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META-ANALYSIS FOR COMPARING EFFECT BETWEEN GAME-BASED LEARNING VERSUS GAMIFICATION UTILIZED IN NUTRITION EDUCATION

by

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A Dissertation
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for the degree of
Doctor of Philosophy

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Chia-Lin Chang
June 29th, 2022

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Abstract

The prevalence of obesity tripled from 1975 to 2016 and was declared as a global epidemic by the World Health Organization (WHO) in 1997 (Haththotuwa et al., 2020; "*Controlling the global obesity epidemic*," 2022). Nutrition education that involves knowledge and behavioral change is one major component addressing the problem ("*Controlling the global obesity epidemic*," 2022). Therefore, the effectiveness of each learning session is essential (Sharifirad et al., 2013). Thus, many nutrition educators have used gamified nutrition education to improve teaching effectiveness to increase healthy behavior or knowledge (Chow et al., 2020.; Munguba et al., 2008; Azevedo et al., 2019). Two approaches were often used for gamified learning: gamification and GBL (GBL; Browne et al., 2014; Johnson et al., 2016; Chow et al., 2020). Gamification applies a game mechanism to non-game content, while GBL or serious gaming involves a game that was built to achieve educational goals (De Freitas, 2006; Johnson et al., 2016). Despite many positive outcomes promoted by gamified education as a whole (Chow et al., 2020; Hamari et al., 2014), there is disagreement among researchers and professionals regarding how games affect education. This study aims to identify and analyze research literature on the effects of active game, gamification and GBL applied to nutrition knowledge and behavior.

The researcher performed a network meta-analysis with three sub-constructs. First, searching journal articles that addressed nutrition education implied an intervention consolidated educational strategies into food choice knowledge, fruit and vegetable consumption, and physical activity to a non-medical background population. Then, the studies were compared on the average effect of treatment indirectly through the control group. Results indicated there were plenty of studies that investigated the effect of gamification or GBL to nutrition education. Out of three focused outcomes: food choice knowledge, fruit and vegetable consumption, and physical activity, only studies focusing on physical activity were able to produce measurable differences by comparing hours per week spent performing physical activity. Comparison of the treatment result showed that gamification had the greatest improvement in facilitating physical activity, but it was non-significant. This suggests that utilizing gamification across the globe would be the more successful intervention strategy, but would require improved heterogeneity of measurements for food knowledge and fruit and vegetable consumption in order to achieve consistent measurable results for comparison.

Keywords: nutrition education, game-based learning, gamification, meta-analysis

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Your love and support get me though two of my masters' degree and this PhD journey

CHAPTER I

INTRODUCTION

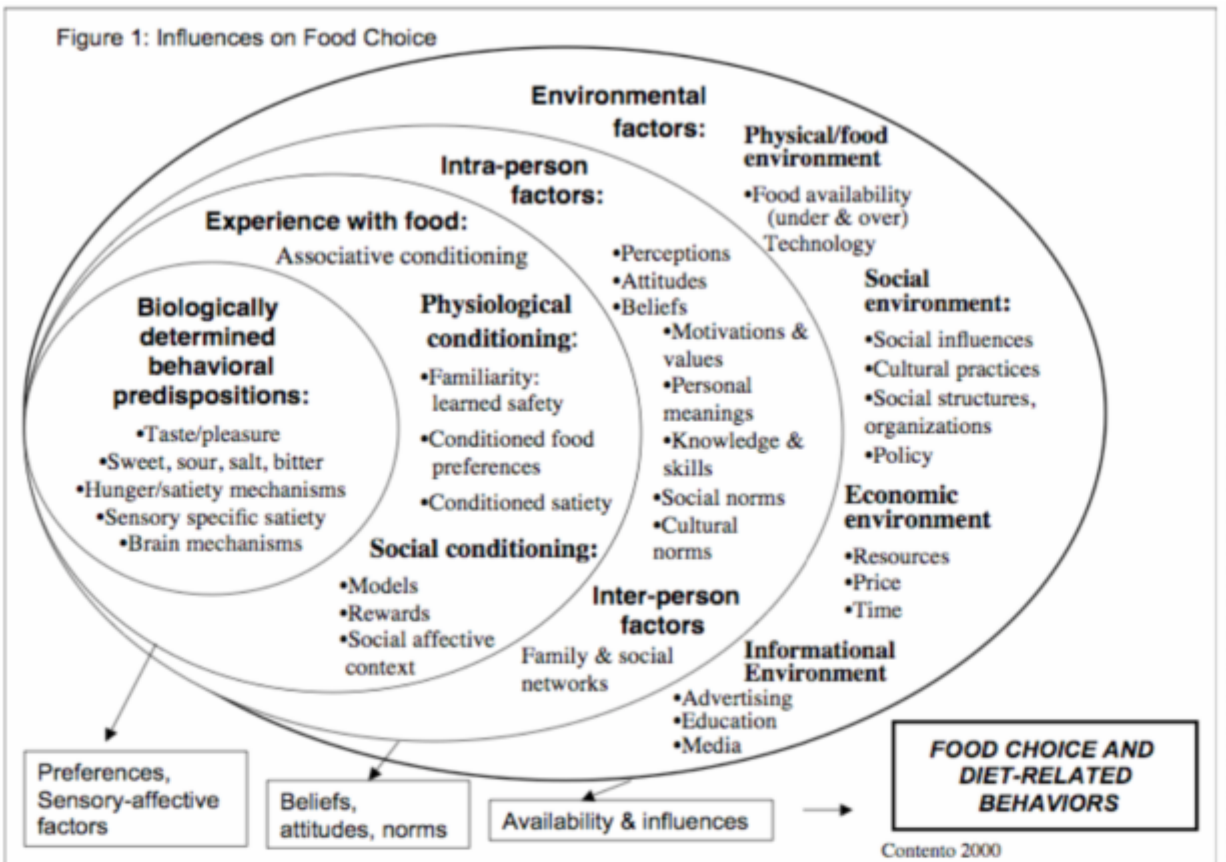
Nutrition education that involves knowledge and behavioral change is one major component in addressing the global epidemic of obesity ("*Controlling the global obesity epidemic*," 2022). Each learning session's effectiveness is essential, and an innovative way of presenting the session is encouraged (Sharifirad et al., 2013). Many nutrition educators have used gamified nutrition education to improve teaching effectiveness and to promote healthy knowledge or behavior, especially for K–12 students (Azevedo et al., 2019; Chow et al., 2020, for all reviewed papers; Munguba et al., 2008). In the research literature, there are two different approaches for gamified learning — gamification and game-based learning (GBL). Gamification is applying game mechanisms to learning content, while GBL or serious gaming involves a game built to achieve educational goals (De Freitas, 2006; Johnson et al., 2016). Despite many positive outcomes promoted by gamified education as a whole (Hamari et al., 2014; Chow et al., 2020), there is disagreement among researchers and professionals regarding how games affect education. Some say gamification may not maintain user's motivation and engagement within the learning system (Rooij et al., 2014; Hamari et al., 2014), while others believe that GBL limits students' interaction among each other (Loh et al., 2016). This study aims to identify and analyze the current evidence on differences between gamification versus GBL and how each of them enhances nutrition knowledge and behavior for all populations that have been studied.

Why Do We Need Nutrition Education?

The need for innovative nutrition education comes from the rapid worldwide increase in obesity. The prevalence of obesity tripled from 1975 to 2016 and was declared a global epidemic by the World Health Organization ("*Controlling the global obesity epidemic*," 2022; Haththotuwa et al., 2020) in 1997 (Haththotuwa et al., 2020). Obesity is a significant risk factor for non-communicable diseases such as type 2 diabetes, cardiovascular diseases, and musculoskeletal disorders (Contento, 2008; Eisenberg & Burgess, 2015; Haththotuwa et al., 2020). The fundamental cause of obesity is the imbalance of energy intake and output of an individual, for example, an increased intake of energy-dense foods or decreased physical activity (Haththotuwa et al., 2020). Figure 1 indicates the complexity of one's food choices is influenced by factors like biology, experience with food, personal factors, and environmental factors (Contento, 2008). As can be seen in this model, food-related knowledge and the ability to make healthy food choices, is the only category that education can influence directly among numerous others; yet this is only a small piece and is often seen as less relevant (Contento, 2008). Although providing knowledge and skills may not be seen as effective for its portion in the bigger picture, nutrition educators try to address people's food choices by influencing three factors: (1) food preferences and affective sensation; (2) person-related factors such as perceptions, beliefs, attitudes, meanings, and social norms; and (3) environmental factors (Steenkamp, 1993; Contento, 2000; Contento, 2008). In this study, the definition of *nutrition education* is “the individual level intervention that combines educational strategies to address the possible cause of obesity, including food choice knowledge and nutrition-related behaviors in the non-medical background population" (Contento, 2008, p 176).

Figure 1

Influences On Food Choice (Contento, 2008, p 177)



Researchers applied gamified education to the nutrition field to increase the effectiveness of nutrition education (Guy et al., 2011; Chow et al., 2020). Gamified education intervention studies were developed flourishingly to facilitate general health outcomes in the past decade. The result shows that gamified nutrition education helped to spread nutrition knowledge, fighting obesity through changing dietary behavior or increasing fruits and vegetable consumption (Johnson et al., 2016; Baranowski et al., 2019; Chow et al., 2020). The following Chapter will give examples of how games were utilized in the nutrition education field i.

Gamified Nutrition Education: Two Approaches

There are two approaches to embedding games to facilitate learning across various topic areas: GBL and gamification (Browne et al., 2014; Landers, 2014; Chow et al., 2020). *GBL* or serious gaming helps students/learners by building a game that has an educational purpose in mind (De Freitas, 2006). An example of GBL in the nutrition field is *Squire's Quest! II* (an online video game by Thompson et al., 2015). The aim of the game is to increase the fruit and vegetable intake of nine to eleven-year-old children. They designed the game by using episodes of stories, challenging tasks, and characters that allowed children to bring themselves into the adventure of saving the Kingdom of Fivealot by eating healthily. The game is structured to lead students through various topics, the same way a teacher might, to facilitate learning. Some researchers believe that when children learn in enjoyable ways via games, it is better than traditional teaching materials and techniques (Yien et al., 2011). Topics covered by GBL in the nutrition field include fruit and vegetable consumption (Rosi et al., 2015; Thompson et al., 2016), increasing nutrition knowledge (Turnin et al., 2001; Banos et al., 2014), changing dietary behavior (Baranowski et al., 2003), reducing snacking behavior (Majumdar et al., 2014), and increasing physical activity (Johnson et al., 2016). The research team of Guy et al. (2011) performed a systematic review and found that there is a small amount of increased physical activity and nutritional knowledge as a result of GBL, but no integrated effect size from the meta-analysis.

The second approach is *gamification* that applies game mechanisms to a non-game activity, unlike GBL that provides educational material while the game is being played (Deterding, 2011). For example, a study by Jones et al. (2014a) used rewards (e.g., temporary tattoos, mechanical pencils, flying discs, etc.) to encourage students to eat more target fruits or vegetables. Later in their study, if all students reached the goal of consuming certain fruit or vegetables, the teacher participating in the study would read an episode of a story to them. The story was written specifically for this study according to the study's purpose. If the goal was not met, the episode would not be read, and a message from the fictional heroes who encouraged them to eat more of that food than normal was read by the teacher instead. In this study, students did not play any games but performed their daily activities in an altered way—and that is the main difference between GBL and gamification. Gamification had been used to increase fruit and vegetable intake (Jones et al., 2014a; Jones et al., 2014b), change dietary behavior (Kadomura et al., 2014), and increase physical activity (Edney et al., 2017). Schmidt-Kraepelin and his colleagues (2020) reviewed gamification and its effect on health behaviors, but they failed to conclude how the literature they had reviewed conceptualized the role of gamification in health interventions.

Although GBL and gamification are different approaches, the two concepts are often studied together—especially in the new field of gamified education (Johnson et al., 2016; Asadzandi et al., 2020; Chow et al.,2020). For instance, the most comparable systematic review in the nutrition education field was done by Chow et al. (2020), who identified a total of 43 studies assessing the GBL and gamification influence on fruit and vegetable intake published in Medline, Scopus, and PsycINFO. This systematic review showed that both GBL and gamification increased fruit and vegetable intake and promoted healthy eating by children. However, no meta-analysis was performed, as the studied variables were different from study to study.

Results from other health-related meta-analyses, however, might provide a piece of evidence that gamified nutrition education is effective. For example, DeSmet et al. (2014) reviewed health related GBL and concluded it increased healthy lifestyle adoption (g=0.260, 95% CI 0.148; 0.373), and the result was from combining the effect across several health domains, including physical activity, knowledge gain, and clinical outcome. Nutrition-related portions from other general health systematic reviews also showed a positive result from applying games to nutrition education (Guy, Ratzki-Leewing, & Gwadry-Sridhar, 2011; Johnson et al., 2016; DeSmet et al., 2014; Seaborn & Fels, 2015). The positive outcome of embedding GBL or gamification in nutrition education is expected according to those results. In summary, there are many overlaps between GBL and gamification (Landers, 2014; Chow et al., 2020), and evidence showed that there is a positive association between gamified content to nutrition education. However, the "gamification literature has already begun to grow apart from the serious games literature" (Landers, 2014, p. 755), and the difference between GBL and gamification will be further addressed in the next section.

Different Outcomes of GBL and Gamification

In the last section, the different definitions of GBL and gamification were explained. In this section, the rationale for why outcomes of GBL and gamification might be distinct are examined. The differences between GBL and gamification had been mentioned by multiple studies (Landers, 2014; Al-Azawi et al., 2016; Khan et al., 2017) where the overlap was mostly consistent: entertainment and motivation (Landers, 2014; Chow et al., 2020 Johnson et al., 2016; Asadzandi et al., 2020). Games are entertaining and structured with rewards to be engaging (Stiller & Schworm, 2019). Researchers even suggest that a minority of game players experience negative symptoms from gaming (such as mood modification, tolerance, and behavioral salience) that are associated with traditional substance addictions (Kuss & Griffiths, 2012). Although no study was found relating GBL to game addiction, and GBL contains a high level of cognitive load (Stiller & Schworm, 2019), to some researchers, gamification is more appealing for an educator to be used in a classroom. This is because gamification only takes elements of games, such as award systems, badges, points, and level of difficulty, and applies them to pedagogy (Hamari & Koivisto, 2015). Adopting the game mechanism may potentially avoid problematic gaming and entertain the learner, but we must consider the other piece in the equation: motivation.

Motivation plays an important role in behavioral changes, but not all forms of motivation have the same ability to facilitate positive behavioral changes. According to Self-Determination Theory (SDT; Ryan & Deci, 2000), when the three basic psychological needs of competence, autonomy, and relatedness are met, intrinsic motivation will be experienced, and the behavior will be self-determined and persistent. Otherwise, that behavior might be motivated but will be extrinsic (Ryan & Deci, 2000). If one's behavior only happens because of external motivators, that behavior is externally regulated, and the person will show less interest, value, and effort toward achievement (Ryan & Deci, 2000). Thus, if rewarding a system of gamification only provides a learner with extrinsic rewards and not the proper motivation, it may negatively influence their long-term success (Ryan & Deci, 2000; Landers, 2014). Although the long-term effects of nutrition education are one of the emphases suggested by many studies (Chow et al., 2020; DeSmet et al., 2014; Nacke & Deterding 2016), limited research has been done to study the endurance of the education's effect. Only a few studies about the persistence of knowledge or behavior for gamification or GBL have been conducted (Azevedo et al., 2019; Chow et al., 2020; Munguba et al., 2008).

Problem Statement

Despite GBL and gamification both showing some beneficial effects pertaining to nutrition education (Chow et al., 2020; Hamari et al., 2014), each has its unique advantages and disadvantages (Al-Azawi et al., 2016; Landers, 2014; Khan et al., 2017). A better understanding of which elements work (and which do not) is a primary concern for gamified education (Landers, 2014) and more comparative studies are needed (DeSmet et al., 2014). Unfortunately, only two known studies applied both GBL and gamification in a randomized control trial (Braga-Pontes et al., 2021; Browne et al., 2014) and the information provided is also limited for comparing GBL versus gamification. The study by Browne and colleagues did not compare the effects of GBL versus gamification, unfortunately, and the content presented by GBL was different from the content presented by gamification and traditional teaching. Braga-Pontes et al. (2021) presented the mean differences in their study, but they only focused on the consumption of lettuce, carrot, purple cabbage, cucumber, and tomato for Portuguese children who were 3-6 years old. With limited studies that directly compare the effect between GBL and gamification, and much more literature comparing either GBL or gamification to a control, the researcher can perform an indirect comparison meta-analysis or network meta-analysis to address the research question (Bucher et al., 1997). The next section will explain more about the present research and the research question of this study.

Present Research

This study compared the different effects between GBL and gamification by using network meta-analysis, a method of integrating existing evidence of two treatments or more that may or may not have been compared directly in a single randomized control trial (RCT) (Bucher et al., 1997; Hu et al., 2020). When there is limited direct comparison between A and B, but evidence is available from studies comparing A to placebo and B to placebo using the same comparator, it is possible to generate an indirect comparison of treatments A and B or network meta-analysis (Bucher et al., 1997; EUnetHTA Guidance, 2013; Mills et al., 2011). Although past literature showed more positive outcomes than negative impacts in the nutrition field, how the two mechanisms promote the effectiveness of nutrition education needs further investigation (Chow et al., 2020). This study aims to identify and analyze the research literature on different effects of gamification and GBL to enhance nutrition knowledge and behavior for all populations. Building games and training educators are expensive and take intensive effort (Baranowski et al., 2019). If GBL stimulates learners more effectively, it will be cost-effective to support developing more well-designed learning games and repeatedly using them afterward (Baranowski et al., 2019). If gamification shows more improvement, it can be included in the educator's curriculum, so the educator demonstrates how to use it. Results of the study can provide evidence that stakeholders, policymakers, and health workers can use to direct the future allocation of resources to the most cost-efficient method of facilitating learning in the nutrition field and try to resolve the world epidemic of obesity.

Research Questions

This study adopted Contento's (2008, p176) definition of nutrition education and defines “nutrition education as the individual-level educational intervention that combines strategies addressing the possible causes of obesity, including the information about food choices and nutrition-related behavior, targeting populations without a medical background”. Thus, for example, interventions that taught participants the benefit of eating more fruits and vegetables or performing physical activity by trying to change their personal-related factors such as perceptions or behavior was considered as nutrition education. However, a study in which the subjects' diet was altered by researchers will not be considered as nutrition education but a dietary intervention.

This meta-analysis examined studies on participants' knowledge and/or behavioral change after a gamified nutrition education intervention (GBL or gamification) and compared the different effects. The length of the intervention is associated with the learning outcome, and it is suggested by research that the effects of games are stronger when players engage in multiple sessions over longer periods of time (Sailer & Homner, 2019). This meta-analysis investigated the duration of each gamified intervention, given that long-term persistence of the knowledge or behavior is vital for nutrition education as suggested by multiple reviews (Chow et al., 2020; DeSmet et al., 2014; Nacke & Deterding, 2016). It was also investigated if the participants were followed up with, and the effect that had on the outcome. The research questions guiding this study are:

1. Which type of gamified nutrition education, gamification or GBL, delivers a stronger overall effect of increasing knowledge?
2. Which type of gamified nutrition education, gamification or GBL, delivers a stronger overall effect of promoting fruit and vegetable intake amount?
3. Which type of gamified nutrition education, gamification or GBL, is more effective in increasing physical activity?
4. What is the average time required to apply gamified nutrition education for different outcome/treatment?
5. If there was follow-up, what consequence did the duration of the intervention have on its effectiveness?

These questions guided the analysis of this study. A meta-analysis with three sub-constructs was performed to answer research questions one through three. First, the researcher calculated the average effect of GBL and gamification for each construct: knowledge (Q1), fruit and vegetable intake (Q2), and physical activity behavior(Q3). This allowed for a comparison of the effect of GBL versus gamification indirectly through the control group using Bucher's simple adjusted indirect comparison method (Bucher et al., 1997). The indirect comparison result can reveal the effectiveness of GBL versus gamification when used to increase knowledge (Q1), fruit and vegetable intake (Q2) and physical activity (Q3). This study also evaluates how much time is used to apply the intervention (Q4) and the duration of the effectiveness of the intervention (Q5). Preliminary search results indicate that the literature may lack information about the duration of the intervention effectiveness. Thus, the researcher only reports the descriptive statistics for research questions four and five.

Based on this evidence, the research can lead to recommendations to nutritionists, public health workers, and curriculum developers about which approach they should employ for different participants since building games and training educators are expensive and take intensive effort (Baranowski et al., 2019). Comparisons between the two approaches can also benefit future resource allocation to the most cost-efficient method of facilitating learning in the field of nutrition to fight obesity, a global epidemic (Haththotuwa et al., 2020).

CHAPTER II

LITERATURE REVIEW

The purpose of this study was to examine if there are different effects for GBL and gamification utilized in nutrition education. Ryan and Deci's (2000) self-determination theory (SDT) was adopted as the theoretical framework for this study as it addresses the role of different motivators and their association to persistent behavioral change. This literature review synthesized the existing academic work that informed this study. Accordingly, this chapter covers the following four main sections:

1. Nutrition education, which describes the importance of nutrition education and how it was defined in this study;
2. Gamified education, which describes the history of gamified nutrition education and different approaches of GBL and gamification
3. Self-Determination Theory (SDT), which provides an overview of the theory, including the basic psychological needs (autonomy, competence, and relatedness) and the associated types of motivation, and a discussion of the hypothesis of why there might be a difference between GBL and gamification;
4. Preliminary search result, which provides an overview of the first screening search, including the backward search from articles and PubMed search to identify the possibility of executing this project.

This integration of previous literature was not only to identify the current study gap but also to provide the important background information and definitions necessary to frame the rationales, methods, and conclusions of this study.

How is Nutrition Education Defined?

The previous chapter mentioned the rising importance of nutrition education due to the global epidemic of obesity and other possible health risks that come with it (Haththotuwa et al., 2020). However, nutrition education can be a class in the university curriculum (Adams et al., 2010) or an image of dietary guidelines like MyPlate (U.S. Department of Agriculture, 2022). Nutrition education can be delivered in different settings and involves activities at the individual, community, and policy levels (Contento, 2008). Contento's (2008) model of explaining nutrition education indicated that the complexity of one's food choices is influenced by various factors, while limited access can interfere with nutrition education. In this study, the definition of nutrition education is "the individual level intervention that combines educational strategies to address the possible cause of obesity, including food choice knowledge and nutrition-related behaviors in the non-medical background population" (Contento, 2008, p 176).

Gamified Education

The activity of play has been in human history for a long time. People play games as a way to step out of the daily routine and it also brings people pleasure and enjoyment. Huizinga (1938, p. 13) refers to play as "a free activity (...) outside "ordinary" life as being "not serious", but at the same time absorbing the player intensely and utterly. So, play is not only an enjoyable pastime activity, but it also has a social meaning connecting people associated with gameplay.

People started to adapt games to learning in 1971. The game was used to support training and learning objectives. The first games and simulations for specific educational purposes were war games, and this trend may partially explain the diversity of 'first person' shoot 'em up games available in the games market today (de Freitas, 2006). After that, there are many diverse games that support different subjects of learning like language learning, history, physical education, science, and math. Study of the benefits of games to education became a trend for researchers, and can be witnessed from as early as kindergarten, all the way to higher education (Barr, 2017; de Freitas, 2006).

GBL

GBL uses learning games to achieve an instructional goal. The terms 'GBL', 'learning games', and 'serious games' are interchangeable. What makes the learning game different from other games? The answer is a learning goal. Learning games have both a game goal (what players must do to win) and a learning goal (what players are to learn through playing the game).

There are many games designed with learning goals in mind. Some games might have a direct focus on science (e.g., Physics, Geoworld, Virtual Cell, Sneeze, World of Goo), mathematics (e.g., DimensionM, ASTRA EAGLE), languages (e.g., My Spanish Coach), or history (e.g., Civilization, Oregon Trail, Assassin's Creed). But there are also games to provide a virtual environment for students to learn (e.g., Quest Atlantis, River City, and Second Life.) Most of the games mentioned above can be fun and immersive while engaging students outside the space and time reserved for classes (Young et al, 2012). But there are some more benefits about GBL than just putting educational material in a more appealing wrap.

In the review that de Freitas accomplished in 2006, she found that learning through exploration is one of the strengths of GBL, allowing learners and learner groups time and scope for exploring environments freely. She also mentioned that games have been identified to have several different uses: as metaphors, as tools, for therapy and for the rehearsal of skills, for supporting higher cognition in microworlds and as open-ended spaces for experimentation. And one researcher found that GBL interventions have a role to play in higher education as well by using a pilot project game that promotes effective communication, adaptability and resourcefulness, all of which offer advantages for attribute development over-and-above existing university provision (Barr, 2017).

However, there is still a lack of empirical data to support the facts of how games work under learning contexts, as well as a lack of understanding about how these games can be used most effectively in practice (de Freitas, 2006). But the six factors that hinder teachers' use of games in the classroom were discovered. Baek (2008) found that inflexibility of curriculum, negative effects of gaming, students' lack of readiness, lack of supporting materials, fixed class schedules, and limited budgets are the six factors which inhibit teachers using games in class.

Squire's Quest! II is an iconic example of GBL to increase the fruit and vegetable intake of nine to eleven-year-old children (Thompson et al., 2015). Children can play episodes of stories, challenging tasks in game with an Avatar that represents themselves in the game. They can try to save the Kingdom of Fivealot by eating healthily, and the game promotes learning for students. This study found various topic of GBL including fruit and vegetable consumption, increasing nutrition knowledge, changing dietary behavior, reducing snacking behavior, and increasing physical activity (Banos et al., 2014; Baranowski et al., 2003; Johnson et al., 2016; Majumdar et al., 2014; Rosi et al., 2015; Thompson et al., 2016; Turnin et al., 2001). The research team of Guy et al. (2011) performed a systematic review and found that there is a small amount of increased physical activity and nutritional knowledge as a result of GBL, but no integrated effect size from the meta-analysis they conducted.

Gamification

Gamification has been defined as a process of enhancing services with (motivational) affordances in order to invoke gameful experiences and further behavioral outcomes (Hamari, Koivisto, & Sarsa, 2014). Gamification is an emergent approach to instruction which facilitates learning and encourages motivation through the use of game elements, mechanics and game-based thinking. (Karl Kapp, 2013) The purpose of it is to engage and motivate learners to become active participants in their own learning process. For example, the teacher gives out points for good behavior and subtracts points for undesired behaviors. In my opinion, gamification is the application of positive reinforcement but in a more complex way to make a learner feel a sense of achievement. The study of gamification and its benefits became a trending topic and a subject of note in recent years. The following paragraph is the result from a review article for gamification after examining 24 empirical articles to answer one question: “Does gamification work?”

Researchers found that according to a majority of the reviewed studies, gamification does produce positive effects and benefits. Most of the papers they reviewed reported positive results from gamification implementations to the motivational affordances. All the studies they reviewed were in educational contexts and considered the learning outcomes of gamification as mostly positive. However, they pointed out some things that need to be paid attention to when implementing gamification, such as the effects of increased competition, task evaluation difficulties, and design features.

Overall, in answer to the question posed: “Does gamification work?”, literature suggests that, indeed, gamification does work, but some caveats exist (Hamari, Koivisto, & Sarsa, 2014).

How is Gamified Nutrition Education Studied?

Three studies listed below were found when investigating the difference between gamification, GBL, and non-gaming education setup. The first article is an example of true experimental design research in the nutrition education field. The second study is a quasi-experimental design in the nutrition education field. And the last study is a pre-post treatment comparison design research that tries to analyze the different effects among gamification, GBL, and non-game treatment in the health field.

Study 1

In the Sharps and Robison’s (2016) study, participants were led to believe that the study was looking at how people played board games and was randomly assigned to one of the three conditions; descriptive social norm-based message vs. health message vs. control. Individual participants were randomly assigned to play one of three board games. One board contained images of fruit and vegetables used in the descriptive social norm-based message and health message conditions. In contrast, the other board printed images of animals, which was used in the control condition. The measure used in their study was snack food that participants consumed, bodyweight, fruit and vegetable consumption and Liking, hunger, and beliefs about descriptive social norms (Sharps and Robison’s; 2016). Researchers found that children in the health message condition ate significantly more fruit and vegetables than children in the control condition. Still, there was no significant difference between the health message condition and the descriptive social norm-based message condition. There was no significant difference between the descriptive social norm-based message condition and the control condition, either (Sharps and Robison's; 2016).

In the study, variables were clearly defined and measured. Controlled variables like BMI, age, gender, beliefs about the fruit and vegetable intake of other children were measured to determine whether three groups were statistically similar (Sharps and Robison's; 2016). The independent variable is three conditions in the study; descriptive social norm-based message vs. health message vs. control (animal image) showing on the board game (Sharps and Robison's; 2016). Dependent variables, including fruit and vegetable intake, high calorie snack food intake, were scaled and recorded. Researchers set up a well-controlled environment in a UK primary school where these three conditions were the only variance among participants. For example, they have a set timeframe from 9 am to 3.30 pm for one child at a time to take in the experiment. They followed a protocol of the study procedure and explained the game; the explanation was identical. After playing the game, the child can take snacks during the break; the amount and category of snacks taken was tracked and analyzed (Sharps and Robison's; 2016). The snack foods they could choose were also equivalent to every child. The protocol also instructed researchers to check if the studied child knew the true study purpose and if he/she knows the difference between vegetables and fruits. On top of that, this study used a blinding technique: some people in the study did not know which group they were assigned to study to minimize the positive or negative interference because of the expectation to the assigned group (Mitchell, 2015). This study is a single-blinded study in which participants did not know whether they are in the treatment or control group, but the researcher knows (Sharps and Robison's; 2016).

However, the process of randomization was not well stated. It only mentioned that participants are randomly assigned. Based on a similar number of participants for each group, researchers might have assigned the coming child each to a different group in order. The difference between the two treatment groups is the message cards used during the game, which were selected at predetermined points during the game (Sharps & Robison, 2016). In the descriptive social norm-based message condition, the messages stated 'other children eat lots of fruit and vegetables every day and like them' (Sharps and Robison's; 2016, p.20). In the health message condition the messages stated 'fruit and vegetables are really good for you' (Sharps and Robison's; 2016, p.20). The result showed that only the health message condition significantly differs from control. This might also indicate that the game is not the main effect here but the message presented throughout the interaction.

Study 2

In a study done by de Vlieger et al. (2020), researchers assigned the control and intervention treatment to two different primary schools. Included students in both schools completed a nutrition knowledge survey on a tablet at baseline and a week later. The control school (n = 94) received no nutrition education and the other school (n = 75) played VitaVillage, a game designed for this study aiming to promote nutrition knowledge, twice in the week of study for 20 minutes. The change in nutrition knowledge survey results from baseline and one week later were measured as outcome variables. Game likeability was also measured. Researchers found that VitaVillage improved participants' nutrition knowledge significantly on overall scores and scores for the categories 'serve sizes' and 'balanced meals,' compared to participants not getting nutrition education. The participants indicated they liked the game, with a mean score of 77 (SD 24.6), on a scale of 0-100.

Researchers utilized the strength of quasi-experimental design and gave out the treatment all at once to more than 100 total participants in different schools. In this study, the independent variable is the involvement of the VitaVillage game. However, their method of monitoring participants was not mentioned. Did students play 20 mins in class or at home? Were they required to play or was it optional? How far the participant should play through the game is not mentioned either. If any other controlled variables were included, they were not described.

The dependent variable, nutrition knowledge score, was measured by a nutrition knowledge survey before and after the treatment, but in this study, no nutrition education was given to the control condition school. This indicated that the difference between two schools that was measured was not gamified education compared to non-gamified setup but the different effects of repeated tests to gamified nutrition education. Study design may show the difference between gamified and non-gamified setup, but it is not the result that we are interested in. Randomization is not seriously executed as well. On top of that, no characteristics of the two schools were described. For example, the researcher did not mention how they decided which school gets what. The fact that this is a quasi-experiment may explain why it only has one or two of the three design elements for studies (manipulation, control, and randomization). And it generally lacks randomization (Thompson & Panacek, 2006)

Study 3

The third study is not about nutrition, but it compares the different effects of gamification, GBL, and non-game setting. Browne et al. (2014) used three different tablet apps: the homophone app, the punctuation app, and the comma app. The homophone app is intended as a gamification app to motivate user behavior, whereas the punctuation app is intended as a serious game where literacy-skill improvement is the primary goal rather than entertainment (Browne et al.; 2014). The comma app was developed after the experiment when participants indicated that a combination of traditional instruction and the tablet app might be most helpful (Browne et al.; 2014). Four one-hour experiment sessions were conducted, two sessions each week for two weeks. Participants could only attend one session per week, and some participants did not attend a session in both weeks. In the first week's session, the homophone app was tested, and in the second week's session, the punctuation app was tested followed by the comma app. Study procedure as follows:

1. After explaining the study purpose, a pre-experiment questionnaire was given to participants, followed by a first quiz sheet.

2. The participants were instructed using either traditional methods or the iPad app to learn.

3. The participants completed the second quiz sheet, and the user experience survey if the iPad app had just been used.

4. The participants were again instructed using either traditional methods or the iPad app, whichever method they had NOT received in the previous instruction session.

5. The participants completed the third quiz sheet, and the user experience survey if the iPad app had just been used.

6. The participants completed the post-experiment questionnaire asking if they preferred the app or a traditional instructor.

The same quiz was given three times to track the difference in the learning process. Adding qualitative observational data, researchers concluded that gamification and GBL were both effective in adult literacy education, but no significance was reported, and no gamification and GBL were examined either (Browne et al., 2014).

Although three facets - gamification, GBL, and non-game education - were the independent variables in this study, the participants got to choose what condition they wanted (traditional or app) first. This might cause an error and bias because the people who chose to use an app first might be people more comfortable with new technology. The third app researchers created was the comma app, which was created roughly after the first-week session because the participants suggested doing so. This should not happen in a well-planned study design. The topic mapped to each treatment was different from one to another. They used homophone learning content to combine gamification elements and punctuation teaching content to build a serious game (Browne et al.; 2014). As for non-game setup, the original procedure was to use traditional teaching but changed for the second-week session to the app plus teaching session.

They did not do an excellent job of controlling elements. The participants were allowed to interact with one another. Researchers described, “the very participant discussed some aspect of the app while using the app with either the other participants,” which is not at all a controlled environment and may result in several other variabilities.

On top of that, they did not design a washout time between two instructions, so the same topic was taught by two mediums back to back. So in the result session, the researcher stated that " the quiz results for punctuation sessions showed a decrease after the second method. Perhaps some participants became bored after learning the same skills twice in a row." (p.)

Finally, gamified and GBL's effect difference was not analyzed, so the question - "Does gamification, GBL and non-game setup have different effects on promoting learning especially when applied to nutrition education" - remain unknown.

Self-Determination Theory and Motivation

In this section, the rationale for why outcomes of GBL and gamification might be distinct are examined from a self-determination theory perspective. The differences between GBL and gamification had been mentioned by multiple studies (Landers, 2014; Al-Azawi et al., 2016; Khan et al., 2017). Some researchers may favor gamification over GBL because they think gamification only takes elements of games, such as award systems, badges, points, and level of difficulty, and applies them to pedagogy (Hamari & Koivisto, 2015). Although no study suggested that GBL may lead to game addiction (Stiller & Schworm, 2019), to some researchers, gamification is more appealing for an educator to be used in a classroom. However, types of motivation promoted might be different suggested by SDT and the association between the theory and gamified nutrition education will be explain more in the follow up section.

Motivation plays an important role in behavioral changes, but not all forms of motivation have the same ability to facilitate positive behavioral changes. According to Ryan and Deci (2000), contextual condition can promote optimal motivation and by providing opportunities for individuals to fulfill their basic psychological needs of competence, autonomy, and relatedness. Contrariwise, a lack of contextual condition weakens individuals' motivation and well-being. Guided by the degree of need satisfaction, SDT posits three main types of motivation as mediating processes between need satisfaction and well-being.

First, intrinsic motivation, as the most self-determined form of motivation, intrinsic motivation refers to a state in which an individual performs a behavior for the inherent interest to seek out novelty and challenges, to extend and exercise one's capacities, to explore, and to learn (Ryan & Deci, 2000). To this end, an activity may be pursued because it is deemed to be enjoyable, optimally challenging, or aesthetically pleasing (Ryan & Deci, 2000). Intrinsic motivation is consider to be the optimal motivation that persist the behavior voluntarily (Ryan & Deci, 2000).

Second, extrinsic motivation, refers to an individual performs a behavior in order to obtain an external outcome (Ryan & Deci, 2000). More specific, with extrinsic motivation, an individual may be moved to act for and external incentive caused by the result of their action (external regulation), the presence of internally-imposed feelings of guilt (introjected regulation), the importance of the task (identified regulation), or in alignment of the task with personal values and needs (integrated regulation). These parenthetically referenced conditions represent separate regulatory styles, which are presented in detail below. In comparison with intrinsically motivated behaviors, which are more likely to be sustained in the long-term, extrinsically motivated behaviors tend to cease when the external motivator is no longer present (Ryan & Deci, 2000).

Thus, if rewarding a system of gamification only provides a learner with extrinsic rewards and not the proper motivation, it may influence their long-term success (Ryan & Deci, 2000; Landers, 2014). Although the long-term effects of nutrition education are one of the emphases suggested by many studies (DeSmet et al., 2014; Nacke & Deterding 2016; Chow et al., 2020), limited research has been done to study the endurance of the education's effect. Only a few studies about the persistence of knowledge or behavior for gamification or GBL have been conducted (Azevedo et al., 2019; Chow et al., 2020; Munguba et al., 2008).

Preliminary Search and Characteristic

There were two main sources of preliminary search (see Figure): backward search for reviewed literature and PubMed literature search. Backward search identified relevant literature by examining the references or works cited in an article (Jalali & Wohlin, 2012). In the backward search, this study used four published literature review articles identified in this Chapter (Chow et al., 2020; DeSmet et al., 2014; Guy et al., 2011; Seaborn & Fels, 2015), one book (Horn & Cleaves, 1980), and two articles (Nour et al., 2017, Yang et al., 2015) that contain relevant literature comparing GBL and gamification in the nutrition education field. The purpose of this preliminary search was to make sure there were enough literature to perform this meta-analysis process. After backward search, using the literature mentioned above, 44 non-repeated relevant articles were found written in English (see Table 1).

Table 1

Research Method and Intervention in the Preliminary Search

Study	*Research method*	*Form of intervention*
Pemprk & Calvert, 2009	experiment	Advergame

Study	*Research method*	*Form of intervention*
Dias & Agante, 2011	experiment	Advergame
Harris et al, 2012	experiment	Advergame
Folkvord et al, 2013	experiment	Advergame
Folkvord et al, 2014	experiment	Advergame
Folkvord et al, 2015	experiment	Advergame
Folkvord et al, 2016	experiment	Advergame
Sharps & Robinson, 2016	experiment	board game
Folkvord et al, 2017	experiment	board game
Florack et al, 2018	experiment	board game
Porter et al, 2018	experiment	board game
Gillis, 2003	Pre-, post- intervention comparison	Board game
Coulthard & Ahmed, 2017	experiment	board game
Lakshman et al, 2010	Quasi-experiment	board game
Amaro et al, 2006	experiment	board game (Kaledo)
Viggiano et al, 2018	experiment	board game (Kaledo)
Rose et al. (2013)	Usability evaluation	Gamification *(*Smartphone App)
Jones et al. (2014a)	*Pre-,* post- intervention comparison	Gamification activity
Jones et al (2014b)	*Pre-,* post- intervention comparison	Gamification activity
Joyner et al., 2017	*Pre-,* post- intervention comparison	Gamification activity
Azevedo et al, 2019	Quasi-experiment	Gamification *(*Smartphone App)
Kadomura et al, 2014	Pre-, post- intervention comparison	Gamification (fork)
Nour et al 2017	Focus group	Gamified(smartphone application)
Yang et al (2015)	Quasi-experiment	online team-based competitive game
Thompson et al., 2009	experiment	online video game
Schneider et al, 2012	Pre-, post- intervention comparison	online video game (Fitter Critters)
Thompson et al., 2015	Pre-, post- intervention comparison	online video game(Squire's Quest! II)
Cullen et al, 2016	Pre-, post- intervention comparison	online video game(Squire's Quest! II)
Thompson et al, 2016	Pre-, post- intervention comparison	online video game(Squire's Quest! II)
Desmet et al, 2017	Pre-, post- intervention comparison	online video game(Squire's Quest! II)
Putnam et al, 2018a	experiment	tablet game (Dora the Explorer)
Putnam et al, 2018b	experiment	teblet game(D.W.'s Unicorn Adventure)
Munguba et al., 2008	Quasi-experiment, semi-structured interview and structured observation	1 video game, 1 board game
Rosi et al, 2015	Pre-, post- intervention comparison	video game
Turnin et al, 2001	Quasi-experiment	video game
Banos et al, 2013	Quasi-experiment	video game
Majumdar et al, 2013	Quasi-experiment	video game
Wang et al 2017	Quasi-experiment	video game (Escape for Diab)
Jiang et al, 2016	experiment	video game (Happy Goat Says)
Pampaloni et al, 2015	Pre-, post- intervention comparison	video game (Mr. Bone)
Sharma et al, 2015	Quasi-experiment	video game (Quest to Lava Mountain)
Baranowski et al, 2003	Pre-, post- intervention comparison	video game (Squire's quest)
Johnson-Glenberg & Hekler, 2013	Pre-, post- intervention comparison	video game(Alien health game)
Johnson-Glenberg et al, 2014	experiment	video game(Alien health game)

For the PubMed literature search, search term (nutrition education) OR (eating behavior) OR (nutrition literacy) OR (healthy eating) AND ((serious gaming) OR (game based learning) OR (gamif*)) was used on 7/20/2020; there were 113 hits. After screening, there were 28 relevant articles non-repeated from source one. Indicating there were a total of 72 articles which might be eligible for main analysis. Among the 28 articles from the PubMed search, 16 used randomized control design (or true experiment), nine used one group pre-post intervention comparison, one of the studies used quasi-experiment, and two used quantitative methods: see Table 2.

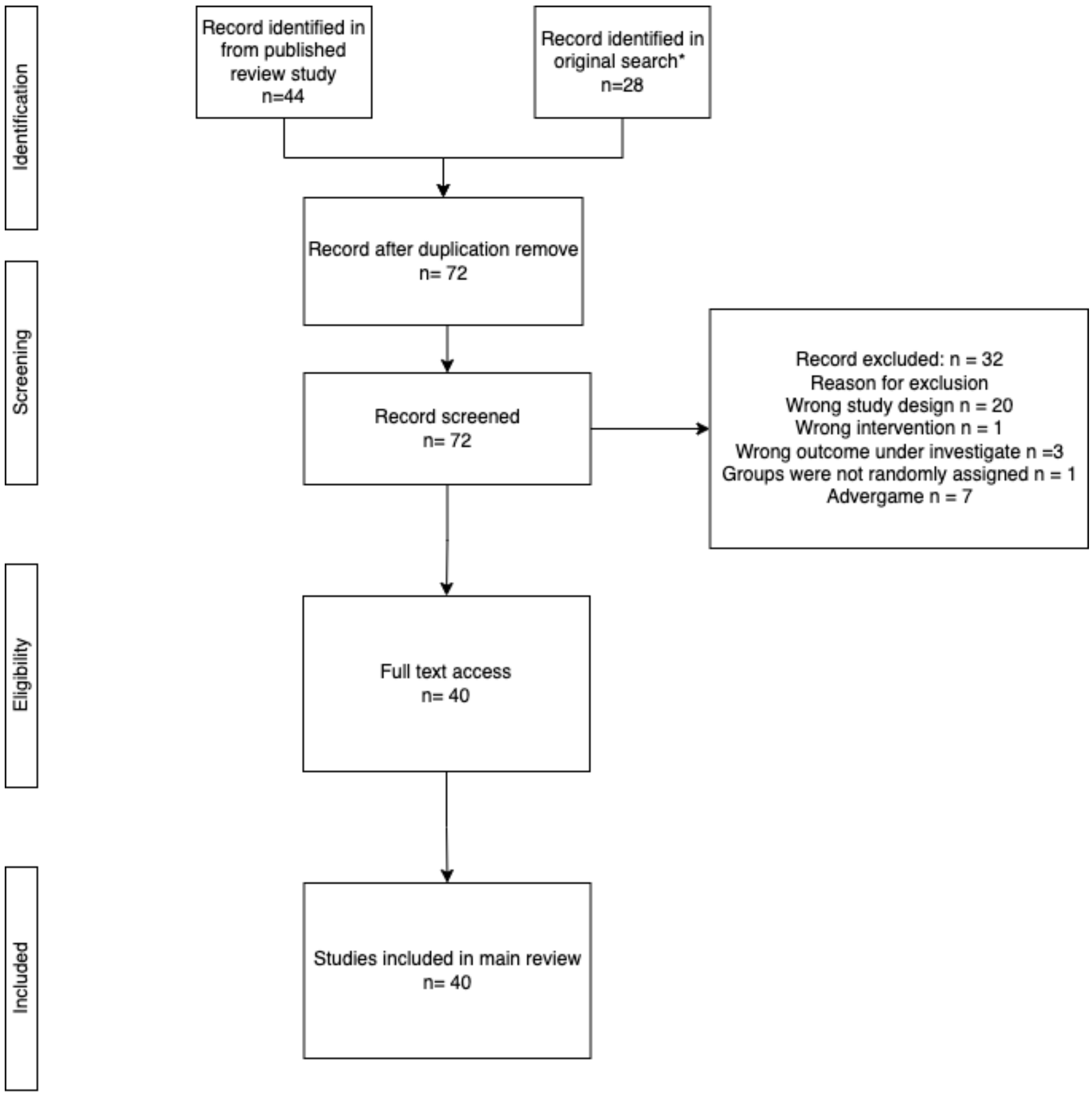
Table 2

PubMed literature search result

RCT	Pre-post intervention	Quasi experiment	Qualitative
Beleigoli et al, 2018	Espinosa-Curiel et al, 2020	Del Río et al, 2019	Corepal et al, 2018
Belogianni et al, 2019	Grassley et al, 2017		Ezezika et al, 2018
Beltran et al, 2013	Holzmann et al, 2019		
Blackburne et al, 2016	Lowensteyn et al, 2019		
Chagas et al, 2018	Rohde et al, 2019		
Dassen et al, 2018	Ruggiero et al, 2020		
Edney et al, 2017	Shiyko et al, 2016		
Fang et al, 2019	Spook et al, 2016		
Harrison et al, 2019	Van Lippevelde et al, 2016		
Mack et al, 2020			
Podina et al, 2017			
Pope et al, 2018			
Poppelaars et al, 2018			
Schakel et al, 2018			
Schakel et al, 2020			
Skouw et al, 2020			
16	9	1	2

Figure 2

Preliminary Search Flow Chart



Search term (nutrition education) OR (eating behavior) OR (nutrition literacy) OR (healthy eating) AND ((serious gaming) OR (game based learning) OR (gamif)) was used in PubMed on 7/20/2020

Many studies used true experiments to provide evidence with reliable scientific validity demonstrating the ability to create positive outcomes embedding GBL or gamification in nutrition education. In the preliminary result, only one study focused on adult participants (Rose et al., 2013), while the majority of studies were pertaining to younger participants ranging from kindergarten age to adolescents. Positive outcomes have been found for children (Munguba et al., 2008; Azevedo et al., 2019), adolescents (Thompson et al., 2009; Yang et al., 2015), and young adults (Nour et al., 2017) using game-based or gamification in increasing fruits and vegetable intake. The preliminary search result suggested that gamified nutrition education was growing at a fast speed and it was possible to have sufficient literature to support the study.

CHAPTER III

METHOD

This study performed an indirect comparison meta-analysis to compare the effect of GBL versus gamification applied to nutrition education under three sub-constructs: knowledge, fruit and vegetable intake, and physical activity. Meta-analysis is a set of statistical techniques used to synthesize the quantitative results from a set of studies and can be used to estimate an average effect from a set of studies, explore variation across study results, examine potential risk of bias in a systematic review, and compare effectiveness (Conn et al., 2012; Haidich, 2010). This section contains the methodology of the study: preliminary search and characteristic, inclusion and exclusion criteria, coding procedures, study variables, and data analysis. The results of using meta-analysis are statistically more powerful than individual studies (Lipsey & Wilson, 2001), which is why this approach is chosen to stitch pieces of evidence together and find out which gamified method is more effective when applied to nutrition education.

Criteria for Selection of Research Articles

First, only studies that are empirical were included. Second, a meta-analysis can only use studies that employ a quantitative method. Finally, it is important to understand that meta-analyses are only statistical summaries of data and that analyzing raw data provides more comprehensive and detailed results (Lipsey & Wilson, 2001). Search methods that were used to identify studies include peer-reviewed journal articles, and gray literature including doctoral dissertation with full-text access. Nutrition education in this study refers to an intervention that consolidates educational strategies into food choice knowledge, fruit and vegetable consumption, and physical activity to a non-medical background population.

After modification based on suggestions received from the committee, updated search terms included (nutrition education) OR (eating behavior) OR (nutrition literacy) OR (healthy eating) AND ((serious gaming) OR (game-based learning) OR (gamify*)); Active video game ; (nutrition education) OR (eating behavior) OR (nutrition literacy) OR (healthy eating) AND game. All three search terms were entered into the following databases: PubMed, Psycinfo, Science direct, Education Resources Information Center (ERIC), and ProQuest Dissertations & Theses Global (see for full detail). The searches were done between January 3rd and January 23rd, 2022. There were 1,249 records identified after deletion of duplication. Hand searches were conducted in the Journal of Nutrition Education and Behavior, Nutrients, and Appetite in March 2022. Hand search is a method of identifying relevant literature by reviewing materials not found through traditional searches. It is a manual process to examine and identify further relevant studies and includes going through issues of key journals. Journal of Nutrition Education and Behavior, Nutrients, and Appetite were identified as key journals during the process of database search due to the higher number of articles in the journals that were recognized as relevant when screening. Chinese database (Aseairiti library) search was conducted by using the vague term of game (遊戲) and nutrition education (營養教育). The author only screened search results that were indexed in Taiwan Citation Index - Humanities and Social Sciences (TSSCI) to ensure the quality of the research.

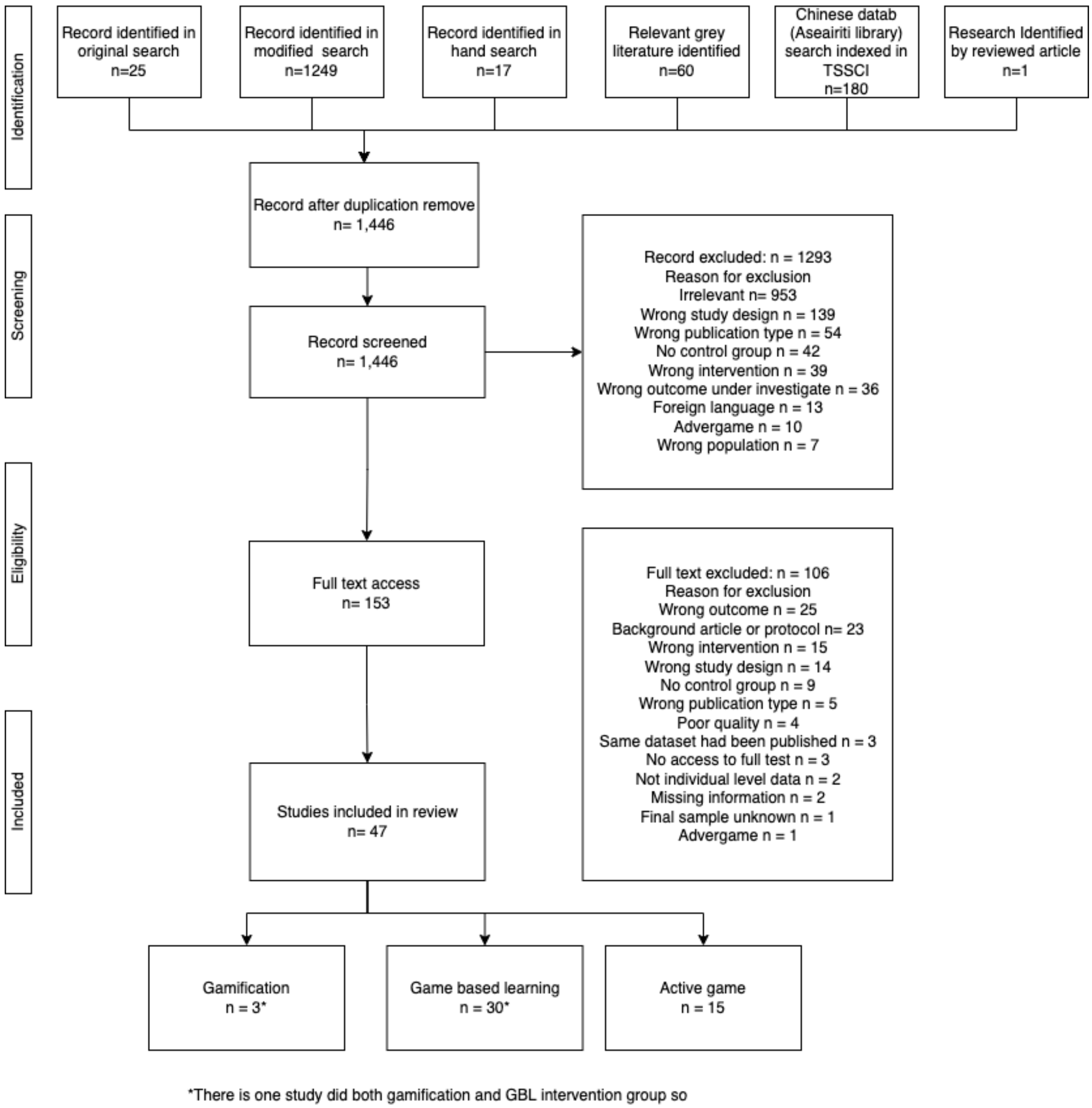
Records identified in the original search were included as they were the result of checking reference lists of identified review articles and documents. One article was identified by searching the published study results of a research protocol that was identified as relevant during screening but excluded from the final study sample due to being a background article or research protocol.

Inclusion and Exclusion Criteria

Only empirical studies that used quantitative methods, and were English- or Chinese-language, were included in the study. The search included peer-reviewed journal articles and unpublished doctoral dissertations whose full-text can be found. This study focused on experimental design, in that participants were randomly assigned to a control group or treatment group for either gamification or GBL. Indirect treatment analysis allowed the researcher to compare two treatments, for instance A and B, when they had not yet been evaluated in well-conducted RCTs to evaluate their effects (Bucher, 1997; Mills et al., 2011). When there is no RCT or direct comparison between A and B, but there is evidence from studies comparing A to control and B to control, it is possible to generate an indirect comparison of treatments A and B by means of using the same comparator control (EUnetHTA Guidance, 2013; Bucher et al., 1997; Mills et al., 2011). However, "Investigators making indirect comparisons should look carefully for differences in methodology, outcome measurement, or the populations included in studies" (Bucher, 1997, p. 7). Thus, the study included a randomized control group and a gamified nutrition education treatment group—either gamification or GBL for participants of a non-medical background. The study needed an intervention that consolidated educational strategies into food choice knowledge, fruit and vegetable consumption, and physical activity in a way that was considered valid for the non-medical background population. In a preliminary search, the majority of relevant articles used true experimental design (*n* = 37), while many studies (*n* =35) used pre- and post-intervention comparison. From a preliminary search done by the author, some studies involved advergame, "a game that promote certain brand, product or service by using advertising techniques" (Definition of ADVERGAME., 2022., Definition section), which promotes snacking behavior, and those articles were not included in this meta-analysis (Pempek & Calvert, 2009). The screening process began after the deletion of duplicate studies identified in the initial search.

Figure 3

Flow Chart of Literature Selection



Categorizing the Studies

First, the collected studies were categorized in a systematic way. Categories included:a) the goal of the gamified nutrition education, b) population, c) form of intervention, d) pedagogy used, and e) grounded theory. If the intervention was about increasing nutritional knowledge, then that study was categorized as knowledge; if the intervention addressed healthy behavior (fruit and vegetable consumption or physical activity), then the study was categorized as behavioral. There were studies that included more than one goal; these studies were categorized as having multiple purposes. For example, Amaro et al. (2006) investigated both knowledge gain and vegetable intake in one study. What population was studied in the research was noted. Whether the study was using GBL by utilizing board games, video games, or using gamification was reported. What pedagogy, if any, was noted. According to Zemliansky (2010, p114) pedagogy elements used within GBL and gamification intervention can be broken down into three dimensions: (1) the properties and behavior of in-game components; (2) the relationships between in-game components; and (3) the solving of problems in the scenario. What theory, if any, was used when constructing the education content? When comparing all studies, some of them could fall into more than one category, thus creating additional criteria for categorizing. Such cases will be explained as needed. A coding form was created to categorize the data, which included the following categories planning for now:

- Knowledge / behavioral (fruit and vegetable consumption; physical activity)
- Population under investigation
- Form of intervention (GBL or gamification)
- Pedagogy used

- Grounded theory
- Language

It should be noted that categorizing the studies may also lead to further exclusions if a particular study does not fall into specific categories as listed above. After categorizing each study, accounting for any that may need excluding, the remaining studies were coded according to their effect sizes or findings. Other than categorizing the research studies, the characteristic of each article in the final study sample can also be described as an alternative method of presenting articles (Zhou, 2006).

Coding Method

Calculating the effect size was the next step in the meta-analysis process (Bucher, 1997). To do this, a coding page was created to include the following information about each study:

- Outcome variable (knowledge score; fruit and vegetable intake; moderate to vigorous physical activity per hour per day)
- effect size value
- sample size
- level of significance of effect size (1 = not significant; 2 = < .01; 3 = < .05)

Independent Variables

In this study, the independent variable is the different intervention types: GBL, gamification or active game. GBL refers to games built for educational purposes and can include, but is not limited to, video games or board games (De Freitas, 2006). Gamification is an intervention that applies game mechanisms to a non-game activity

(Deterding, 2011). Active games are commercially produced games that require players to perform physical activity to play (del Corral et al., 2018).

GBL

An example of GBL is Squire's Quest II: Saving the Kingdom of Fivealot, which was created by Thompson and colleagues (2015). Saving the Kingdom of Fivealot (SQ2) is a 10-episode online video game designed to encourage children ages 9 to 11 to consume at least five servings of fruits and vegetables each day. The design framework of SQ2 included multiple theories related to behavior change, including Social Cognitive Theory and Self-Determination Theory (Thompson et al., 2015).

Gamification

A study in which the researchers applied game mechanisms to a non-game activity was coded as gamification (Deterding, 2011). For example, a study done in 2014 by Jones et al. (2014a) used a reward (e.g., temporary tattoo, mechanical pencil, flying disc, etc.) to encourage students to eat more target fruits or vegetables.

***Active* Game**

Active games are usually commercially produced, and can be seen as moderate-intensity physical activity when played because they require players to perform physical activity to play (Bowling et al., 2021; del Corral et al., 2018). The most common active games include but are not limited to Wii Fit Plus™ , Sony PlayStation EyeToy™ , Xbox 360 Kinect™, Wii sports™ , or Ring fit adventure. The purpose of an active game is to convert sedentary time into more active time by using motivational messaging during game play with in-game rewards to boost players' motivation. When using an active game in a study, the goal was to increase the self-determination of the player in order to encourage exercise devotion and the possibility of eventually engaging in non-screen-based physical activity.

Control / Placebo

As comparators, the study control group should not contain any gamified element as an alternate activity. But whether the control should be no learning alternative, a traditional nutrition education, or a game that did not involve any learning was determined from the literature search results. For example, research by Jiang et al. (2016) let the control group children play with Lego blocks in another classroom during the time the research was done. However, the study by Putnam et al. (2018) only visited the children in the control group once and children answered the measures without any alternative activity. This meta-analysis uses the control group activity, which is no intervention, as a comparison.

Dependent Variables

Knowledge Score

As a dependent variable in the study, knowledge scores were presented differently across various studies. From previous results, some studies used a nutrition knowledge score (Froome et al., 2020; Gan et al., 2019) while others recorded awareness or attitude (Lakshman et al., 2010). Studies reporting only awareness or attitude were not included in this meta-analysis.

Behavior Measures

The behavior measures vary among studies, but many focused on either fruit and vegetable consumption or physical activity. The unit of fruit and vegetable intake used for the study includes grams of fruit and vegetable eaten per day (Braga-Pontes et al., 2021), servings per day (Baranowski et al., 2011) or the number of times healthy options were chosen over unhealthy options (Alblas et al., 2018).

Many included studies measure participants' physical activity through accelerometer (Baranowski et al., 2012; 2021; Hamari et al., 2019; Lau et al., 2020; Liang et al., 2020; Maddison et al., 2011; Pasco et al., 2017; Peng et al., 2015). The accelerometer tracked detailed physical activity patterns of participants and allowed researchers to separate the time they spent on light, moderate or vigorous physical activity. To unify the entity of physical activity, this study recalculated the data to hours of moderate or vigorous physical activity per hour per day.

Time Consumption

The amount of time spent on one intervention or treatment was studied as well to capture the effectiveness of GBL and gamification intervention in the past literature. Given that the length of the intervention is associated with the learning outcome and the effects of games (Sailer & Homner, 2019), both duration and frequency was logged and calculated to a total time spent on each intervention. For example, a study intervention that has 45 mins for each session twice a week over a 2-week period, was considered as 180 mins total time spent on the intervention (Mack et al., 2020).

Duration

The long-term effect of the intervention is considered as the persistence of learning in this study. This study recorded long-term follow-ups of knowledge gain or behavioral change, if any. For example, fruit and vegetable consumption amount after research intervention period (Braga-Pontes et al., 2021; Wengreen et al., 2021)

Data analyses

The intent of this study was to understand how gamified nutrition education affects people's knowledge and behavioral change. For this to be done, a set of information from each study included in the meta-analysis was collected. Unfortunately, in preliminary search results, no research studied the different effects of gamification and GBL in the field of nutrition education in the same RCT; therefore, an indirect comparison must be conducted to answer proposed research questions one through three (Mills et al., 2011; Yang, 2013). A traditional pairwise meta-analysis merges the effect of treatment A and treatment B, which are compared in the same study design. But an indirect comparison combines the effect of treatment A to a placebo and compares it to the combined effects of treatment B to a placebo (Bucher, 1997) (see figure 2).

Methods for indirect comparisons have only been readily applied since the late 1990s, including unadjusted indirect comparison, Bucher's adjusted indirect comparison, Lumley's method of network meta-analysis, and Bayesian mixed-treatment comparison (EUNETHTA Guidance, 2013). Unadjusted indirect comparisons combine data as they are from a single, large trial. Unfortunately, preliminary search results for this study suggested that gamified nutrition education research was highly incohesive. Study population can be children or undergraduate students in the US (Johnson-Glenberg et al., 2014; Peng, 2009) to various age population around the globe (Braga-Pontes et al., 2021; Chae et al., 2022; Chagas et al., 2018; de Vlieger et al., 2021; Lakshman et al., 2010; Liang et al., 2020). Thus, unadjusted indirect comparison was not possible to perform for this study. Bucher's method assumes that independence of pairwise comparison extensions available for several direct comparisons is linked by common comparators

(Bender & Sturtz, 2013; EUNETHTA Guidance, 2013) and can be used when no data directly comparing two treatments are available. Lumley's (2002) network meta-analysis assumes that a single study can be summarized as a mean and standard error with a normally distributed estimate of treatment differences and that it is possible to compute the amount of agreement between the results obtained when different linking treatments are used. Since at least one direct effect study should be included in the analysis when using network meta-analysis and during the literature search, it is fortunate that there is one study (Braga-Pontes et al., 2021) which investigated the effect of gamified education on fruit and vegetable consumption for children who were 3 to 6 years old in Portugal. Any combination of studies can be combined if all are connected in some way using mixed treatment comparisons (MTC; Bender & Sturtz, 2013; EUNETHTA Guidance, 2013; Wells et al., 2009). Although the open resource analytical tool for MTC is limited, there are still R packages that support outcome types that are continuous, binary, and count; for example, BUGSnet (Béliveau et al., 2019). BUGSnet is an R package full of features to conduct Bayesian network meta-analyses in accordance with best practice and reporting guidelines. Bayesian analyses are conducted with JAGS and BUGS code is automatically generated by the package based on the user's inputs. Outputs include network plots, tables of network characteristics, league tables and league heat plots, SUCRA plots, rankograms, and forest plots that are highly customizable.

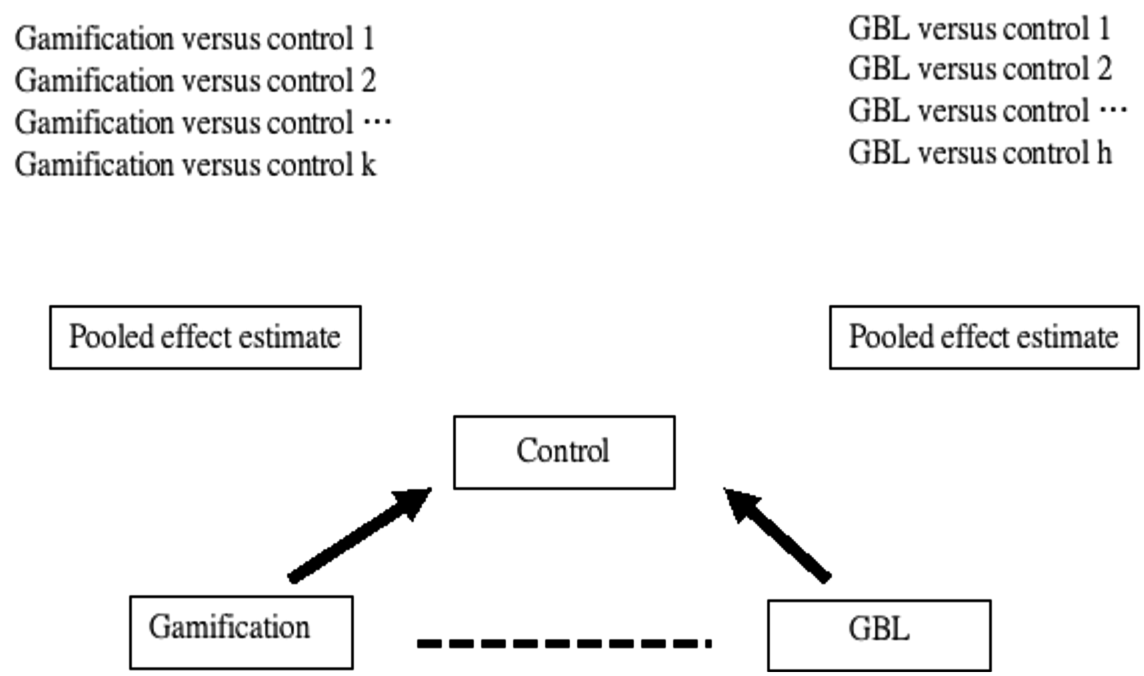
Network analysis was established from Bucher's simple adjusted indirect comparison. To use Bucher's method (1997), it is assumed that the treatment's effectiveness is the same across all trials used in the comparison. This method was originally created by comparing odds ratios but was extended to indirect comparison of relative risks (RR), hazard ratios (HR), risk differences (RD), and mean differences (MD), and is present as a measure of association in $\hat{A}$ later notation (Wells et al., 2009). A pooled effect measure for gamification versus control and a pooled association of GBL versus control is based on the weighted average of referenced studies. Given k number of treatments T1, T2,...,Tk where pairs have been consecutively compared (T1 versus T2, T2 versus T3,...,Tk−1 versus Tk), the indirect 100(1 − α/2)% estimator of the measure of association $\hat{A}$ for a pair of treatments is (Ti, Ti+1) $\sum_{i=1}^{k-1} \hat{A}_{TiTi+1}$ and the test statistic for testing the indirect association between treatments T1 and Tk for k number of studies used is (Miladinovic et al., 2014, p.77):

$$\chi^2_{df=n} = \frac{\sum_{i=1}^{k-2} \sum_{j=i+1}^{k-1} \left(\sum_{j=1}^{n} W_{T_i T_{i+1},j} \right) \left(\sum_{j=1}^{n} W_{T_j T_{j+1},j} \right) \left(\widehat{A}_{T_i T_{i+1}} - \widehat{A}_{T_j T_{j+1}} \right)^2}{\sum_{i=1}^{k-1} \sum_{j=1}^{n} W_{T_i T_{i+1},j}}$$

Equation 1

Figure 2

Adjusted Indirect Treatment Comparison Method (Wells et al., 2009)



Network meta-analysis, however, assumes that a single study can be summarized as a mean and standard error with a normally distributed estimate of treatment differences and that it is possible to compute the amount of agreement between the results obtained when different linking treatments are used (Lumley, 2002). However, to perform a network meta-analysis, at least one direct effect should be reported. Braga-Pontes et al. (2021) included both GBL and gamification in their study to investigate the effect of treatment compared to education control by using a four arms RCT with story, story plus sticker (gamification), GBL treatment and control to understand treatment's association to vegetable consumption. However, they only focused on the consumption of lettuce, carrot, purple cabbage, cucumber, and tomato for Portuguese children who were 3-6 years old without other outcomes under investigation in this study (Braga-Pontes et al.,2021). Thus, only fruit and vegetable consumption were potentially eligible for a network meta-analysis.

An effect size was calculated for outcome for those studies that can be included in an indirect or network meta-analysis. Hedges' g, which provides a measure of effect size weighted according to the relative size of each sample. If a study did not report the standard deviation for the mean change, in this case, the researcher can calculate the missing SDs by using equation2 that includes SD for baseline, SD for post-treatment (final) and correlation coefficient of target variable,

$$\mathrm{SD}_{E,\mathrm{change}} = \sqrt{\mathrm{SD}^2_{E,\mathrm{baseline}} + \mathrm{SD}^2_{E,\mathrm{final}} - \left(2 \times \mathrm{Corr} \times \mathrm{SD}_{E,\mathrm{baseline}} \times \mathrm{SD}_{E,\mathrm{final}}\right)}$$

.Equation 2

(*Choosing effect measures and computing estimates of effect*, 2022.).

However, the correlation coefficients to describe the association of target variables are often unreported (*Choosing effect measures and computing estimates of effect*, 2022.).

The best way to estimate the missing SD for changes from baseline to post-treatment is to use another study's known SDs for changes and impute the correlation coefficient from it (Abrams et al., 2005; Follmann et al., 1992)

$$\mathrm{Corr}_E = \frac{\mathrm{SD}^2_{E,\mathrm{baseline}} + \mathrm{SD}^2_{E,\mathrm{final}} - \mathrm{SD}^2_{E,\mathrm{change}}}{2 \times SD_{E,\mathrm{baseline}} \times SD_{E,\mathrm{final}}}$$

.Equation 3

The appropriateness of using a SD from another study relies on whether the studies used the same measurement scale, had the same degree of measurement error, had the same time interval between baseline and post-intervention measurement, and were in a similar population (*Choosing effect measures and computing estimates of effect*, 2022). If the assumption is met, researchers can use or calculate the correlation coefficient reported in that specific study with known correlation coefficient. The obtained correlation coefficient describing baseline and post-intervention measurements across participants then can be applied to substitute the unknown correlation coefficient in equation 2.

CHAPTER IV

RESULTS

The purpose of this study was to understand how GBL versus gamification was utilized in nutrition education affecting participant's knowledge and behavioral change. Ryan and Deci's (2000) self-determination theory (SDT) was the rationale of the hypothesis that GBL might have a different effect from gamification nutrition intervention for the different motivators provided. For this to be done, a systematic literature review and meta-analysis was collected. A preliminary search was conducted to investigate the possibility of executing a meta-analysis on the topic followed by main literature research and meta-analysis. An indirect comparison meta-analysis was used due to limited research and information provided in the past literature for direct comparison of GBL versus gamification (Braga-Pontes et al., 2021; Browne et al., 2014). This chapter provides the results of a comprehensive analysis of the data. It describes the studies reviewed in this study and presents the relationship of gamified education to nutrition knowledge, fruit and vegetable intake, and physical activity. A systematic review and meta-analysis were performed to address the five research questions listed below.

1. Which type of gamified nutrition education, gamification or GBL, delivers a stronger overall effect of increasing knowledge?
2. Which type of gamified nutrition education, gamification or GBL, delivers a stronger overall effect of promoting fruit and vegetable intake amount?

3. Which type of gamified nutrition education, gamification or GBL, is more effective in increasing physical activity?
4. What is the average time required to apply gamified nutrition education for different outcome/treatment?
5. If there was follow-up, what consequence did the duration of the intervention have on its effectiveness?

This chapter reports the findings for each of the research questions noted above. The process of the literature search data and the participant/study characteristics were presented in Chapter III. Results across different research questions were limited to the final interpretation of the findings presented in Chapter V. The present chapter concludes with a brief discussion of the literature search results.

Preliminary Search Results That Were Included in the Final Study Sample

Full-text review used set inclusion and exclusion criteria; for example, each study was required to have a control group and an intervention of GBL, gamification, or active game focused on nutrition education related to increasing healthy food choice, fruit and vegetable consumption or physical activity. After full text review, 12 studies from the preliminary search were included in the final study sample for meta-analysis. The reasons why certain articles were excluded were listed in Table 4. Seven studies did not investigate the outcome related to healthy food choice knowledge, increasing fruit and vegetable consumption or physical activity; six studies were excluded for using interventions that were not focused on in this study. For example, Dassen et al (2018) used a game designed to stimulate the working memory of children. In this study, the healthy lifestyle intervention was given as an online psychoeducation instead of from gamified education. There were three working memory tasks in the game: “a visuospatial working memory task, a backward digit span task and an object memory task” (Dassen et al., 2018, p.91). None of the tasks were directly relevant to nutrition education, the only link was that the researcher used a restaurant setting with kitchen-related objects in the game like scales or mixers. However, food related objects were presented to both groups and the difference between experimental group and control was that the control group had basic, easy level tasks throughout the study instead of increasing difficulties. Six studies were excluded for only reporting the procedure of study without results, but the researcher was able to find the published result for Beleigoli et al. (2018), and the finding of Beleigoli and their colleagues was presented in Beleigoli, et al. (2020).

Table 3

Excluded reason for studies in preliminary search

Study	Excludes reason
Beleigoli et al, 2018	Research protocol
Belogianni et al, 2019	Research protocol
Edney et al, 2017	Research protocol
Fang et al, 2019	Research protocol
Harrison et al, 2019	Research protocol
Podina et al, 2017	Research protocol
Pope et al, 2018	Missing information
Beltran et al, 2013	No control
Majumdar et al, 2013	No control
Azevedo et al, 2019	Not individual level data
Joyner et al., 2017	Not individual level data
Wang et al 2017	Not randomly assigned
Baranowski et al, 2003	Same sample had been included with detail outcome
Dassen et al, 2018	Wrong intervention
Florack et al, 2018	Wrong intervention
Pemprk & Calvert, 2009	Wrong intervention
Porter et al, 2018	Wrong intervention
Putnam et al, 2018b	Wrong intervention
Sharps & Robinson, 2016	Wrong intervention
Banos et al, 2013	Wrong outcome
Coulthard & Ahmed, 2017	Wrong outcome
Gillis, 2003	Wrong outcome
Poppelaars et al, 2018	Wrong outcome
Rosi et al, 2015	Wrong outcome
Schakel et al, 2018	Wrong outcome
Schakel et al, 2020	Wrong outcome

Desmet et al, 2017	Wrong study design
Johnson-Glenberg & Hekler, 2013	Wrong study design

This study aims to identify and analyze the research literature on different effects of gamification and GBL to enhance nutrition knowledge and behavior for all populations. If GBL has a stronger effect of stimulating learners, it will be more cost-effective to support the building of good learning games and use them repeatedly thereafter (Baranowski et al., 2019). Results of the study can provide evidence comparing the two given that the future allocation of the resources can be directed to the most cost-efficient method of facilitating learning in the nutrition field.

In the first round of the result, only one study focused on adult participants (Rose et al., 2013), while most studies were pertaining to younger participants ranging from kindergarten age to adolescents (see Table 1.). Positive outcomes using game-based or gamification in increasing fruits and vegetable intake were found for children (Chow et al., 2020; Munguba et al., 2008; Azevedo et al., 2019), adolescents (Thompson et al., 2009; Yang et al., 2015), and young adults (Nour et al., 2017). Given that only a small number of studies focused on the population outside of the K-12 scenario (Nour et al., 2017; Rose et al., 2013), it is not clear what relationship exists between the different groups to the effect of game-based or gamification of nutrition education since it is not commonly reported.

Descriptive of Included Studies

There were a total of 47 studies included in this meta-analysis (see Table). Other than GBL and gamification, many active game interventions (*n*= 15) were identified. If broken down into three categories, the largest number of studies utilized GBL interventions (*n* = 30), several utilized gamification (*n* = 3) or active games (*n* = 15), and only one study had both GBL and gamification interventions. Active games are video games that require physical activity to play, and can be seen as moderate-intensity physical activity when playing (Bowling et al., 2021; del Corral et al., 2018). The purpose of active games is to convert sedentary time into more active time by using in-game features that can encourage exercise, such as motivational messaging during game play to boost players' self-determination, encourage exercise devotion, and hopefully eventually result in non-screen-based physical activity.

Table 4

Final study literature distribution for intervention and outcome

	GBL		Gamification (Active game includes)		
	RCT	Quasi experiment	RCT	Quasi experiment	Total studies
Knowledge	11	10	0	0	21
FV consumption	6	5	1	2	13
Physical activity	1	1	12	1	15
weight loss	3	4	4	3	14
Total study*	17	13	13	5	48**

**Note: There are multiple study investigated more than one outcome thus the add up of outcome was not equal to total study number.*
***Note: There are one study had both GBL and gamification intervention used quasi experiment design, thus the add up of total studies do no equal to sum of the total studies.*
FV is abbreviate for fruit and vegetable

There were 22 studies investigating the outcome of food choice knowledge, 14 on weight loss, 14 tested physical activity change, and 13 investigated the outcome of fruit and vegetable consumption. Multiple studies investigated more than one outcome, thus the sum total of studies in different categories was not equal to 47 (see Table 3.). Other than knowledge or behavioral indicators, there were 14 articles that investigated the association between gamified education and BMI change or other anthropometric measures like waist circumference. Most of the studies investigated weight loss in tandem with other outcomes like food knowledge or fruit and vegetable consumption, but three articles only investigated weight loss as the outcome. The majority of articles were peer-reviewed (N = 46) with the exception of one doctoral dissertation. About half of the studies were of strong quality, using reliable and valid measures, on a representative sample of the population, and reported low participant drop-out rates.

Gamification of various outcomes to prevent obesity is progressing at a fast pace (see Figure 4) and the majority of the studies included were published in the most recent decade. Gamified education was studied around the globe. There are studies conducted in Asia (China, Japan, Korea, Taiwan), Europe (Holland, UK), North America (Canada, US), South America (Brazil), Africa (Saudi Arabia) and Oceania (Australia and New Zealand). Table 5 expressed the origin of all included studies of this research.

Figure 4

Published Year for Included Studies

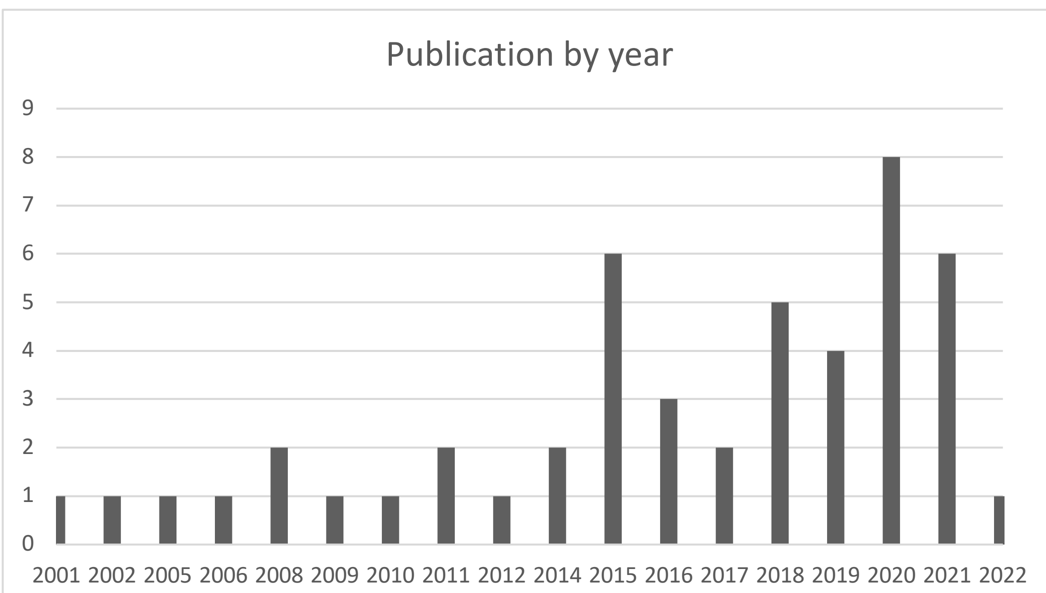


Table 5

Where the Sample of Study Was From

Country	Count

Australia	3
Australia and New New Zealand	1
Brazil	3
China	1
Ekelund	1
Finland	1
France	2
Germany	1
Holland	5
Hong Kong	2
India	1
Italy	2
Japan	1
Korean	1
New Zealand	1
Ontario	1
Philippines	1
Portugal	1
Rosenheim	1
Saudi Arabia	1
Taiwan	1
Turkey	1
UK	2
US	13

Research Question 1. Which Type of Gamified Nutrition Education, Namely Gamification or GBL, Delivers a Stronger Overall Effect of Increasing Knowledge?

Nineteen studies investigated GBL to increase nutrition knowledge of participants; unfortunately, none of those studies used RCT or quasi-experimental design. Thus, there were not enough studies to perform a network or indirect meta-analysis. About half of the studies (47%, *n* = 9) that investigated knowledge change pertaining to food choice used RCT and the other half used quasi-experimental design (53%, *n* = 10). None of the included articles used the same treatment game in the study, and nutrition knowledge score measurements were different from study to study. For example, Peng, (2009) used a self-developed survey to obtain knowledge score and so did Peterson (2002) used eight multiple choice questions to assess Food Pyramid knowledge created by the researcher. While there were studies like Sharma et al. (2015) used Nutrition and

Physical Activity Habits and Related Psychosocial Mediators or Froome et al.(2020) used Nutrition Attitudes and Knowledge Questionnaire that were scales previously validated.

Table 6

Studies Investigated Knowledge and Characteristic

Study	Method	Investigated outcome					Measurement	Final sample
		Knowledge	Attitudes	FV consumption	PA	weight loss		
Abdollahi et al., 2021	Quasi exp	x					Questionnaire assessing knowledge	68 intervention, 62 control
Altammami, et al., 2017	RCT	x					Quiz, 12-item survey about dietary recall (	19 intervention, 19 control
Barwood, et al., 2020	RCT	x	x				Three knowledge and two attitude indicator scores	36 intervention, 34 control
Blackburne et al., 2016	RCT	x					Barratt impulsiveness scale for food consumption healthy eating quiz	26 intervention, 26 control
Chagas et al., 2020	Quasi exp	x					Fifteen statements and express their level of agreement	117 intervantion, 202 control
de Vlieger et al., 2021	Quasi exp	x					Child nutrition knowledge quastionnaire	75 intervention, 94 control
Froome et al., 2020	RCT	x					Nutrition attitudes and knowledge (nak) questionnaire	39 intervention, 34 control
Gan et al., 2019	Quasi exp	x					Nutrition Knowledge Questionnaire for the study	180 intervention 180 control
Hermans et al., 2018	quasi exp	x				x	Weight and hight, nutrition score scale	58 intervention, 50 control
Holzmann, et al., 2019	quasi exp	x				x	Weight and hight, nutrition score scale	36 intervention, 40 control
Johnson-Glenberg, et al., 2014	RCT	x					The nutrition and food choice test	20 intervention, 20 control
Lakshman et al., 2010	RCT	x	x				Questionnaire	502 intervention, 631 control
Mack et al., 2020	RCT	x			x		Questionnaire, index for healthy nutrition, knowledge (eg, nutrition and stress coping) measured	40 intervention, 42 control
Peng, 2009	RCT	x					Study developed survey	19 intervention, 13 control
Peterson, 2002	Quasi exp	x					Eight multiple choice questions	36 intervention, 33 control
Sharma et al., 2015	Quasi exp	x		x		x	Nutrition and physical activity habits and related psychosocial mediators, weight and hight, dietary intake	44 intervention, 50 control
Silk et al., 2008	RCT	x					Thirty-three multiple-choice questions	47 intervention, 108 control
Viggiano et al., 2015	Quasi exp	x				x	Questionnaire, weight and height	624 intervention, 421 control
Yang, et al., 2015	Quasi exp	x		x			Cloud diet assessment system (cdas)	28 intervention, 25 control
Turnin et al 2001	Quasi exp	x					Dietary knowledge tests	827 intervention, 794 control

FV is abbreviate for fruit and vegetable
PA is abbreviate of physical activity

There were three typical findings reported; knowledge score significantly and positively changed after intervention (*n= 13)*, knowledge score significantly and positively changed after intervention and even for follow-up (*n= 4)*, or control was educational and researchers found no difference between intervention and control (*n= 2)*. The majority of studies found GBL is effective in increasing nutrition knowledge or is as good as traditional instruction. In studies that presented significant change of knowledge score intervention there were studies that were significantly better than lecture or traditional nutrition education (Mack et al., 2020; Peterson, 2002; Viggiano et al., 2018) Mack et al. (2020) found the knowledge score increased from treatment group versus control ($p<.001$) when using healthy lifestyle brochure. The effect persisted at follow-up: the knowledge score of the treatment group remained at the same level as that of immediate post-test (Mack et al., 2020).

Research Question 2. Which Type of Gamified Nutrition Education Delivers a Stronger Overall Effect of Promoting Fruit and Vegetable Intake Amount?

Three studies in the final sample used a gamification intervention while 11 studies used a GBL intervention to promote fruit and vegetable intake. One study (Braga-Pontes et al., 2021) included both gamification and GBL in their study. No study that used the gamification intervention reported SD for changes from baseline. Usually, we can use similar studies to calculate a correlation coefficient for describing how baseline and post-intervention measurements were associated and the researcher imputes the estimates of SD for changes from baseline (*Choosing effect measures and computing estimates of effect*, 2022). However, the populations were very different in the included studies pertaining to fruit and vegetable consumption, so there were not enough studies to perform a network meta-analysis nor indirect meta-analysis.

About half of the studies measure both fruit and vegetable consumption (see Table 6). However, the measurements used in the studies were greatly different (see Table 7). Studies like Cullen et al. (2005), Spook et al. (2016) used commonly used nutrition assessment tools like 24-h dietary recall or food frequency questionnaire; while Wengreen et al. (2021) focused on weighting food wastes of children in school cafeterias. The uniqueness of each study made it hard to integrate the findings to a pooled effect.

Table 7

Variables Coded for Meta-analysis with Frequency of Study

Variable	Level of the variable	Frequency
Study design	Quasi-experiment	6
	RCT	7
Measurement	Both fruit and vegetable	7
	Fruit intake	3
	Vegetable intake	2
	Food liking	1
Control type	No intervention	5
	None nutrition related game	4
	Educational material or lecture	3
	Not clearly stated	1
Follow up	Yes	3
	No	10

Table 8

Studies Investigated Fruit and Vegetable Consumption and Characteristic

Study	Method	Investigated outcome					Measurement	Final sample
		Knowledge	Attitudes	FV consumption	PA	weight loss		
Alblas et al., 2018	RCT		x	x			implicit attitudes, actual choice	128 undergraduate students Radboud University, Holland
Amaro, 2006	Quasi exp			x	x			Middle schooler in Naples, Italy.
Baranowski et al., 2011	RCT			x			24-hour dietary recalls	10–12 years, between the 50th and 95th percentile for BMI who speaks English in TX and NC, US
Beleigoli, et al., 2020	RCT			x	x	x	BMI	University students or employees with 25 kg/m2 minimum body mass index in Brazil
Braga-Pontes et al., 2021	Quasi exp			x			Waist circumference	3 to 6 years in Portuguese
Cullen et al., 2005	Quasi exp			x			Triceps skinfold	749 intervention, 740 control
Jiang et al., 2016	RCT			x		x	Actigraph AM-7164 accelerometers"	indergarten in Zhe- jiang province, China
Kato-Lin et al., 2020	RCT			x			BMI, daily vegetable/fruit intake, physical activit	10 to 11 years in Chennai, India
Schakel, et al., 2018	RCT			x			real food presented	Participants had to be fluent in Dutch and between 18 and 35 years old
Sharma et al., 2015	Quasi exp			x		v	Food Intake Recording Software System (FIR), 24-h dietary recall	Children aged 8 to 12 years who study public schoo in Dallas, TX, US
Spook et al., 2016	RCT			x				vocational education schools in the Netherlands
Wengreen et al., 2021	Quasi exp			x			real food presented	kindergarten through fifth-grade (ages 5–11) at-tending one of four public elementary schools in Logan, UT, USA
Yang, et al., 2015	Quasi exp			x			seven food product pairs task	girls' senior high school in northern Taiwan

FV is abbreviate for fruit and vegetable

Findings of studies that investigated fruit and vegetable consumption utilizing gamified education could be: insignificant, significant after intervention compared to non-education control, significant after intervention compared to educational control, significant after intervention and follow-up, or control is educational but found no difference between treatment and control (see Table 8). The majority of studies found both GBL and gamification are effective in increasing fruit and vegetable consumption compared to non-educational control groups and one study showed that GBL had a significantly stronger effect than lecture or traditional nutrition education (Yang et al., 2015). Braga-Pontes et al. (2021) used a four arms RCT with story, story plus sticker (gamification), GBL treatment and control with educational material to understand treatment's association to vegetable consumption. The control group received educational sessions with the Portuguese Food Wheel Guide, which was the golden standard tool in nutrition education in Portugal and promoted vegetable consumption (Braga-Pontes et al.,2021). At the end of each session, a play food item was distributed to each child and they had to place it in the right group according to the food guide. However, this study focused solely on the consumption of lettuce, carrot, purple cabbage, cucumber, and tomato for Portuguese children who were 3-6 years old (Braga-Pontes et al.,2021). Braga-Pontes and her colleagues concluded that all interventions tested were effective in increasing vegetable consumption without statistically significant differences, compared to the control group.

Table 9

Findings for Studies Investigated Fruit and Vegetable Consumption

Not significant increase	Significant after intervention compare to NON-education control	Significant after intervention compare to education	Significant after intervention and follow-up	Control is educational, find no difference
Spook et al., 2016	Sharma et al., 2015	Yang, et al., 2015	Baranowski et al., 2011	et al., 2021**
Schakel, et al., 2018	Alblas et al., 2018		Wengreen et al., 2021*	
	Jiang et al., 2016			
	Beleigoli, et al., 2020*			
	Amaro, 2006			
	Cullen et al., 2005			
	Kato-Lin et al., 2020			

**study used gamification intervention*
*** study used gamification and GBL intervention at same time*

Research Question 3. Which Type of Gamified Nutrition Education, Gamification or GBL, Is More Effective in Increasing Physical Activity?

Given that the nature of active games is to promote physical activity, many studies which utilized active games investigated the association between using active games and increased physical activity (see Table 9). In a total of 15 studies that investigated the possibility of gamified education to increase physical activity, thirteen studies used gamification intervention (active game included) and two studies utilized GBL. The vast majority of the studies used RCT, and controls were either no intervention, inactive game or educational material or lecture.

Table 10

Variables Coded for Research Question 3 with Frequency of Study

Variable	Level of the variable	Frequency
Intervention	GBL	2
	Gamification	1
	Active game	12
Study design	Quasi-experiment	2
	RCT	13
Measurement	Accelerometer	9
	Questionnaire	6
	Anthropometric measure*	5
Control type	No intervention	5
	Inactive game on Wii	4
	Educational material or lecture	3
Follow up	Yes	3
	No	12

*Five study reported both anthropometric measure and accelerometer or self-reported questionnaire data the sum of study was greater than total study included

Active games are considered moderate-intensity physical activity when playing (Bowling et al., 2021; del Corral et al., 2018), thus majority of the studies that investigated PA use time participants spent on moderate to vigorous PA (MVPA) as an indicator of the involvement of subjects. The unit of MVPA may vary from study to study, for example, minutes per day or hours per week. To enter the network meta-analysis, this study calculated the unit of mean change MVPA from baseline to post-treatment in hours per week. Studies that did not report the SD for change from baseline to post-treatment were calculated by using the correlation coefficients of Tripette (Tripette et al., 2014) and Liang et al. (2020). Tripette and colleagues (2014) conducted an intervention on the association between active games and MVPA by recruiting postpartum women from Tokyo Metropolitan Area, Japan. Liang et al. (2020) conducted an active game intervention to assess the association to MVPA using primary school children 9–12 years old in Hong Kong. The correlation coefficient for the treatment group was 0.99 for Tripette et al.'s research and 0.92 for Liang et al., and for the control group was 0.99 for Tripette et al. and 0.89 for Liang et al. To perform a network analysis, all treatments were categorized as active game, inactive game, gamification, reading material, and no intervention (See Figure 4). There were 1011 participants in the network from 9 different studies (See Table 4.). Two studies of GBL were not included due to only reporting post-treatment measurements (Amaro et al., 2006) or effect size (Mack et al., 2020). The forest plot of using no intervention as a reference treatment is presented in Figure 5. The effect of gamification and active games were higher than the no intervention, but only one study used gamification and it was not statistically significant.

Figure 5

Network Plot

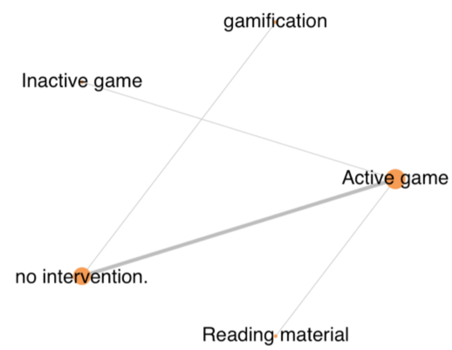


Figure 6

Forest Plot of Treatments and MVPA per Hour per Week

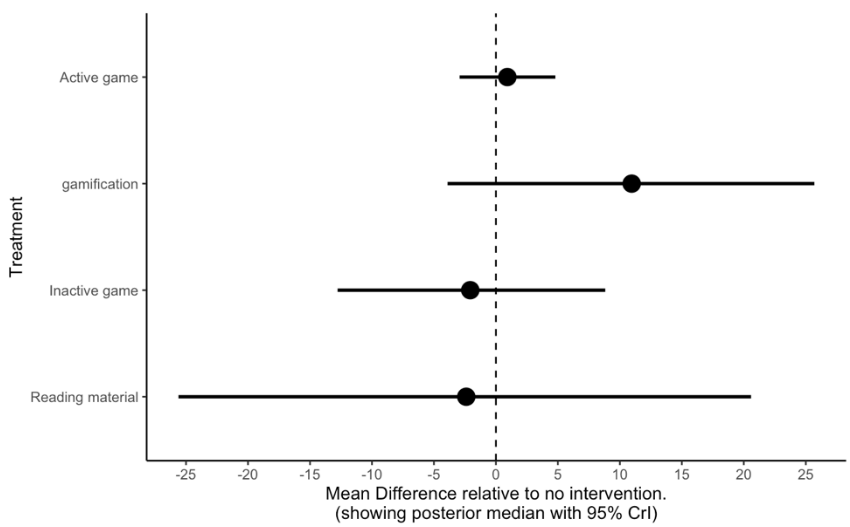


Table 11

Effect for Study Included in Meta-Analysis

Study ID	Treatment	Number of Participants	PA hour per week change	SD for change
Baranowski T et al., 2012	Active game	37	0.49	8.94
(Baranowski T et al., 2012)	Inactive game	41	-2.49	6.54
Beleigoli et al., 2020	gamification	90	-4.00	52.52
Beleigoli et al, 2020	no intervention.	90	-15.00	19.10
Bowling et al., 2021	Active game	11	-1.09	2.51
Bowling et al., 2021	no intervention.	12	-0.16	0.97
Hamari et al., 2019	Active game	17	4.00	22.26
Hamari et al., 2019	Reading material	19	1.00	41.27
Lau et al., 2020	Active game	121	-1.13	2.29
Lau et al., 2020	no intervention.	73	0.05	1.29
Liang et al., 2020	Active game	29	0.14	1.02
Liang et al., 2020	no intervention.	51	-0.28	1.15
Maddison et al., 2011	Active game	160	-0.77	2.00
Maddison et al., 2011	no intervention.	162	-0.90	1.91
Peng et al., 2015	Active game	34	4.20	3.23
Peng et al., 2015	no intervention.	30	-3.43	2.37
Tripette et al., 2014	Active game	17	-0.90	0.30
Tripette et al., 2014	no intervention.	17	-0.50	0.70

Note: This table only contains the study that can be included in the network meta-analysis, not all studies that includes a physical activity change outcome

Research Question 4. What is the average time required to apply gamified nutrition education for different outcome/treatment?

For studies that reported duration of the intervention over the full duration of the intervention (*n*= 37), average play duration was 356.41 minutes (SD = 499.10). Some of the studies were not included in this analysis because there was no requirement for the participant to use the specific gamified material, only a suggestion (Bowling et al., 2021; Maddison et al., 2011), or because time spent on active game was a dependent variable under investigation for those studies (Baranowski et al., 2012; Ni Mhurchu et al., 2008; Simons et al., 2015). For example, Baranowski et al. (2012) gave all participants 12 weeks to have access to a Wii™ console. Children in the treatment group could freely choose 1 out of 5 active video games available from the researcher to play (or not), while the control group had access to 1 out of 5 inactive video games. Then researchers tracked how long these children were performing MVPA by accelerometer and time spent on playing active games by game log and diaries.

The majority of first effect measurements were conducted on the same day as the intervention. The duration of intervention was different because of the outcome under investigation. For studies that investigated the nutrition knowledge gain of the intervention, average play duration was 125.5 minutes (SD = 142.54). For studies that investigated increases in fruit and vegetable consumption, average play duration was 191.09 (SD = 188.69) minutes. For studies on the increase in physical activity, average play duration was 670.00 (SD =519.87) minutes. An analysis of variance (ANOVA) of the three outcomes under investigation was significant $F(2,38) = 20.62$, $p<.005$ indicating that duration of different targeted outcomes over the period of study intervention was different. Post hoc comparisons using the t-test with Bonferroni correction indicated that the mean duration for the physical activity focused studies was significantly different than the nutrition knowledge focused studies and FRUIT AND VEGETABLE intake studies. However, the nutrition knowledge focused studies did not significantly differ from FRUIT AND VEGETABLE intake studies.

Type of intervention also affected the duration of the intervention. Active games took 920.00 minutes on average (SD = 637.07) over the full duration of the intervention. Only two of the gamification studies reported duration of the intervention and the average time consumed was 116.00 minutes (SD = 22.63). GBL took an average of 136.46

minutes (SD = 146.89) to complete the intervention over the full duration of the intervention. ANOVA of three interventions was significant $F(2,35) = 18.73$, $p<.005$ indicating that the duration of interventions over the period of study was different. Post hoc comparisons using the t-test with Bonferroni correction indicated that the mean duration for the active game condition was significantly different than the GBL condition and gamification condition. However, the nutrition knowledge focused studies did not significantly differ from FRUIT AND VEGETABLE intake studies.

Research Question 5. If There Was Follow-Up, What Consequence Did the Duration of the Intervention Have on Its Effectiveness?

Eleven studies indicated some form of follow up, ranging from one month to one year after intervention ended (see Table 11). Knowledge score at the second post-test was not aligned by looking at the study result. Three studies showed the knowledge score of the treatment group was significant at follow up and persisted or was better than the control group at follow up (see Table 12).

Table 12

Second Post-Test Follow-Up Timing

	Frequency
Within one month	4
Within three month	2
Within half year	1
Within one Year	1
More than one year	2

Table 13

Variables Coded for Studies with Follow Up

Variable	Level of the variable	Frequency
Intervention*	GBL	8
	Gamification	2
	Active game	1
Study design	Quasi-experiment	4
	RCT	7
Outcome**	Knowledge	6
	FV consumption	3
	physical activity,	3
	weight loss	2
Control type	No intervention	3
	Game	2
	Educational material or lecture	6

*One study reported both gamification and GBL intervention thus the sum of study was greater than total study included
** Three study reported two investigated outcome thus the sum of study was greater than total study included

FV is abbreviate for fruit and vegetable

Table 14

Findings for Studies had Second Post-Test

	Not significant	Significant at follow up but decreased	Significant at follow up and persist	Significant better then control at follow up
Knowledge	Hermans et al., 2018 Silk et al., 2008 Viggiano et al., 2015		Mack et al., 2020	Johnson-Glenberg, et al., 2014 Peng, 2009**
FV consumption			Baranowski et al., 2011 Wengreen et al., 2021*	Braga-Pontes et al., 2021***
Physical activity	Hamari et al., 2019**	Mack et al., 2020		Maddison et al., 2011

*The study used gamification intervention
** The study used active game intervention
***The study used GBL and gamification intervention
FV is abbreviate for fruit and vegetable

All three studies investigating fruit and vegetable consumption that had a second post-test measurement showed that the effect of increased fruit and vegetable intake persisted at follow up. For the other behavioral outcome, at second post-test physical activity one study indicated that time spent for physical activity did not differ between the groups nor at one year follow up (Hamari et al., 2019). See table 14 for characteristic of studies with follow up.

Table 15

Studies with Follow Up and Its Characteristic

Study	Method	Investigated outcome					Measurement
		Knowledge	Attitudes	FV consumption	PA	weight loss	
Baranowski et al., 2011	RCT			X			103 intervention, 50 control
Braga-Pontes et al., 2021	Quasi exp			X			GBL 32, gamification 37, control 29
Hamari et al., 2019	RCT				X		17 intervention, 19 control
Hermans et al., 2018	quasi exp	X				X	58 intervention, 50 control
Johnson-Glenberg, et al., 2014	RCT	X					20 intervention, 20 control
Mack et al., 2020	RCT	X			X		40 intervention, 42 control
Maddison et al., 2011	RCT				X		160 intervention, 162 control
Peng, 2009	RCT	X					19 intervention, 13 control
Silk et al., 2008	RCT	X					47 intervention, 108 control
Viggiano et al., 2015	Quasi exp	X				X	624 intervention, 421 control
Wengreen et al., 2021	Quasi exp			X			881 intervention, 978 control

FV is abbreviate for fruit and vegetable

CHAPTER V

DISCUSSION

GBL and gamification each have their unique advantages and disadvantages (Landers, 2014; Al-Azawi et al., 2016; Khan et al., 2017). A study is needed to investigate the mechanism of how two gamified education approaches work (Landers, 2014, DeSmet et al., 2014). Unfortunately, two known studies comparing GBL and gamification provided limited information for comparing one versus another (Braga-Pontes et al., 2021; Browne et al., 2014). This study aimed to identify and analyze the research literature on different effects of gamification, active game, and GBL to enhance nutrition knowledge and behavior for all populations. This is the first network meta-analysis of GBL, active games, and gamification examining nutrition knowledge and behavioral outcomes including FRUIT AND VEGETABLE consumption and physical activity. This study was not able to perform a network meta-analysis on either food knowledge or fruit and vegetable intake, due to not having enough literature. However, the included literature investigating knowledge increase showed a positive change of knowledge score. The vast majority of the literature showed a significantly higher score after intervention with only two out of 16 studies finding no difference between intervention and control. This supports the meta-analysis result of DeSmet et al. (2014) who found GBL has a small positive effect on healthy lifestyles and their determinants like knowledge. As the preliminary search result indicated, gamified education was mostly reported to be grounded in self-determination theory or social cognitive theory. The result of network meta-analysis showed that gamification might have a stronger effect of stimulating participants to perform physical activity, however, it was not statistically significant.

Implementation

This study is in support of the notion that GBL had positive effects on nutrition knowledge of food choice and was able to facilitate nutrition education. For studies that compared GBL to lecture or reading material, GBL showed that game intervention was as effective or more effective at increasing nutrition knowledge as traditional instruction (Abdollahi AM et al., 2021). After the COVID 19 pandemic, many countries implemented online synchronous or asynchronous remote learning. Based on this study's results, GBL can serve as a great alternative when face-to-face education is not feasible. The average duration needed for completing a set of GBL was equal to two to three standard teaching sessions, and could easily stand in as a replacement for traditional instruction, especially when remote learning is being used.

For increasing fruit and vegetables intake, reviewed articles indicated that there was only a small effect for gamified education to fruit and vegetable intake. This result aligns with the findings of Chow et al. (2020); they found that GBL interventions have the potential for increasing fruit and vegetable intake and educating children about healthy eating, and limited interpretation can be made for long-term effects (Chow et al., 2020). However, looking at the follow up effect of fruit and vegetable intake pertaining to the treatment group included in this study, three out of three studies reported the increasing effect carried over to the second post-test. The reason why gamified education might work to promote fruit and vegetable intake and have long-term effects might be due to the repeated exposure of healthy options to participants (Alblas et al., 2018).

According to incentive-sensitization theory (Robinson & Berridge, 1993), one of the key procedures in eating behavior is the automatic associations triggered by specific food cues. Specific food cues are formed by repeated exposure to food products, informed by family background such as the food preferences of parents or feeding styles during childhood (Robinson & Berridge, 1993). GBL and gamification can facilitate the repeated exposure in short time periods and thus help promote fruit and vegetable intake.

Increasing physical activity was mostly studied by incorporating active game intervention. The network meta-analysis, however, indicated that the effect size of active games was small. The reason active games may not have been as effective as hypothesized could be that physical activity is a long-term habit that needs time to form. Acquiring a new active video game does not magically lead to increased physical activity (Baranowski T et al., 2012), so much as simply adding another option to the types of physical activity one might perform. An online platform that incorporates gamification and social interaction may be an effective and innovative way of managing obesity by motivating people to be active (Beleigoli et al., 2018). Increasing physical activity is a public health goal that needs endless effort (*Healthy People 2020* |, 2022). As gym accessibility might be a concern for some people during and after the COVID-19 pandemic, an online platform or active game that has engaging features could be extremely useful.

Strengths

Being a limitation but also a strength, this study includes studies from around the globe. There are studies conducted in Asia (China, Japan, Korea, Taiwan), Europe (Holland, UK), North America (Canada, US), South America (Brazil), Africa (Saudi

Arabia) and Australia. The downside of including this many studies from different cultures was a lack of heterogeneity of the treatment. However, various treatments presented in the study indicate numerous evidence-based interventions that can be further implemented.

This is a first of its kind network meta-analysis including GBL, gamification as well as active game and looking at both knowledge and behavioral outcomes. Although this study was not able to perform a network meta-analysis on nutrition knowledge score or fruit and vegetable consumption outcomes, the result of network meta-analysis on physical activity did show a different effect between various treatments from gamification and active game.

Literature was included based on whether they were adjusted for confounder or not, the screen of the quality of the study took place. There were two studies excluded from this study due to low quality; for example, they included nutrition knowledge as an outcome but did not report the mean (Sleet, 1985). The majority of studies reported dropout rate of participants and used reliable and valid measures, on a representative sample of the population.

Limitation

There are several limitations of the study. First, the vast majority of the treatments utilized in each study were different especially for knowledge and fruit and vegetable consumption. This could be a result of dietary and lifestyle patterns that were impacted by race and cultural background (Knudsen et al., 2014). Due to the goal of nutrition education is to promote healthy behavior in an achievable way, highly customized content to the culture, community, even personalized nutrition was promoted (Ordovas et al., 2018). Though the various treatments may be a limitation when conducting meta-analysis, it should be celebrated for the sake of participants and the public for the diversity of evidence-based intervention.

Second, in order to include as much literature as possible, when reviewing literature, quality of literature was not the priority when excluding research. A study was conducted as to whether or not they adjusted for confounding variables when analyzing the association between gamified nutrition education and knowledge, or behavioral outcomes. Third, conference presentations were not included in this study. Some innovative implications might be missed due to this limitation. Fourth, this study only contained articles that have the full text available; as a result, three studies were excluded (authors were contacted but full text was not received). Fifth, many gamifications were limited to pre-post or quasi experimental design because of how gamification was designed.

Sixth, estimated SD was also used to get the missing SD of change for study. The correlation coefficient for the treatment group was imputed from Tripette et al. and Liang et al.'s study. It is not ideal for the population not to be similar to other studies included in the category, but these are the only two studies that have known SD of change with the same outcome under investigation. Lastly, the result of network meta-analysis on physical activity showed a different effect between gamification and active game. However, only one gamification study was included in the analysis, thus the interpretation of the result must be considered carefully.

Future study

Due to limited research, the potential different effect of GBL and gamification on nutrition knowledge, FRUIT AND VEGETABLE consumption and physical activity is still unknown. However, a small effect difference between gamification and active game was presented by the meta-analysis facilitating physical activity. Future studies can examine the different effects for example target age, cultural background or previous game experience. For nutrition knowledge and for fruit and vegetable consumption, researcher found a lack of heterogeneity in terms of how the outcomes were measured and reported. It was suggested that some guidance for those who design and use these games in research could be put in place, in order to have common metrics that can be compared across different games or interventions. Other than studies that investigated physical activity promotion by active games, most of the included literature used different treatments that were not reused. Future studies can focus on utilizing the treatments that are evidenced to be effective. This study also found that gamified studies were rooted in various countries around the globe. Future research should be able to identify or adapt relevant studies from the existing intervention game.

To conclude, based on the current findings we can see that research of gamified interventions to achieve various outcomes to prevent obesity is progressing at a fast pace. Still, studies that compared different gamified interventions and non-gamified approaches in the nutrition education field are still limited. Lack of heterogeneity in both treatment and outcome measurement was observed in the areas of fruit and vegetable intake and of food knowledge. Fortunately, highly diverse treatment also demonstrates the strong growth of the field and the possibility for implementing gamified education in numerous settings.

Appendix A

Preliminary Result

Study	Theory of game grounded	n	Research method	Form of intervention	population	Pedagogy using	Key finding
Pemprk & Calvert, 2009	NA	30	experiment	Advergame	Children aged 9-10 years	NA	concerns about online advergames that market unhealthy foods are justified
Dias & Agante, 2011	NA	231	experiment	Advergame	Children aged 7-8	NA	although children's nutritional knowledge is good, they might not employ it when selecting snacks
Harris et al, 2012	NA	152	experiment	Advergame	Children aged 7- 12 years	NA	After playing unhealthy food advergames, children consumed more nutrient-poor snack foods and fewer fruits and vegetables
Folkvord et al, 2013	NA	270	experiment	advergame	Children aged 8-10 years	NA	Playing an advergame contain- ing food cues increased general energy intake
Folkvord et al, 2014	NA	261	experiment	advergame	Children aged 7- 10 years	NA	Playing an advergame containing food cues increased general caloric intake.
Folkvord et al, 2015	NA	92	experiment	advergame	Children from grade 2-4 in Netherlands	NA	Playing an advergame let children eat more in general and advertised snacks.
Folkvord et al, 2016	NA	133	experiment	advergame, task	Children aged 7- 10 years	(i), (ii)	other than advergame, task inhibit the advertised food selection
Sharps & Robinson, 2016	NA	143	experiment	board game	Children aged 6- 11 years	(i), (ii)	Increased FV intake
Folkvord et al, 2017	NA	127	experiment	board game	Children aged 7- 12 years	(i)	Increased fruit intake
Florack et al, 2018	NA	81	experiment	board game	Children aged 3-6 years	(i)	Cued snake in game were chosen more
Porter et al, 2018	NA	236	experiment	board game	Children aged 4- 11 years	(i)	Time of reflecting healthy or unhealthy food shorten
Gillis, 2003	NA	3	Pre-, post-intervention comparison	Board game	Children aged 6 years and their patents	(i), (ii)	increased repertoire of foods and maintained for a year

FV is abbreviate for fruit and vegetable

Study	Theory of game grounded	n	Research method	Form of intervention	population	Pedagogy using	Key finding
Coulthard & Ahmed, 2017	NA	102	experiment	board game	Children aged 4- 8 years	(i), (ii)	multisensory exposure increases children trying novel food more than visual exposure
Lakshman et al, 2010	NA	1133	Quasi-experiment	board game	Children aged 9-11 years	(i), (ii)	nutrition knowledge score increased, positive attitudes to healthy diet
Amaro et al, 2006	NA	153	experiment	board game (Kaledo)	Children aged 11–14 years	(i), (ii)	Significant increases in knowledge and vegetable intake
Viggiano et al, 2018	NA	1313	experiment	board game (Kaledo)	Children aged 7- 11 years	(i), (ii)	Significant increases in healthy food intake after even 18 months
Rose et al. (2013)	*NA*	17	Usability evaluation	Gamification (Smartphone App)	Participants with Type I diabetes	(i), (ii), (iii)	the retention of active mySugr users was measured at 88% over a 12-week period.
Jones et al. (2014a)	*NA*	251	*Pre-,* post-intervention comparison	Gamification activity	Children aged 7- 11 years, US	(i), (ii), (iii)	Increase FV intake
Jones et al (2014b)	social learning theory and operant learning theory	180	*Pre-,* post-intervention comparison	Gamification activity	Children aged 5-6 years, US	(i), (ii), (iii)	Increase FV intake
Joyner et al., 2017	*NA*	572	*Pre-,* post-intervention comparison	Gamification activity	Children aged 5- 11 years, US	(i), (ii), (iii)	Increase FV intake
Azevedo et al, 2019	NA	189	Quasi-experiment	Gamification (Smartphone App)	kindergartens in Portugal and their family	(i), (ii)	Gamified platform seems to be a useful, easily adapted educational tool
Kadomura et al, 2014	NA	5	Pre-, post-intervention comparison	Gamification (fork)	Children aged 1- 14 years	(i), (ii)	users could eat their disliked foods more easily
Nour et al 2017	COM-B framework (Michie, van Stralen, & West, 2011) and Taxonomy of behavior change techniques	32	Focus group	Gamified(smartphone application)	young adults	(i), (ii)	use of social media and mobile gaming was seen as an acceptable approach for improving vegetable intake
Yang et al (2015)	Social-interdependence	C, n=31; E1, n = 20; E2, n = 37	Quasi-experiment	online team-based competitive game	tenth graders from three sections of a "Health Education" course	(i), (ii), (iii)	improvement intake of most food groups, as well as for macronutrients and micronutrients

Study	Theory of game grounded	n	Research method	Form of intervention	population	Pedagogy using	Key finding
Thompson et al., 2009	Social Cognitive Theory to enhance self-efficacy	473	experiment	online Video game	boy scouts (42 troops) aged 10–14 years.	(i), (ii), (iii)	Increase FV intake
Schneider et al, 2012	NA	75	Pre-, post-intervention comparison	online video game (Fitter Critters)	Children aged 11	(i), (ii), (iii)	Significant increases in positive attitudes toward healthy eating, healthy eating self-efficacy
Thompson et al., 2015	Goal setting, Social Cognitive Theory, Self Determination Theory, Behavioral Inoculation Theory, Maintenance Theory, and Elaboration Likelihood Model	400	Pre-, post-intervention comparison	online Video game(Squire's Quest! II)	Children aged 9-11 years and their patents	(i), (ii), (iii)	Increased FV intake
Cullen et al, 2016	Goal setting, Social Cognitive Theory, Self Determination Theory, Behavioral Inoculation Theory, Maintenance Theory, and Elaboration Likelihood Model	400	Pre-, post-intervention comparison	online Video game(Squire's Quest! II)	Children aged 9-11 years and their patents	(i), (ii), (iii)	Increased FV intake after 6-month post intervention
Thompson et al, 2016	Goal setting, Social Cognitive Theory, Self Determination Theory, Behavioral Inoculation Theory, Maintenance Theory, and Elaboration Likelihood Model	400	Pre-, post-intervention comparison	online Video game(Squire's Quest! II)	Children aged 9-11 years and their patents	(i), (ii), (iii)	Increased FV intake and decrease of energy density
Desmet et al, 2017	Goal setting, Social Cognitive Theory, Self Determination Theory, Behavioral Inoculation Theory, Maintenance Theory, and Elaboration Likelihood Model	400	Pre-, post-intervention comparison	online Video game(Squire's Quest! II)	Children aged 9-11 years and their patents	(i), (ii), (iii)	Children's asking behavior about FV and home FV availability increased after intervention, but these increases did not mediate the increase in children's FV intake
Putnam et al, 2018a	NA	132	experiment	tablet game (Dora the Explorer)	Children aged 4- 5 years	(i), (ii), (iii)	No difference on intake but awareness was increased
Putnam et al, 2018b	exposure effect	114	experiment	tablet game(D.W.'s Unicorn Adventure)	Children aged 4- 5 years	(i), (ii), (iii)	Can recall more healthy and unhealthy food item

Study	Theory of game grounded	n	Research method	Form of intervention	population	Pedagogy using	Key finding
Munguba et al., 2008	*NA*	200	Quasi-experiment, semi-structured interview and structured observation	1 video game, 1 board game	public school children between 8 and 10 years old (95 M, 105 F).	(i), (ii), (iii)	Both games promoted learning of nutritional concepts.
Rosi et al, 2015	NA	76	Pre-, post-intervention comparison	video game	Children aged 10–12 years	(i), (ii), (iii)	Increased FV intake
Turnin et al, 2001	NA	1878	Quasi-experiment	video game	Children aged 7- 12 years	(i), (ii), (iii)	Significant better nutritional knowledge and balanced diet
Banos et al, 2013	NA	228	Quasi-experiment	video game	Children aged 10–13 years	(i), (ii), (iii)	nutrition knowledge score increased
Majumdar et al, 2013	Self-determination, social cognitive	342	Quasi-experiment	video game	Children aged 11–13 years	(i), (ii), (iii)	decreasing frequency and amount of sweetened beverage and processed snack intake
Wang et al 2017	Self-determination, social cognitive	179	Quasi-experiment	video game (Escape for Diab)	Chinese children aged 8-12	(i), (ii), (iii)	Increased fruit and water intake
Jiang et al, 2016	NA	42	experiment	video game (Happy Goat Says)	Children aged 6- 7 years	(i), (ii), (iii)	Children can control over unhealthy option by daily-life inhibitor training game
Pampaloni et al, 2015	NA	176	Pre-, post-intervention comparison	video game (Mr. Bone)	Children aged 9-11 years	(i), (ii), (iii)	significant increase of calcium and vitamin D
Sharma et al, 2015	Social Cognitive Theory, Theory of Reasoned Action	94	Quasi-experiment	video game (Quest to Lava Mountain)	Children aged 9-11 years	(i), (ii), (iii)	decreased sugar consumption and higher nutrition/physical activity attitudes
Baranowski et al, 2003	social cognitive theory	1578	Pre-, post-intervention comparison	video game (Squire's quest)	Children aged 8-12 years	(i), (ii), (iii)	Potential to change dietary behavior
Johnson-Glenberg & Hekler, 2013	embodiment	19	Pre-, post-intervention comparison	video game(Alien health game)	Children aged 11	(i), (ii), (iii)	nutrition knowledge score increased
Johnson-Glenberg et al, 2014	embodiment	20	experiment	video game(Alien health game)	Children aged 12–13 years	(i), (ii), (iii)	nutrition knowledge score increased right away and in 2 weeks follow up

Appendix B

Final study literature

	Method	Outcome	Measurement	Final sample	Population under investigation	Intervention	Game	Duration	Control group content	Follow up	Main finding
Abdollahi et al., 2021	Quasi exp	Knowledge score	questionnaire assessing knowledge	68 intervention, 62 control	11–14 year old children from Helsinki, Finland and Reading, United Kingdom (UK)	GBL	The escape game Zombie Attack	1h.	self study,read the material	None	No significant differences in gained knowledge existed between groups
Alblas et al., 2018	RCT	Fruit vs. chocolate snack intake	implicit attitudes, actual choice	62 intervention, 63 control	128 undergraduate students Radboud University, Holland	GBL	Sky Islands	10 min	Control game was identical to health but rather than pictures of food, pictures of clean and fossil fuels were used,	None	Significant increases in knowledge and vegetable intake
Altammami , et al., 2017	RCT	Health-risk dietary scores	quiz, 12-item survey about dietary recall (	19 intervention, 19 control	12 – 18 years Saudi Arabian who understand and comprehend the English language	GBL	Diet Coach One	not reported but the play time of game over 3 day	no intervention.	None	Participants in the intervention group exhibited significant changes in their health-risk dietary scores
Amaro, 2006	Quasi exp	PA incease, vegetable intake	FV intake	153 intervention, 88 control	Middle schooler in Naples, Italy.	GBL	Kaledo	15–30 min a week for 24 weeks	no intervention.	None	Treatment could be an effective instrument to teach children about healthy diet.
Baranowski et al., 2012	RCT	PA incease	Acti- graph GT33accelero meters	37 intervention 41 control,	9 to 12 years of age, with a BMI > 50th percentile, but < 99th percentile in TX, US	Active game	Wii console active video game	Time being a dependent variable	Inactive game on Wii	None	Children receiving the active video games were not more active
Baranowski et al., 2011	RCT	FV intake	24-hour dietary recalls BMI Waist circumference Triceps skinfold	103 intervention, 50 control	10–12 years, between the 50th and 95th percentile for BMI who speaks English in TX and NC, US	GBL	6 hours of new game-play per game	9 sessions and a minimum of approximately 40 minutes	knowledge enhancing Internet experience presented in two parts	2-months postgame	Effect of increasing FV intake pertain after 2 month later end of intervention

FV is abbreviate for fruit and vegetable

			Accelerometers					of game-play per session.			
Barwood, et al., 2020	RCT	Knowledge score	Three knowledge and two attitude indicator scores	36 intervention, 34 control	72 adolescent school students in Australia	GBL	Test Game B	Time unkown for 12 weeks	similar concepts to Test Game B by focusing on the processes of digestion and the digestive system	None	Significant increase from pre- to post-trial in the mean knowledge score for treatment but not control
Beleigoli, et al., 2020	RCT	BMI, daily vegetable/fruit intake, physical activit	BMI, daily vegetable/fruit intake, physical activit	90 intervention, 90 control	University students or employees with 25 kg/m2 minimum body mass index in Brazil	gamification	gamification mechanics weight loss program or program plus personal feedback	Access to platform for 24 weeks	Minimal intervention group	None	The platform-only compared with the waiting list group, had a greater increase in the consumption of vegetables but not for physical activity
Blackburne et al., 2016	RCT	Healthy Eating Quiz	Barratt Impulsiveness Scale for food consumption Healthy Eating Quiz	26 intervention, 26 control	Wollongong (Australia)be older than 13 years (range 19-61, mean 36.48, SD 14.22), have a BMI higher than 25 (mean 29.54, SD 4.05), and possess an iOS device	GBL	go, nogo game 10 games per day for 14 consecutive days with each game taking approximately 1 minute to complete	1 minute for 90 games over the 14-day period	waitlist-control	None	Both treatment and waitlist group showed a significant increase at post intervention for Healthy eating quiz
Bowling et al., 2021	RCT	physical activity	accelerometer	11 in intervention, 12 in control	Mean age 15.1 years, SD 1.5; 17 males, 9 people of color) recruited in person from clinic and special education settings in Boston, US	Active game	Adaptive GameSquad	recommend 10-40 mins, 10 weeks	wait-list	None	PA per day significantly decreased for the control (wait-list) but not for the intervention group

Braga-Pontes et al., 2021	Quasi exp	Vegetable consumption	real food presented	GBL 32, gamification 37, control 29	3 to 6 years in Portugal	GBL, gamification	20-min educational sessions once a week for 5 weeks.	20-min once a week 5 weeks	Portuguese Food Wheel Guide	week 29	All interventions tested were effective in increasing vegetable consumption without statistically significant differences, compared to the control group.
Chae et al., 2022	Quasi exp	WC, BMI	Anthropometric factors, physiological factors, physical activity	50 in intervention, 59 in control	Korean high school adolescents	Active game	School-based Nintendo Wii sport game, health education (SNS), dietary diary feedback for students from a nurse and school nurse	30 min 5 times per week for 12-week	no intervention.	None	The intervention group showed a significantly decreased WC and reduced weekend sitting time.
Chagas et al., 2020	Quasi exp	nutrition knowledge	fifteen statements and express their level of agreement	117 intervantion, 202 control	male and female adolescents from private schools in the Federal District, Brazil	GBL	Rango Cards	Time unkown for 7 (minimum) to 17 (maximum) days.	no intervention.	None	Inhibitory control training was associated with increased healthy and reduced unhealthy food consumption.
Coknaz et al., 2019	Quasi exp	BMI change	weight, BMI, FR and RTs, SP	53 intervention, 53 control	children were 8–13 years old, pre-occupied with technology and physically inactive in Ekelund	Active game	wii sports	50-60 min, 3 times a week, 12 weeks	no intervention.	None	Active video game group significantly showed favourable responses for body mass index from baseline scores.
Cullen et al., 2005	Quasi exp	FV intake	Food Intake Recording Software System (FIR), 24-h dietary recall	749 intervention, 740 control	26 Houston area elementary schools and 1578 fourth grade children participated during the 1999–2000 school year.	GBL	Squire's Quest!	25 mins, 10-session intervention	no intervention.	None	Treatment demonstrates that with meal and environment targeted goal setting and intervention messages can induce dietary behavior change

de Vlieger et al., 2021	Quasi exp	Knowledge score	child nutrition knowledge quastionnaire	75 intervention, 94 control	Students in year 5 and 6 classes Australia.	GBL	VitaVilla ge	twice 20 min in 2 weeks	Play math games	None	Engagement with VitaVillage improved children's overall nutrition knowledge compared to controls
Forman et al., 2021	RCT	BMI change	Weight loss	36 intervention, 40 control	overweight individuals in US from another large cohort study	GBL	Go/No Go task with back story	42 daily and 2 weekly 10 min ICTs, over 8 weeks	go/no go task	None	GBL elements had a positive effect on weight loss for men and not women
Froome et al., 2020	RCT	nutrition knowledge	Nutrition Attitudes and Knowledge (NAK) Questionnaire	39 intervention, 34 control	8–10 years old could read and write English at Ontario	GBL	Foodbot Factory	10-min over 5 days	my salad shop bar a gamified mobile app	None	Children who used Foodbot Factory had significant increases in overall nutrition knowledge
Gan et al., 2019	Quasi exp	nutrition knowledge, questions referred to energy, macronutrients, fruits and vegetables, sugar and salt, water, and beverages, as well as physical activityquestion s referred to energy, macronutrients, fruits and vegetables, sugar and salt, water, and beverages, as well as physical BMI	Nutrition Knowledge Questionnaire for the study	180 intervention 180 control	2 and grade 3 elementary who did not have disability and able to understand English in Philippines	GBL	Healthy Foodie	30 min	no intervention.	None	Healthy Foodie is effective as a reinforcement intervention to previous standard nutrition education
Gomes et al., 2015	RCT	BMI change, body fat	Waist circumference , BMI, Fat mass	13 in intervention, 13 in control	Asthmatic children from a tertiary center specialized in childhood asthma, Brazil	Active game	Xbox 360 kinect	30 min twice a week for 8 weeks	Treadmill 30 min twice a week for 8 weeks	None	BMI and WC were not significantly different from groups

Hamari et al., 2019	RCT	active time	accelerometer	17 intervention, 19 control	Children with cancer, 3–16 years-old in Finland	Active game	Wiifit	30 min/day for 8 weeks	written advice PA of 30 min/day	at 1 year	Physical activity time spent did not differ between the groups. Not different for the one year follow up either.
Hermans et al., 2018	quasi exp	BMI, nutrition score	weight and hight, nutrition score scale	58 intervention, 50 control	sample of three primary schools in the southern part of the Netherlands	GBL	Alien Health Game	30 minutes, twice on two consecuti ve days	Super Shopper.	2wee k	Participants who played Alien Health had better knowledge of the five most important macronutrients of foods at immediate posttest, but not at follow-up
Holzmann, et al., 2019	quasi exp	nutrition knowledge, BMI	weight and hight, nutrition score scale	36 intervention, 40 control	secondary schools in the city and district of Rosenheim	GBL	Fit, Food, Fun	15 min on each of the three consecuti ve days.	no intervention.	None	There was a significant improvement in nutritional knowledge in both teaching and gameplay groups.
Hwang & Lu, 2018	RCT	physical activity	accelerometry International Physical Activity Questionnaire	25 intervention, 25 control	US adults who (1) were between 18 and 25 years old; (2) were free of cardiovascular, cerebrovascular, or neurological diseases, attentional disorders, or physical disability; (3) were not a current or former user of tobacco; and (4) had never previously played the video games used the study.	Active game	a) AVG with narrative (N-AVG); (b) AVG without narrative (AVG); (c) SVG with narrative (N-SVG); and (d) SVG without narrative (SVG)	90 minutes	sedentary video game	None	30-min experimental period had non-significant effects on levels of physical activity intensity.
Jiang et al., 2016	RCT	food intake, BMI	Scale and task response	20 intervention, 20 control	indergarten in Zhe-jiang province, China	GBL	go nogo	10-min “Happy goat says” game in the classroom for 6 days,	Lego	None	Children can control over unhealthy option by daily-life inhibitor training game

Johnson-Glenberg, et al., 2014	RCT	content knoledge	The nutrition and food choice test	20 intervention, 20 control	6th and 7th graders in the US	GBL	food chose: Alien health	50 minute	nonfood choice game	2week	Both groups significant gains on the immediate nutrition knowledge. And experimental group did better in follow up than control.
Kato-Lin et al., 2020	rct	food choice	real food presented	52 intervention, 52 control	10 to 11 years in Chennai, India	GBL	Fooya!	20 minutes twice, 1 week apart	uno	None	healthy foods correctly identiied
Lakshman et al., 2010	RCT	knowledge score, attitudes	questionnaire	502 intervention, 631 control	children aged 9-11 in UK	Gbl	Top Grub'	unknown time for 9 weeks	no intervention.	None	Nutrition knowledge score increased, positive attitudes to healthy diet
Lau, et al., 2020	RCT	physical activity	ActiGraph GT3X + activity monitor, weight and hight	121 intervention, 73 control	children with mild intellectual disabilityged 8–18 years from special education schools in Hong Kong	Active game	Xbox 360 Kinect	30-min twice per week, for a total of 12 weeks.	none	None	Active video game had no marked effect on BMI, PA and motor proficiency in children with intellectual disability.
Liang et al., 2020	Quasi exp	physical activity, BMI	accelerometers	29 intervention, 51control	Primary school children 9–12 years old in Hong Kong	Active game	Xbox 360 Kinect	60 mins, twice a week for 8 weeks	none	None	The intervention group significantly increased total PA but not for BMI
Mack et al., 2020	RCT	nutrition knowledge, physical activity	questionnaire, index for healthy nutrition, knowledge (eg, nutrition and stress coping) measured	40 intervention, 42 control	children aged 9 to 12 years in Germany.	GBL	Game modules	45min each, twice over a 2-week period,	healthy lifestyle via a brochure	4weeks	The knowledge score increased from treatment group versus control (P<.001). At follow up the knowledge score of treatment group remained at the same level as that of post-test.
Maddison et al., 2011	RCT	physical activity	accelerometer, weight and height	160 intervention, 162 control	0–14 y, overweight or obese own PlayStation 2 or 3 and play 2h of video game/wk from Australia and New New Zealand	Active game	Sony PlayStation EyeToy	encouraged to play ACT but not required, got new game	no intervention.	12 week after intervention end	An active video game intervention has a small but definite effect on BMI and body composition and treatment effect on BMI favored the intervention group at follow up.
Ni et al., 2008	RCT	Physical activity level, WC	Physical Activity Ques-tionnaire for	10 intervention, 10 control	10 and 14 years; owned a PlayStation®2 console; English	Active game	Sony PlayStation EyeToy	time being a dependent variable	no intervention.	None	Playing active video games on a regular basis may have positive effects on children's PA level

			Children (PAQ-C)		speaking in Auckland, New Zealand			for 12 weeks			
Pasco et al., 2017	RCT	physical activity	accelerometer	94 intervention, 69 control	undergraduate students in northwest region of France	Active game	Greedy Rabbit exergame	15 min for 10 stages	15 mins of free cycling	None	Experimental group had higher degrees of light PA whereas the control group received higher scores for MVPA
Peng, 2009	RCT	Knowledge score	study developed survey	19 intervention, 13 control	undergraduate students in US	GBL	RightWa y Café game	42 min.	no intervention.	1 mont h	Game was effective in teaching nutrition knowledge and participants in the game-playing group had greater self-efficacy than participants in the control group after 1 month.
Peng et al., 2015	RCT	physical activity	accelerometer	34 (SDT on), 28 (SDT off), control 30	8 and 25 years of age, domestic students, playing video games for at least one hour per month, and no moderate activity than 225 mins in the US	Active game	WiiMote	1 hour time slots three times in a week in 5 weeks	no intervention.	None	Playing the SDT supported active game resulted in greater MVPA
Peterson, 2002	Quasi exp	food Pyramid knowledge	Eight multiple choice questions assessed	36 intervention, 33 control	50+ elders live in senior community centers in the Piedmont region of North Carolina, US	GBL	*Pyramid Power*	90 mins	lecture	None	Average knowledge scores of game players increased by 18.6 percent for intervention while the scores of control with standard lecture increased by 9.7 percent
Schakel, et al., 2018	RCT	real food	seven food product pairs task	29 intervention, 28 control	Participants had to be fluent in Dutch and between 18 and 35 years old	GBL	ViaNova	30 min	none food game	None	Participants in both serious gaming conditions made healthier food choices compared to gaming control. No effects were found on food intake
Sen et al., 2018	RCT	Only BMI in result	Bmi, physical activity, dietary intake	12 intervention, 12 control	Obese children between 9 - 12 in Turkey	GBL	Kaledo	40–60 min at 2-week intervals were performed	Behavioral group sessions	None	BMI and BMI z-scores had no significant difference between groups

								in 3 months			
Sharma et al., 2015	Quasi exp	bmi, food intake, knowledge	Nutrition and Physical Activity Habits and Related Psychosocial Mediators, weight and hight, Dietary Intake	44 intervention, 50 control	Children aged 8 to 12 years who study public schoo in Dallas, TX, US	GBL	Quest to Lava Mountain	90 min/wk for 6 weeks	don't know	None	decreased sugar consumption and higher nutrition/physical activity attitudes
Silk et al., 2008	RCT	knowledge to MyPyramid	Thirty-three multiple-choice questions	47 intervention, 108 control	Low-income, European American and African American mother in US	GBL	The Fantastic Food Challeng e	20-30 min once	web site or pamphlet content	10-12 days later	The Web site performed better than other modalities on knowledge outcomes, with no differences in knowledge retention from post-treatment to follow-up
Simons et al., 2015	RCT	physical activity, BMI	weight and hight, nutrition score scale	134 intervention, 126 control	Adolescents aged 12–17 years played ! Had habit of game play in Netherlands 4 cities	Active game	active video games on PS3	time being a dependent variable for 10 month	no intervention.	None	The active video game intervention did decrease anthropometrics measrue in a group of 'excessive' non-active video gamers who primarily were of healthy weight compared to a control group throughout a ten-month-period
Spook et al., 2016	RCT	fruit intake	Physical Activity in the Netherlands, questionnaire	105 intervention, 126 control	vocational education schools in the Netherlands	GBL	Balance It	Time unknown, 4 continuin g weeks or on a weekly basis for 6 continuin g weeks.	no intervention.	None	No significant differences between the intervention group and control group in terms of dietary intake, PA, and determinants of dietary intake and PA
Tripette et al., 2014	RCT	physical activity, dietary intake, WC	Physical fitness assessment, weight and height	17 intervention, 17 control	Postpartum women from Tokyo Metropolitan Area, Japan	Active game	Wii Fit Plus	30 min on a daily basis for 40 days	no intervention.	None	The AVG group lost more weight than the control group

Turnin et al 2001	Quasi exp	nutrition knowledge	Dietary knowledge tests	827 intervention, 794 control	3 grades in primary schools in France	GBL	The Restaura nt	2 hours a week for 5 weeks	lecture	None	Dietary knowledge tests results were better in the games group
Viggiano et al., 2015	Quasi exp	Knowledge score, BMI	questionnaire, weight and height	624 intervention, 421 control	public middle schools and public high schools students in Italy	GBL	Kaledo	15-30 min once a week for 20 weeks	Adolescent Food Habits	18 mont hs	Significant increases in score of healthy food questions after even 18 month
Wengreen et al., 2021	Quasi exp	food liking	food waste	881 intervention, 978 control	kindergarten through fifth-grade (ages 5–11) at- tending one of four public elementary schools in Logan, UT, USA	gamific ation	FIT Game	3 min per day for 44 days in year 1 , 49 in year 2	no intervention.	3 mont h	Children in treatment group consumed more vegetables, more fruit, and had higher skin carotenoids than at baseline. These were maintained at a 3-month follow-up for vegetables and carotenoids .
Yang, et al., 2015	Quasi exp	nutrition quiz in game	Cloud diet assessment system (CDAS)	28 intervention, 25 control	girls' senior high school in northern Taiwan	GBL	Game-based team learning	two 50 min classes	cognition and knowledge construction,	None	Improvement intake of most food groups, as well as for macronutrients and micronutrients

Appendix C

R Code and data file For Network Meta-analysis

~~~
title: "Meta analysis"
output: html_document
---

```{r setup, include=FALSE}
knitr::opts_chunk$set(echo = TRUE)
```

## R Markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring
HTML, PDF, and MS Word documents. For more details on using R Markdown see
<http://rmarkdown.rstudio.com>.

When you click the **Knit** button a document will be generated that includes both content
as well as the output of any embedded R code chunks within the document. You can embed
an R code chunk like this:


```{r echo=FALSE}

library (compute.es)
#a.fes(14.73, 62, 63, 0.97, 1, level=95, cer = 0.2, dig = 2, verbose = TRUE, id=NULL,
data=NULL)
~~~

FV is abbreviate for fruit and vegetable

~~~
# [illegible]
a.fes(3.03, 25, 25, 0.97, 0, level=95, cer = 0.2, dig = 2, verbose = TRUE, id=NULL,
data=NULL)
a.fes(31.47, 94, 69, 0.90, 0, level=95, cer = 0.2, dig = 2, verbose = TRUE, id=NULL,
data=NULL)



```
a.fes(f, n.1, n.2, R, q, level=95, cer = 0.2, dig = 2, verbose = TRUE, id=NULL, data=NULL)
Arguments
f: Fvalue from ANCOVA.
n.1: Treatment group sample size.
~~~

n.2: Comparison group sample size.
R: Covariate outcome correlation or multiple correlation.
q: number of covariates.
level: Confidence level. Default is 95%.
You can do the calculation using the function "a.fes" directly on this page:

````
```{r}
network.char <- net.tab(data = gamifiednet,
                        outcome = "PA.hour.per.week.change",
                        N = "Number.of.Participants",
                        type.outcome = "continuous",
                        time = NULL)
network.char$network
```

```{r}
random_effects_model <- nma.model(data=gamifiednet,
                    outcome="PA.hour.per.week.change",
                    N="Number.of.Participants",
                    reference="no intervention.",
                    family="normal",
                    link="identity",
                    sd = "SD.for.change",
                    effects="random")

set.seed(20190829)
random_effects_results <- nma.run(random_effects_model,
                          n.adapt=1000,
                          n.burnin=1000,
                          n.iter=10000)
par(mfrow = c(1,2))
nma.fit(random_effects_results, main= "Random Effects Model")
nma.forest(random_effects_results,
           central.tdcy="median",
           comparator = "no intervention.")
```
````

	Study.ID	Treatment	Number.of.Participants	PA.hour.per.week.change	SD.for.change
1	9Baranowski2012	Activegame	37	0.49000000	8.9368977
2	9Baranowski2012	Inactivegame	41	-2.49000000	6.5399924

	Study.ID	Treatment	Number.of.Participants	PA.hour.per.week.change	SD.for.change
3	153Beleigoli,2020	gamification	90	-4.00000000	52.5195176
4	153Beleigoli,2020	nointervention.	90	-15.00000000	19.0980064
5	20Bowling2021	Activegame	11	-1.08500000	2.5083333
6	20Bowling2021	nointervention.	12	-0.16333333	0.9683333
7	62Hamari2019	Activegame	17	4.00000000	22.2609476
8	62Hamari2019	Readingmaterial	19	1.00000000	41.2740727
9	82Lau,2020	Activegame	121	-1.12816667	2.2859765
10	82Lau,2020	nointervention.	73	0.05133333	1.2883642
11	84Liang2020	Activegame	29	0.14000000	1.0224154
12	84Liang2020	nointervention.	51	-0.28000000	1.1450582
13	89Maddison2011	Activegame	160	-0.77000000	2.0035169
14	89Maddison2011	nointervention.	162	-0.89833333	1.9138668
15	106Peng2015	Activegame	34	4.20000000	3.2264005
16	106Peng2015	nointervention.	30	-3.43000000	2.3734911
17	138Tripette2014	Activegame	17	-0.90000000	0.3000000
18	138Tripette2014	nointervention.	17	-0.50000000	0.7000000

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