Fruits (21)		Calcium (3)
	Meat (11)		Caffeine (2)
	Grains (1)		Junk food (2)
	Dairy (6)		Fast food (3)
	Oil (2)		Healthy (3)
	Protein (14)		Unhealthy (2)
Classes	Carbohydrates (10)	Halal (1)	
	Vitamin (5)	Non-halal (1)	
	Fats (3)		
Specific food	Chicken (3)		
	Fish (4)		
	Rice (3)		
	Noodles (3)		
	Bread (4)		
	Toast (3)		

In Figure 4, when analysing the children's responses, the largest group consisted of 20 children (50%) who believed they needed 3 to 5 portions per day. The second most common response came from 15 children (37.5%) who indicated they required 1 to 2 portions. Additionally, 3 (7.5%) mentioned a need for 6 to 7 portions, while 2 (5.0%) did not provide an answer. When asked how many fruits they needed daily, 24 (60.0%) children chose 2 to 4 portions, 9 (22.5%) opted for 5 to 6 portions, and 7 (17.5%) selected just 1 portion (as shown in Figure 5). In terms of their views on daily milk consumption, 20 (50.0%) children thought they required 3 cups, 15 (37.5%) felt they needed 1.5 to 2 cups, 3 (7.5%) indicated 5 cups, and 2 (5.0%) did not provide an answer (as shown in Figure 6). As examples of foods that children associated with grains, 24 (60.0%) children mentioned rice, 9 (22.5%) thought of corn, 7 (17.5%) associated grains with toast, 5 (12.5%) considered noodles, and another 5 (12.5%) included potatoes in this category (as shown in Figure 7).

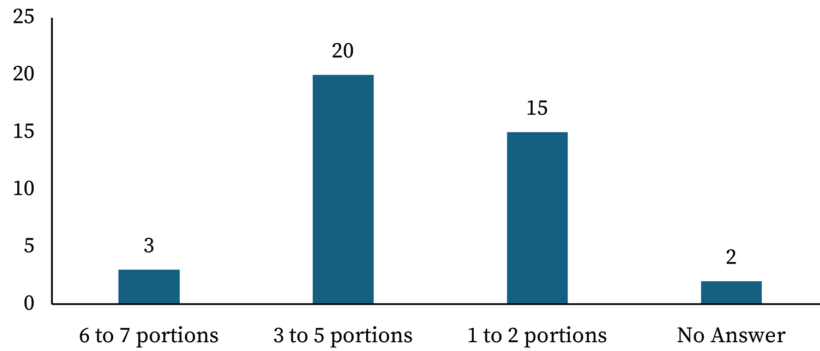


Figure 4: Children's responses when prompted on day-to-day required vegetable intake.

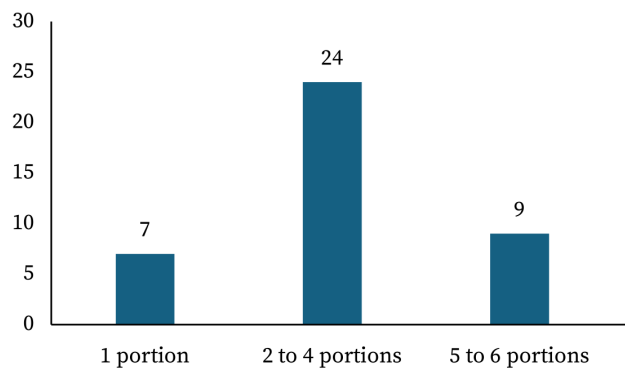


Figure 5: Children's responses when prompted on day-to-day required fruit intake.

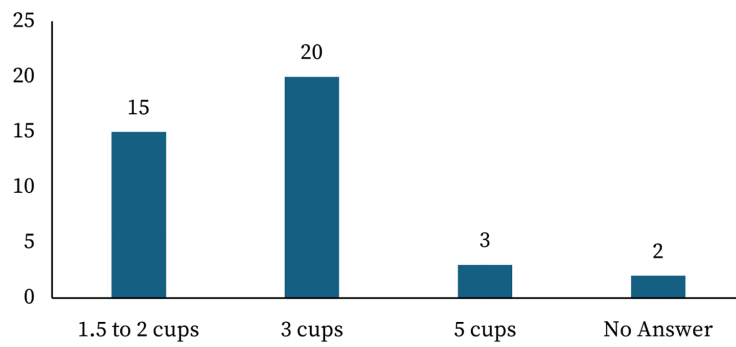


Figure 6: Children's responses when prompted on day-to-day required milk intake.

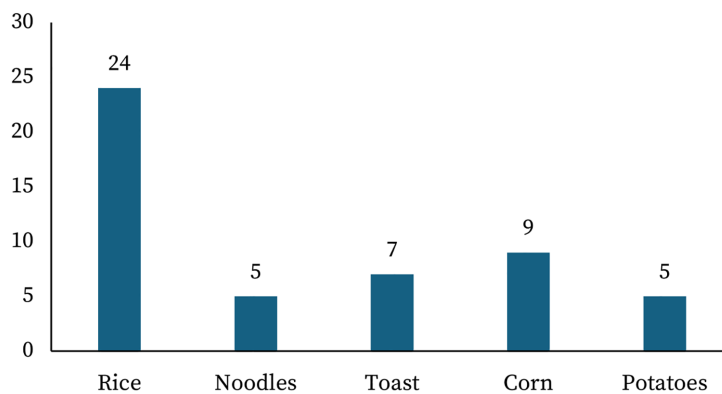


Figure 7: Children's responses when promoted on examples of grains.

In response to the open-ended question regarding which of the six food categories is rich in protein, the children provided a variety of answers (as shown in Table 3). Specifically, 5 children (12.5%) mentioned “meat”, 3 (7.5%) responded with “protein”, 3 (7.5%) referred to “vegetables”, and 2 (5.0%) noted “dairy”. Moreover, 6 children (15%) identified specific foods as sources of protein, with 2 (5%) mentioning fish (5%) and 4 (10%) mentioning rice. When queried regarding what they believed were the essential food categories for daily consumption, 14 children (35%) identified “vegetables”, 10 (25%) mentioned “fruits”, and 2 (5%) indicated “protein” (as shown in Table 4). Some children provided answers that instead fell into broader food groups. For instance, 2 children (5.0%) brought up “vitamins” and 4 (10.0%) noted “carbohydrates”. Additionally, 5 children (12.5%) specified “rice” as a specific food they believed should be consumed daily.

Table 3: Children’s responses on protein-rich food categories

Theme	Responses (Number of children)
Categories	Meat (5) Protein (3) Vegetable (3) Dairy (2)
Specific food	Fish (2) Rice (4)

Table 4: Children’s responses on which food categories should be consumed daily

Theme	Responses (Number of children)
Categories	Vegetables (14) Fruits (10) Proteins (2)
Classes	Vitamin (2) Carbohydrates (4)
Specific food	Rice (5)

A reliability analysis was conducted on the post-play multiple-choice questions to assess the internal consistency of each question within a component and, by extension, the overall set of questions. The Cronbach’s alpha coefficients in Table 5 shows that the thirteen items in the questionnaire achieved satisfactory reliability values ( $\alpha = 0.675$ ). The mean and standard deviation for each of the items are presented in Appendix C. Normality tests were conducted to determine whether the participants’ data followed a normal distribution. The tests employed were the Kolmogorov-Smirnov and Shapiro-Wilk tests. If the  $p$ -value should be below 0.05 ( $p < 0.05$ ), this would suggest that the data significantly deviates from normality, indicating a non-normal distribution, as was the case shown in Appendix D. The normality tests were applied to each component of the questions. Given that the data did not follow a normal distribution, a non-parametric mean test was considered appropriate. As such, the Mann-Whitney test was selected for use in this study, as detailed in Appendix E. The forty participants were compared against a null value, which was calculated from the sum of responses labelled “Neither” (where “Neither” corresponded to 3 on the Likert scale). From the results, it is evident that most participants generally either agreed or strongly agreed with the questions as none of the items had a mean rank higher than those of the participants. However, there is one instance where the participants’ data and null value is identical, specifically with item P5: “I could play the game again without looking at the rules”.

Table 5: Reliability statistics

Cronbach's alpha	Cronbach's alpha based on standardised items	Number of items
0.675	0.665	13

Regarding the results of the open-ended questions during the post-play session, Participants 01, 16, 18, 21, 22, and 37 revised their answers to the question, “What are the six categories of food?”:

1. 01: Added “oil” and “fruit” to their responses.
2. 16: Substituted “fat” with “dairy” and “cake” with “grain” in their original responses.
3. 18: Included the response “nutrition”.
4. 21: Added responses, namely “apple, meat, fish, rice, bread, and vegetable”.
5. 22: Provided answers, namely “meat, fish, broccoli, rice, and sushi”.
6. 37: Included responses such as “dairy” and “protein”.

Participants 01 and 38 amended their responses to the question, “How many vegetables do you believe you should consume per day?”. Participant 01 initially selected 1 to 2 portions but later changed it to 3 to 5 portions. Next, Participant 38 initially chose 3 to 5 portions but subsequently altered their response to 1 to 2 portions. One child, specifically Participant 38, adjusted their response to the question, “How many fruits do you need per day?”, changing from 2 to 4 portions to 1 portion. Two children, Participants 01 and 28, modified their answers to the question, “How much milk do you believe you require daily?”. At first, both children answered three cups but later changed their responses to 1.5 to 3 cups. Two children, Participants 01 and 05, expanded upon their responses to the question, “What are some examples of foods you think belong to the ‘Grains’ category?”. Participant 01 added noodles, while 05 included rice. When asked, “Which food categories do you think you need to consume the most every day?”, only one child, Participant 38, added grains to their response.

In the post-game survey feedback on the *AYCE* game, seven children (Participants 15, 19, 21, 22, 23, 25, and 30) voiced their appreciation for the game by stating, “I like this game”. Similar sentiments were echoed by Participants 9 and 18, with the former expressing a positive view and the latter describing it as “not bad”. Furthermore, Participant 39 commented, “The game is enjoyable to play”.

Two participants provided suggestions for improving the game: (1) 02: “Add desserts because I like it”; and (2) 03: “Include more dairy foods”. Four participants found the game interesting: (1) 04: “The game is fun and interesting to play”; (2) 11: “I think the game is perfectly fine. It is very interesting”; (3) 35: “This game is good and would help other people be interested in eating these foods. It sometimes makes me hungry”; and (4) 37: “It is very interesting”. Two participants expressed their desire to try the game again: (1) 12: “The game is so fun, and I will try it again when I do not have anything to do” and (2) 21: “It was a very good game, and I would play it again”.

Three participants remarked that the game provided learning opportunities: (1) 04: “I hope to learn more about culture”; (2) 13: “From this game, I can understand diets and other countries’ cultural foods”; and (3) 14: “It is good for kids growing up and learning about diet”. Four participants highlighted the game’s impact on health: (1) 25: “I like the game because it helps me control my diet”; (2) 29: “I like the game because it helps me control my diet”; (3) 33: “I love it because I can possibly lose some calories for a healthy body”; and (4) 37: “The game

helps me eat healthier and is very interesting. Hopefully, it will be available on mobile so I can test myself more often". Additional remarks related to the game's design and its impact on their feelings were shared by the following participants: (1) 05: "The design is okay and acceptable"; (2) 38: "Its sprites of food make me hungry, especially the fries and pizza"; and (3) 31: "Is *AYCE* available on any devices?".

## Observation

The researchers conducted an observational assessment using A, O, S, and N scales, where "N" is selected if the behaviour in question never occurs, "S" if it sometimes occurs, "O" if it often occurs, and "A" if it almost always occurs. These assessments encompassed three primary categories: attitude, strategies, and motivation/engagement, each of which contains its own subcategories.

The attitude domain comprises three subcategories: behaviour, interaction, and emotion. In the behaviour subcategory, 33 out of 40 children (82.5%) never reacted negatively during the observation period (as shown in Table 6). Additionally, 35 children (87.5%) never argued, and none of the children ever used foul language. Furthermore, 38 children (95.0%) did not complain, and 37 (92.5%) did not say things that made no sense. In the interaction subcategory, the majority of children (31 out of 40 or 77.5%) almost always engaged in positive interactions. Similarly, 35 children (87.5%) never engaged in any negative interactions. When it came to putting others down, only 1 child (2.5%) was the exception, who sometimes did. Furthermore, 36 children (90%) did not disrupt others. In the emotion subcategory, positive emotions almost always occurred in 32 children (80%), and 38 children (95%) never experienced negative emotions. All except one child never experienced any form of panic; the latter of whom sometimes got angry easily. Additionally, 39 children (97.5%) did not suffer from headaches, with the sole exception of one child who sometimes did.

The strategies category also comprises three subcategories: planning, problem-solving, and decision-making. In the planning subcategory, 33 children (82.5%) often demonstrated "being organised" and "planning ahead", while 24 children (60.0%) often displayed a "taking a step-by-step approach". The problem-solving subcategory concerns the children's ability to track down information when needed. A total of 29 children (72.5%) tracked down information with varying frequencies: 1 child (2.5%) almost always tracked down information when needed, 16 children (40.0%) often tracked down information when needed, and 12 (30.0%) only sometimes did so. However, 11 children (27.5%) never tracked down information, even when the situation called for it. In the decision-making subcategory, it was observed that a majority of the children found it easy to make decisions, with 11 (27.5%) almost always doing so and 20 (50.0%) often able to make decisions. However, only 1 child (2.5%) never found it easy to make decisions. In the reverse metric, 21 children (52.5%) sometimes struggled with making decisions, while 17 (42.5%) never experienced any difficulties.

In the motivation/engagement category, most of the children completed the given tasks without difficulty, with 35 (87.5%) almost always completing them and 5 (12.5%) often doing so. None of the children were unable to complete the tasks expected of them. In the reverse scenario, 36 children (90%) never failed to complete tests, while 4 (10%) sometimes did not complete tests.

Table 6: Observation results by number of children

Rating scales		A	O	S	N	
Attitude	Behaviour	Reacts positive	27	10	3	-
		Reacts negative	-	-	7	33
		Is easy to please	19	16	4	1
		Accepts things as they are	18	17	2	3
		Argues	-	1	4	35
		Pays attention	18	15	6	1
		Is easily distracted	-	4	14	22
		Overly active	-	2	7	31
		Overreacts	-	2	5	33
		Uses foul language	-	-	-	40
		Complains	-	-	2	38
		Says things that make no sense	-	-	3	37
		Babbles to self	-	5	5	30
		Recovers quickly after a setback	5	24	10	1
		Overcomes problems	-	17	1	22
		Works well under pressure	9	24	6	1
		Action without thinking	1	8	21	10
		Interaction	Positive interactions	31	7	2
Negative interactions	-		-	5	35	
Congratulates others when good things happen to them	1		9	21	9	
Encourages/compliments others	2		10	18	10	
Is overly aggressive	-		2	7	31	
Tries to help others	11		13	9	7	
Accepts people who are different from his or herself	9		24	6	1	
Picks on others who are different from his or herself	-		2	11	27	
Puts others down	-		-	1	39	
Disrupts others	-		1	3	36	
Emotion	Positive emotion	32	5	3	-	
	Negative emotion	-	-	2	38	
	Is optimistic	20	14	4	2	
	Is pessimistic	-	1	8	31	
	Gets angry easily	-	-	1	39	
	Has panic attacks	-	-	-	40	
	Has headaches	-	-	1	39	
	Confidence	11	19	8	2	
Afraid to make a mistake	-	2	18	20		

(continued on next page)

Table 6: (continued)

Rating scales			A	O	S	N
Strategies	Planning	Is organised	11	23	5	1
		Plans ahead	7	23	9	1
		Takes a step-by-step approach to work	10	24	6	–
	Problem solving	Finds ways to solve problems	5	26	6	3
		Tracks down information when needed	1	16	12	11
		Has trouble getting information when needed	–	–	13	27
		Breaks large problems into smaller steps	1	11	18	10
	Decision making	Analyses the nature of a problem before starting to solve it	1	18	16	5
		Makes decisions easily	11	20	8	1
		Has trouble making decisions	–	2	21	17
Motivation/ engagement	Quickly joins group activities	24	11	3	2	
	Reluctant/slow to join group activities	–	2	10	28	
	Responds appropriately	16	22	2	–	
	Is highly motivated to succeed	11	21	6	2	
	Completes task	35	5	–	–	
	Does not complete tests	–	–	4	36	

## DISCUSSION

This study delved into the dietary habits of children and their comprehension of proper nutrition, while also examining their behaviour during their session playing *AYCE*. The findings underscore a significant lack of awareness among 10- to 12-year-old children in Brunei regarding healthy food choices, pointing to a drastic need for intervention to minimise the risk of developing obesity or becoming overweight—a likely future scenario for Brunei. In a similar study by Lytle et al. (1997), which examined children’s grasp of nutrition messages and healthy eating habits in the US, their findings indicated that the children frequently and consistently struggled to differentiate between the six food categories and six food classes. Remarkably, the same, if not worse, pattern persisted two decades later, as not a single child provided a fully accurate response to the question summarised in Table 2.

Interestingly, even after participating in the game sessions, a majority of the children exhibited reluctance or, more likely, ignorance in modifying their post-play responses. Although eight children made alterations to their initial responses, those revisions still contained inaccuracies. It is important to note that this outcome does not necessarily indicate the game’s failure, as various factors could have contributed to these results. These include the limited time participants were afforded to adjust their responses, the prolonged duration of testing leading to fatigue, and the possibility that the children were more interested in playing the game itself as opposed to completing paperwork or discussing the details of their gameplay or the significance of the play session. Despite these challenges, the post-play results indicate that the children not only derived satisfaction from *AYCE* but also considered it a valuable tool for learning about healthy eating habits and cultural aspects. As such, it can be argued that the game could greatly benefit from further playtesting with larger groups to fully assess its potential and long-term outcomes (Holzmann et al. 2019; Froome et al. 2020).

The observations and assessments of the children's conduct can be instrumental in developing similarly themed games suited for children and those seeking to learn more about their behaviour. During the course of their playtime, it was observed that most children exhibited positive reactions, interactions, and emotions, with instances of negative behaviours—such as arguing, using foul language, or complaining—being extremely rare. Furthermore, the majority of children displayed confidence during play, especially when engaging with individuals they are familiar with, such as classmates or friends. This extended to their motivation and engagement levels during the activity, as whether they swiftly joined the group activities or hesitated to participate was likewise dependent on whether they played *AYCE* with acquaintances or strangers. However, it is clear that *AYCE*, or rather serious games in general, serves as a meaningful platform for fostering social interactions and engaging individuals, in addition to its educational value, making it ideal for both classroom and household settings.

## LIMITATIONS

This study acknowledges that a sedentary lifestyle, of which games are generally considered one of the leading causes, can contribute to poor knowledge of healthy eating habits and, to a greater degree, obesity. However, based on the outcomes of the pilot study and the limited success of current obesity deterrents, it is evident that the risk is not adequately managed, highlighting the critical need for alternative interventions. Nevertheless, there are areas that could be further refined in future studies that wish to expand upon serious games, whether *AYCE* or beyond.

One glaring limitation to this study is its sample size, a common issue within this field, as most game trials are often conducted with small groups. However, this is only a problem at this research stage, given its status as a prototype and an unpublished game. Moreover, attempts to recruit and schedule playtest sessions with children proved challenging, as obtaining parental consent was sometimes difficult, and capturing the children's interest was initially a struggle. The latter only became much easier once the children saw the game, whereas initially, they were largely uninterested. Secondly, it should be noted that no obese or overweight children took part in the study, as it can be insensitive towards individuals, parents, and children alike, for researchers to make assumptions about the child's health. Ultimately, the paper aimed to improve health through digital interventions in the form of serious games, which, although not detailed here, also include mental health aspects, namely self-body image and self-esteem. Thirdly, while it did not pose any complications, the accidental inclusion of non-halal dishes was an oversight on the researchers' part. Ensuring cultural sensitivity is crucial, depending on where *AYCE* is played and the demographic playing them, especially in a predominantly Muslim nation. Lastly, the lack of corrections during the post-play questioning could be attributed to a variety of factors, including not playing *AYCE* with their peers or close friends, boredom, and other similar reasons. Thus, future researchers should take note of this to eliminate affinity as extraneous variables.

In addition, while the game world may not fully reflect real-life eating habits, *AYCE* still gives useful insight into how children learn and interact with healthy choices. Games create a fun and engaging way to explore healthy behaviours, even if these behaviours did not happen right away in real life. Before the behaviour change, children need to be engaged first. Games like *AYCE* can help by giving children more engaging and fun ways to learn and make healthier decisions.

## CONCLUSION AND FUTURE WORK

The utilisation of serious games not just as a preventative measure against obesity but also as a means to combat it proves promising, as exemplified by the testing of *AYCE*. The online serious game used in this study can be reasonably adapted for various educational environments without being limited by location or hardware constraints, provided that the necessary connectivity infrastructure is made available. Both teachers and parents could use the game as a tool to educate children on healthy eating habits. Building on the results of the previous pilot study, the present study verified that this new format of an existing physical serious game not only piques children's interest with its fun factor but also further engages them in the topic of healthy diets through its rules.

This study also has important implications for public health policy in Brunei. With the country facing high childhood obesity rates, *AYCE* shows promise as a fun and effective way to teach children about healthy eating. It could be implemented in schools or community programmes to support ongoing health education. The *AYCE* can support the Ministry of Health and Education in promoting nutrition awareness among children and families through national programmes. The study will aid other researchers in the cross-disciplinary field to better understand the needs of children in a cohesive manner. These advancements would enable technologies, particularly games, to provide additional social support for health-related issues. Individuals and communities can benefit from improved health and well-being due to *AYCE* and similar games with aligned objectives and play goals, thereby improving their overall quality of life. As such, digital technology as a platform has been demonstrated to effectively accommodate and support a wide range of health issues, particularly when serious games are implemented alongside traditional classroom-based teaching or clinical settings, where children typically acquire these pieces of knowledge, rather than serving as a complete replacement.

The literature review revealed that serious health games are increasingly being utilised, and some might argue there is no shortage of them in this age of modernity. That said, it is equally wise to consider the persistent flaws that have emerged, especially those related to small sample sizes of children or research subjects, and extended exposure to the serious games or research stimuli—issues that many researchers in the same field have overlooked. While the novelty of games remains important, as children are always eager to try the latest things, it would be ideal to further test existing serious games rather than create new ones. This approach would enhance their credibility and ensure they are taken more seriously once their effectiveness is proven beyond doubt.

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## COMPLIANCE WITH ETHICAL STANDARDS

This research complies with the ethical standards of the Faculty of Arts and Social Sciences, Universiti Brunei Darussalam, and has received ethical clearance under reference number UBD/FASS/1.20/2020 Pt.5 (Research and Ethics Research).

## NOTES

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