



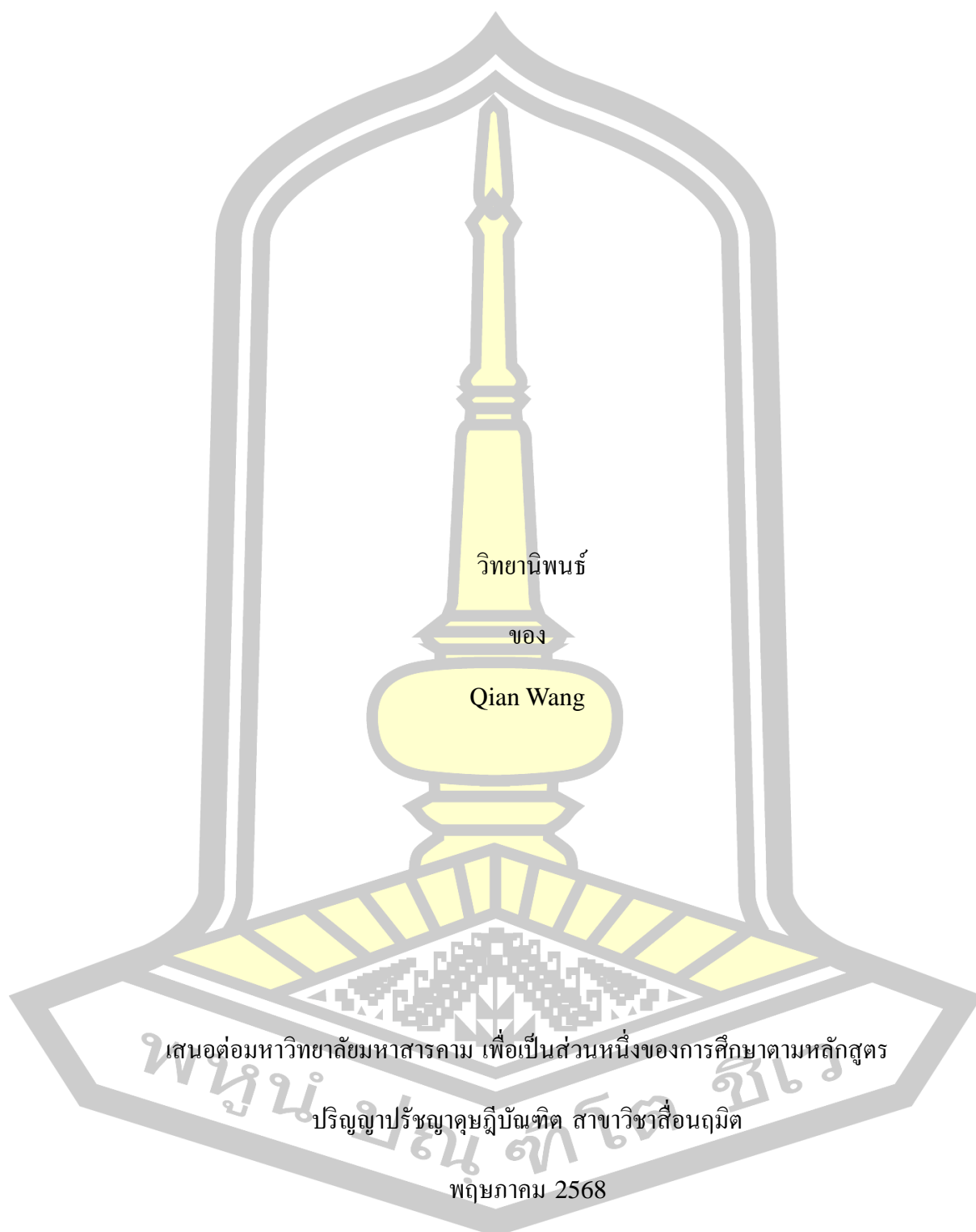
Interactive Learning Relevant to Healthy Diet for Elementary School Students using
Educational Game

Qian Wang

A Thesis Submitted in Partial Fulfillment of Requirements for
degree of Doctor of Philosophy in Creative Media
May 2025

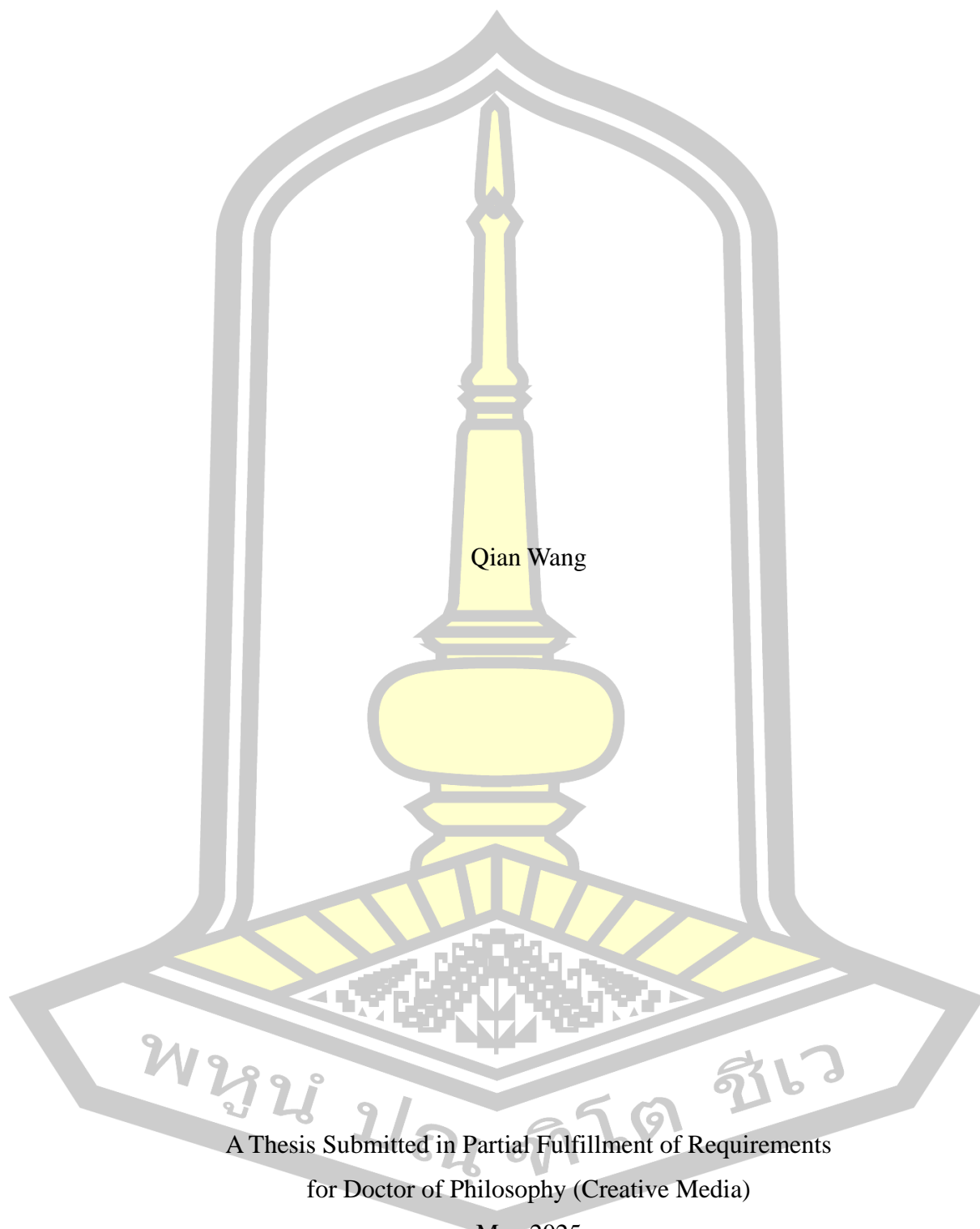
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Interactive Learning Relevant to Healthy Diet for Elementary School Students using
Educational Game



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Interactive Learning Relevant to Healthy Diet for Elementary School Students using
Educational Game



A Thesis Submitted in Partial Fulfillment of Requirements
for Doctor of Philosophy (Creative Media)

May 2025

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The examining committee has unanimously approved this Thesis, submitted by Mr. Qian Wang , as a partial fulfillment of the requirements for the Doctor of Philosophy Creative Media at Maharakham University

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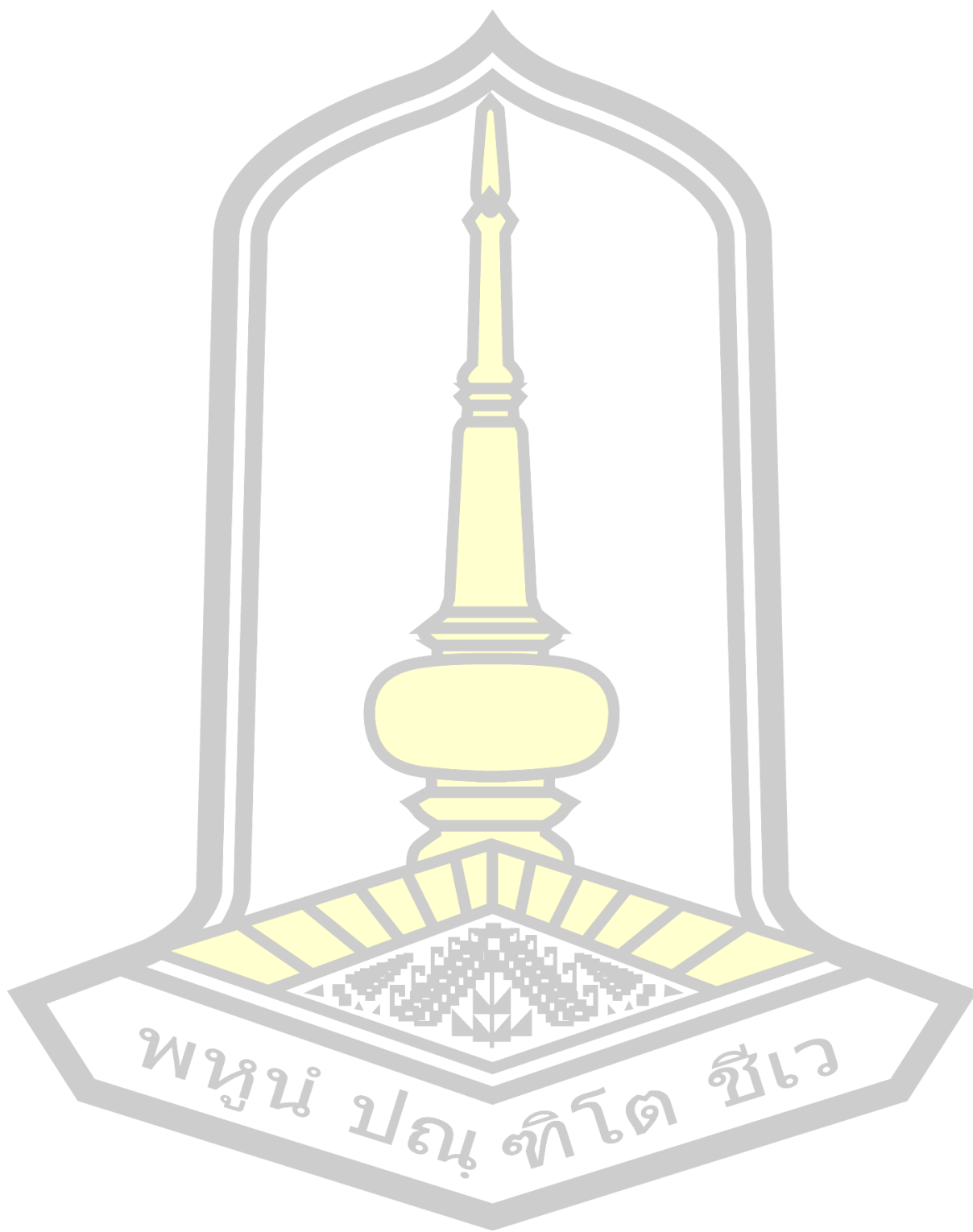
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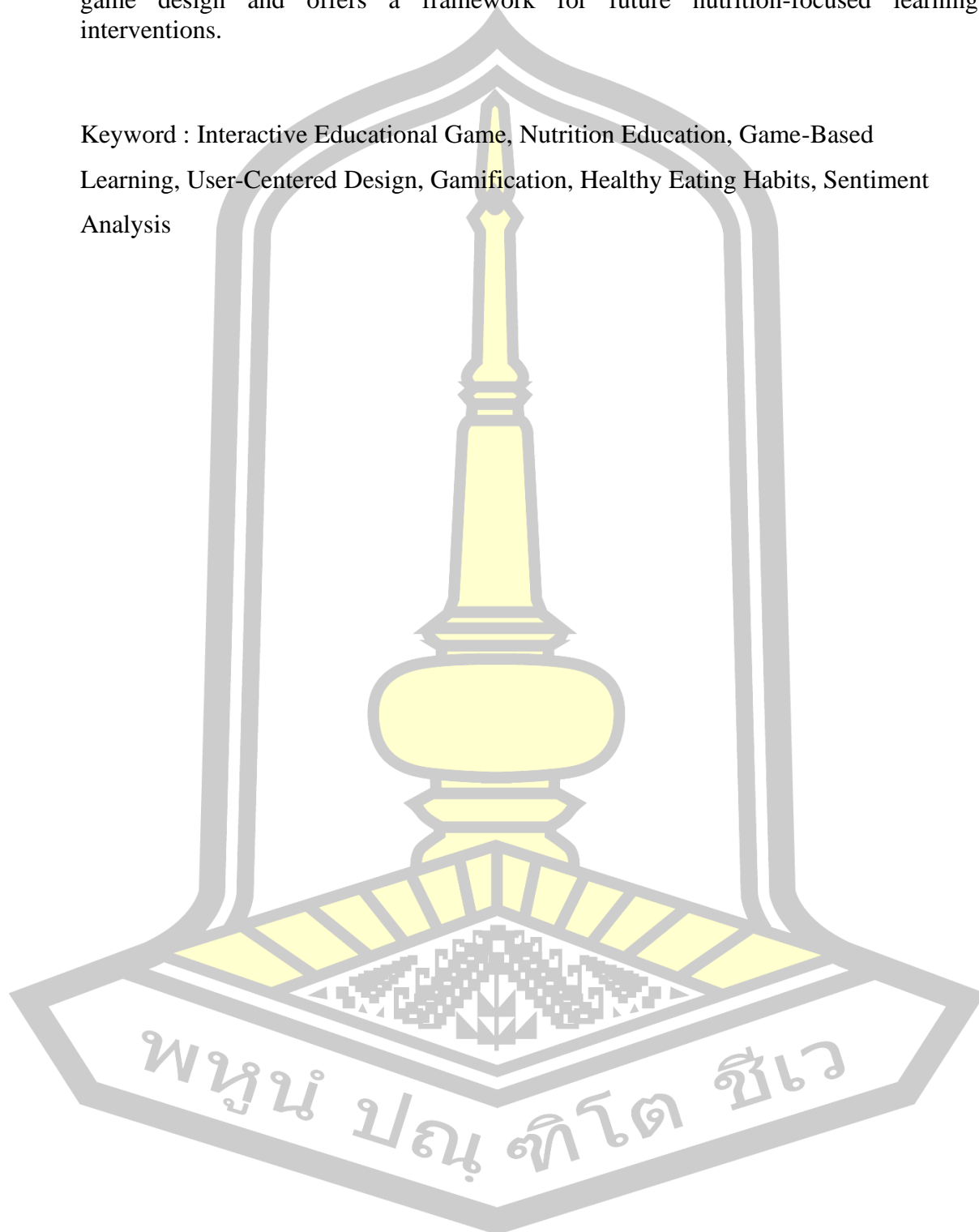
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ABSTRACT

This study explores the development and evaluation of an interactive educational game designed to promote healthy dietary habits among elementary school students. The research integrates game-based User-Centered Design (UCD), Educational Game Theory, Interactive Learning Theory, and Gamification Elements Theory to create an engaging and educationally effective game. Two formats were developed: a Tabletop Board Game and a PC-Based Board Game, both designed to facilitate interactive learning through structured gameplay, reward systems, and immersive challenges. A data-driven approach was employed to enhance the game design. K-Means clustering was applied to analyze educational game reviews, extracting key insights related to content engagement, visual appeal, and motivation mechanisms. The game's effectiveness was evaluated using multiple assessment methods, including expert validation with the N-GUT scale, pre-test and post-test comparisons, behavioral analysis, and sentiment analysis. The pre-test and post-test study demonstrated a statistically significant improvement in students' understanding of food classification, nutrient identification, and balanced meal planning, confirming the game's role in enhancing nutrition knowledge. Behavioral tracking revealed that students who played the game exhibited higher engagement, greater task completion rates, and increased persistence compared to those in the control group. Sentiment analysis highlighted distinct preferences between students and parents. Students favored the PC-Based Board Game, appreciating its interactive elements, animations, and digital accessibility, while parents preferred the Tabletop Board Game, emphasizing its familiarity, hands-on experience, and opportunities for family interaction. However, usability concerns were noted in the PC version, particularly for parents unfamiliar with digital interfaces. Despite the promising results, several challenges and limitations were identified, including technical constraints in game development, usability issues, limited generalizability, and difficulties in tracking long-term behavioral changes. Future research should explore hybrid learning approaches that integrate both physical and digital gameplay, ensuring broader accessibility and engagement. Additionally, expanding the participant pool to diverse educational settings would enhance the generalizability of findings. This study demonstrates the potential of gamification in nutrition education, providing a structured, engaging, and effective tool for promoting healthy eating behaviors in

children. By leveraging interactive learning strategies, real-world dietary data, and game-based incentives, this research contributes to the advancement of educational game design and offers a framework for future nutrition-focused learning interventions.

Keyword : Interactive Educational Game, Nutrition Education, Game-Based Learning, User-Centered Design, Gamification, Healthy Eating Habits, Sentiment Analysis



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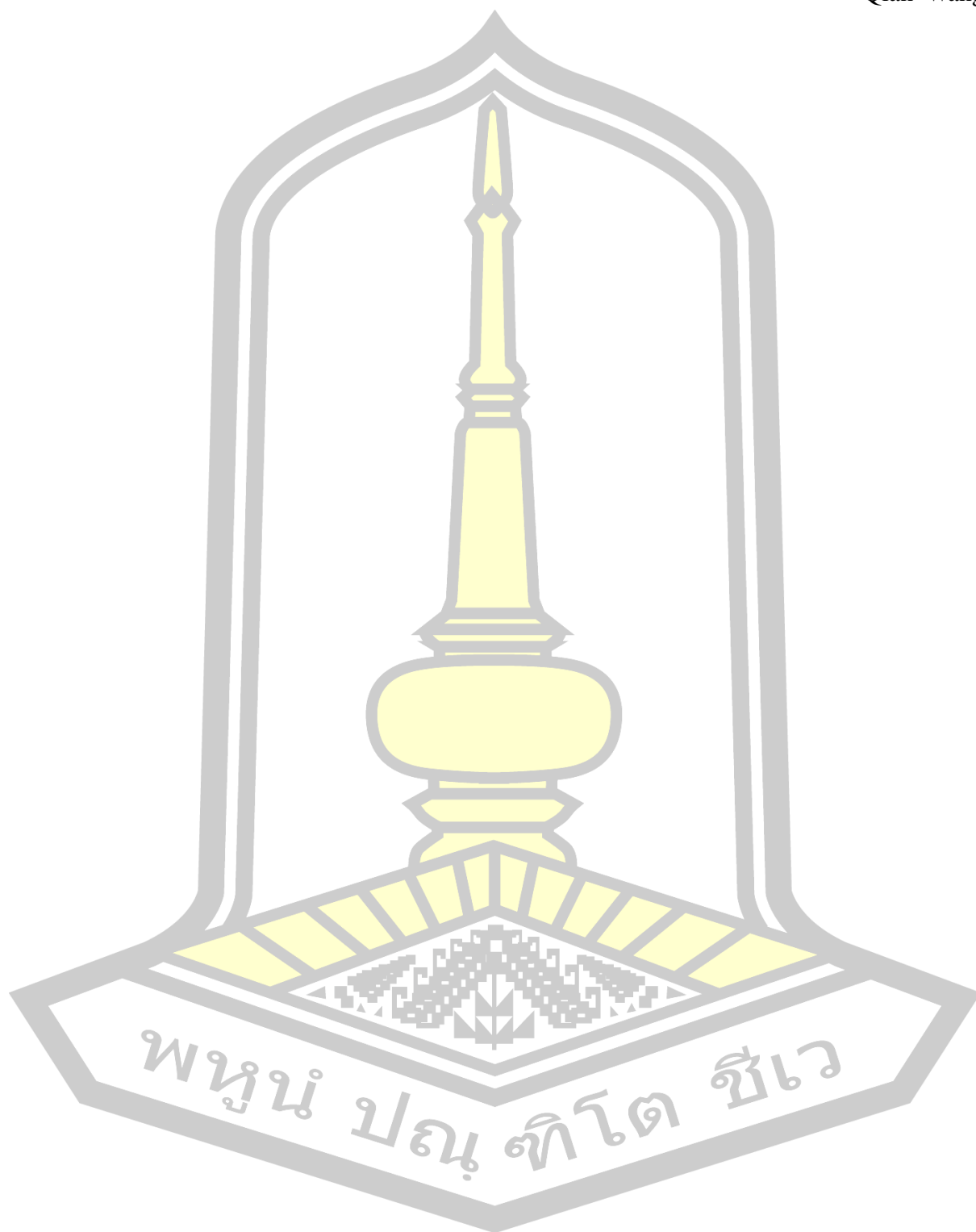
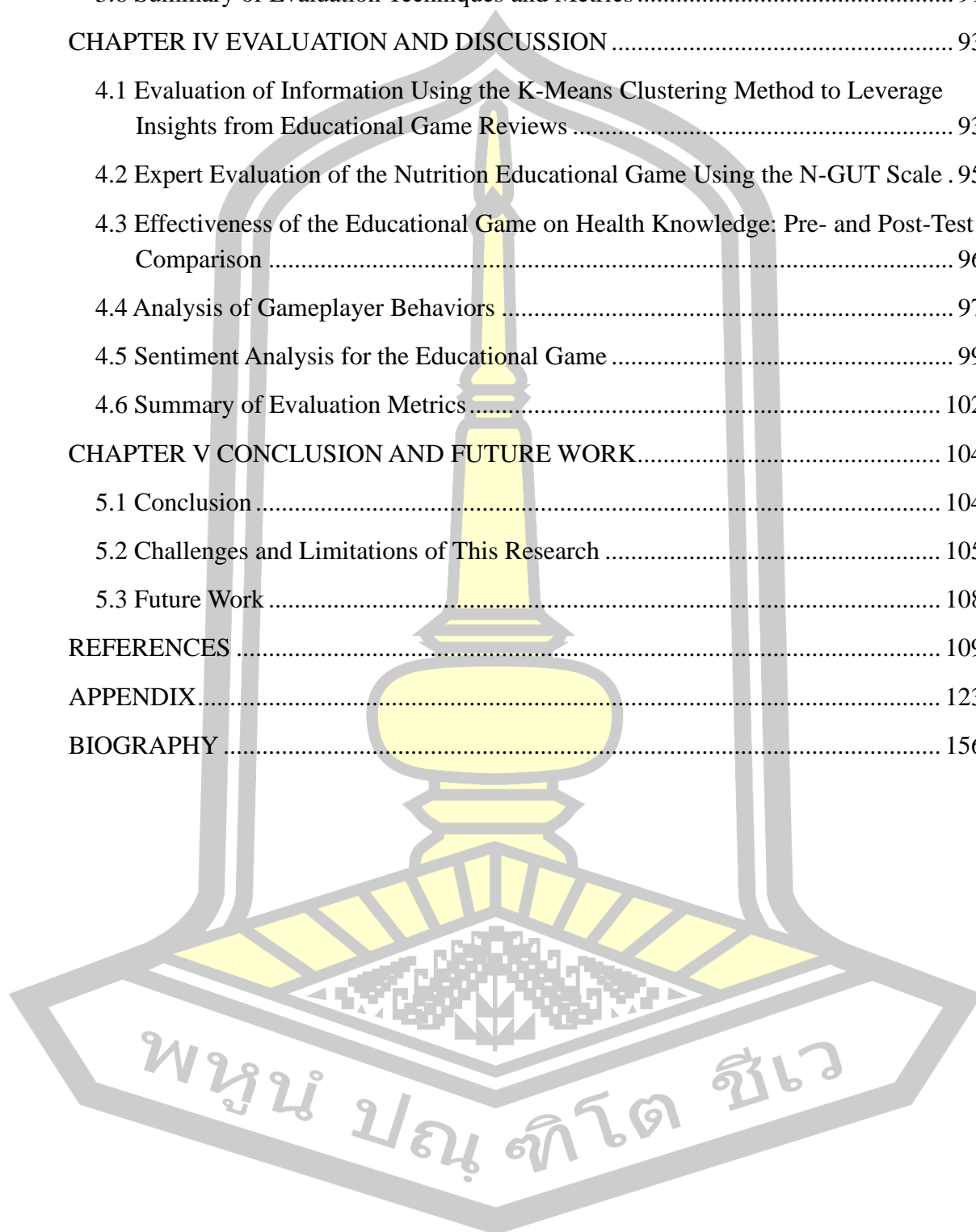


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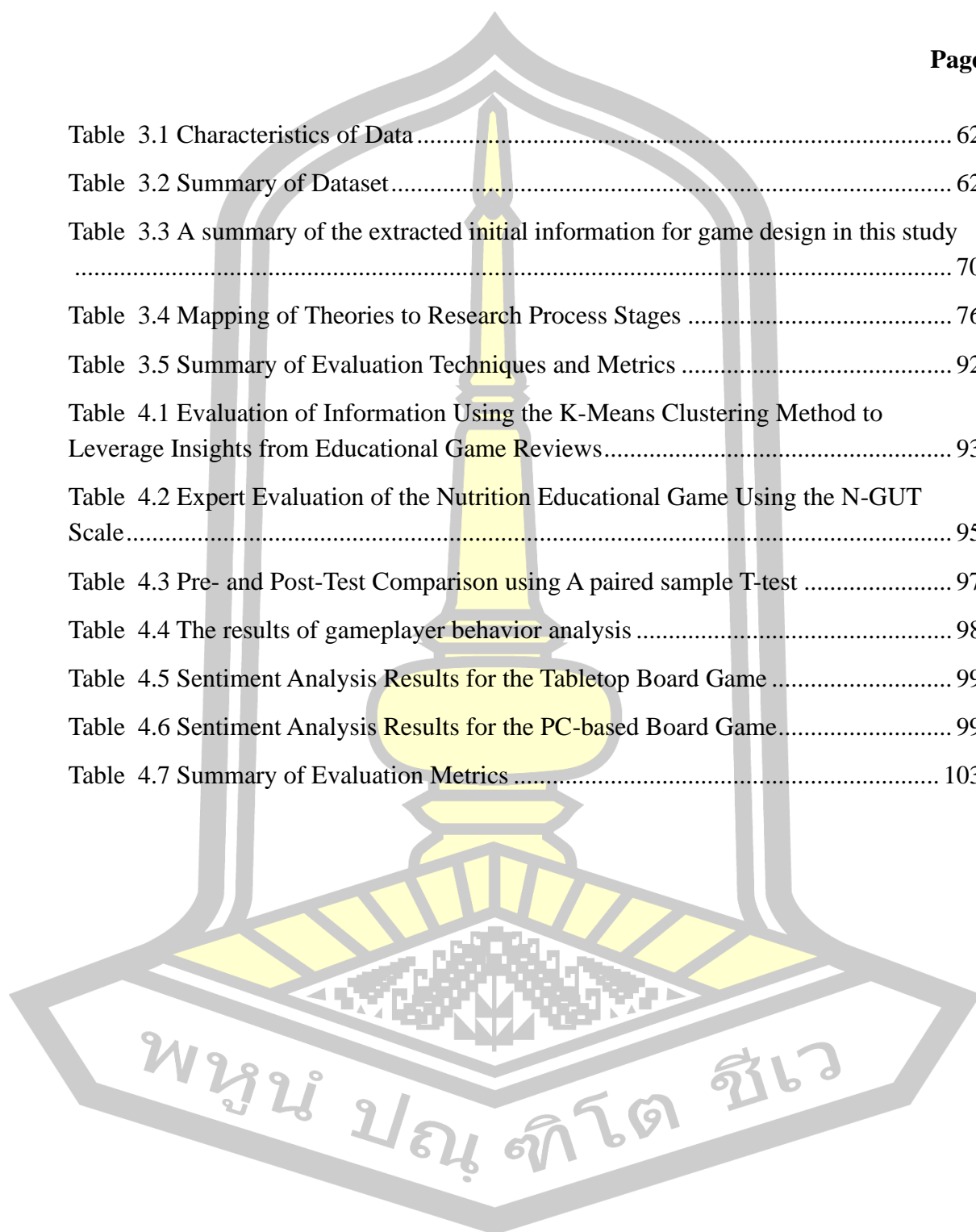
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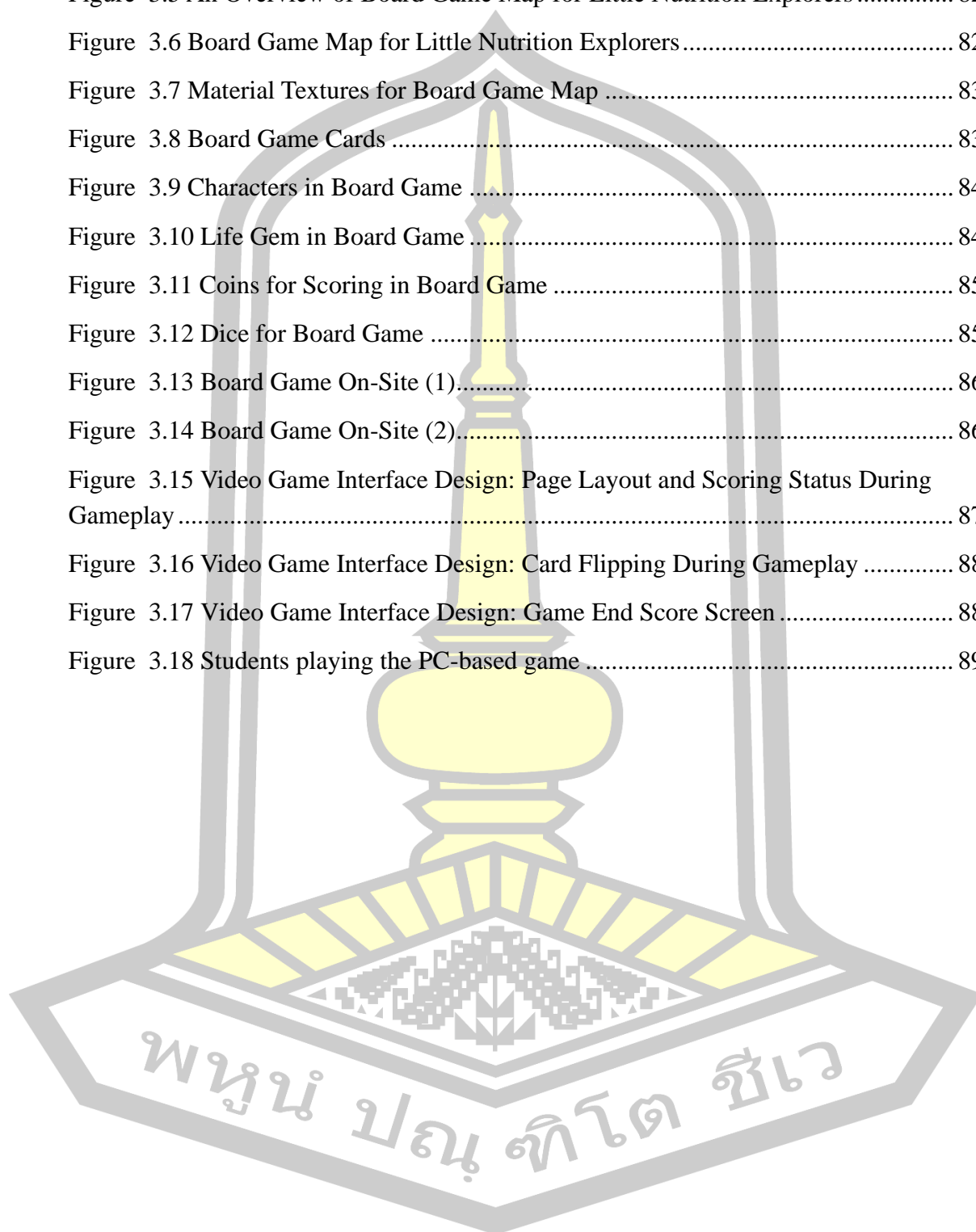
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CHAPTER I

INTRODUCTION

1.1 Background

Promoting healthy dietary choices is a significant challenge for educating younger students in their everyday lives. It is well-known that children's eating habits are frequently formed at an early age, so it is critical to encourage them to make healthful choices that will help their physical and mental health [1]. Unfortunately, teaching younger students in their everyday lives might be difficult [2]. Whether you are a parent, teacher, or caregiver, you may face a variety of challenges while attempting to educate and guide children. This is due to the fact that younger students have a variety of learning methods, such as visual, auditory, or kinesthetic. As a result, a parent, teacher, or caregiver must strive to use a variety of teaching strategies to accommodate these variances and effectively reach all pupils [3-4]. Furthermore, younger children may face emotional difficulties that interfere with their learning and they may have

shorter attention spans and may struggle to focus for lengthy periods of time. This may require emotional support and the creation of a secure environment for them to express their feelings. As a result, in order to sustain their attention, a parent, teacher, or caregiver may need to make learning exercises brief, interactive, and interesting, where it should be remembered that encouraging healthy eating choices is a continuous process that necessitates the involvement of a child caregiver (e.g., a parent or teacher), consistency, and a supportive environment.

To the best of our knowledge, educational games have demonstrated a high level of efficacy in facilitating the learning process and enhancing knowledge retention among younger students [5-10]. When appropriately created, these games effectively engage children in dynamic and pleasurable learning experiences, hence enhancing the effectiveness and impact of the learning process. Today, game-based learning is the integration of game attributes and principles into educational endeavors. Learning activities serve as catalysts for student involvement and foster a sense of passion towards the learning process [5-10]. Game-based learning encompasses several components such as points systems, badges, leaderboards,

discussion boards, quizzes, and classroom response systems [5, 7-8]. Academic rewards, such as the provision of an additional week to complete an assignment upon achieving a specific point level, may be associated with the accumulation of points [5-10]. Nevertheless, it is important to strategically include educational games into the curriculum, ensuring that they are in line with the learning objectives and effectively supplement conventional teaching approaches [9-10]. When included into a comprehensive educational framework, these games have the potential to augment the educational experience for younger learners, rendering it more pleasurable, efficacious, and triumphant [5-6].

As mentioned above, it is possible that utilizing educational games as a tool of promoting practical learning relevant to a healthy diet might prove to be a highly effective approach for younger students [6]. Educational games have the potential to enhance the learning experience by fostering engagement, interactivity, and enjoyment, hence facilitating improved knowledge retention among youngsters. However, it is noted that when developing educational games, it is important to consider the age and developmental stage of the students, guarantee the accuracy and evidence-based nature of the information, and establish a learning atmosphere that is conducive to positivity and support [11-13]. Integrating experiential learning with enjoyable and interactive components, such as games, can prove to be an efficacious strategy in captivating young learners and fostering enduring dietary practices. As a result, this becomes a challenge in this study, which attempts to propose an interactive educational game for increasing learning about healthy eating for younger students.

1.2 Research Question

Can an interactive educational game effectively guide young students towards healthy eating behaviors and habits while also instilling scientific and healthy eating concepts and ultimately reducing obesity and other unhealthy eating issues?

1.3 Research Objective

Utilizing an interactive educational game as a tool for students to acquire and comprehend good eating behaviors and habits is a different and creative method for nutrition learning.

1.4 Research Scope

1.5.1 This study aims to design and develop an interactive educational game as a tool of facilitating interactive learning relevant to healthy dietary habits for elementary school students.

1.5.2 Three datasets are utilized.

(1) Firstly, the dataset on healthy diet comes from the China Nutrition and Health Survey (CHNS).

(2) Secondly, this dataset compiles and extracts relevant information about the development of educational games from reliable websites. The information is utilized to develop an interactive educational game that efficiently learns elementary school students about good food habits.

(3) Thirdly, the study's population consists of Grade 2 students who are currently enrolled in Huanhu Primary School, located in Chancheng District, Foshan City, Guangdong Province. Nevertheless, a total of 46 students from Class 5 at the Grade 2 level have been chosen as the sample for this study. This samples are used to evaluate the proposed game.

1.5.3 To develop an interactive educational game, multiple theories are applied:

(1) Game-based user-centered design (UCD) [14-15] – This game is an approach that integrates principles of game design and user-centered design to create engaging and effective user experiences in interactive systems, applications, or products. It focuses on designing experiences that are not only user-friendly but also enjoyable and motivating, taking inspiration from the elements that make games compelling.

(2) Educational game theory [16] - The area of “educational game design,” which is also known as “game design for learning,” incorporates ideas from both education and game design to produce fun and useful learning experiences in games. It makes use of the interactive and motivating features of games to improve learning outcomes and include students in a more dynamic and immersive learning experience.

(3) Interactive learning theory [17] - The focus of interactive learning theory is on students' active participation in the learning process through meaningful interactions with the course materials, their peers, their teachers, and their

surroundings. The foundation of this theory is the notion that students build knowledge and comprehension by active participation in tasks, conversations, and experiences. Classrooms, online courses, and digital platforms are just a few of the educational situations where interactive learning theory is applicable.

(4) Gamification elements theory [18] - The philosophy of gamification aspects pertains to the utilization of game design principles and mechanics in contexts that are not inherently game-related, such as education, business, marketing, and various other domains. The objective is to augment engagement, motivation, and behavior. The approach utilizes the inherent incentive elements of games in order to promote desired behaviors and outcomes.

1.5.4 In the evaluation stage, we attempt five aspects: evaluation of information using the k-means clustering method to leverage insights from educational game reviews, expert evaluation of the nutrition educational game using the N-GUT scale, effectiveness of the educational game on health knowledge: pre- and post-test comparison, analysis of gameplay behaviors, and sentiment analysis for educational game.

1.5 Research Significance

The development and implementation of an educational interactive game focused on teaching healthy dietary habits to younger students hold significant research value for several key reasons. This initiative aligns with broader public health goals of combating childhood obesity, promoting lifelong healthy eating habits, and integrating technology into education in meaningful ways. Also, the research significance of developing an educational interactive game for learning healthy dietary habits in younger students extends beyond immediate learning outcomes. It encompasses broader implications for public health, educational practices, behavioral science, technology integration, and policy formulation. By systematically investigating these aspects, researchers can contribute to a multidisciplinary understanding of how best to leverage technology for health promotion and education in the digital age.

1.6 Terminologies

1. Educational Interactive Game: Creating an educational interactive game designed to teach younger students about healthy dietary habits involves integrating key nutritional concepts with engaging gameplay elements. The game should be developmentally appropriate, focusing on making learning about nutrition fun and interactive. Therefore, this proposed game aims to make learning about nutrition engaging and impactful for younger students. By integrating educational content into a compelling game environment, it seeks to foster lifelong healthy eating habits. This approach not only educates but also empowers students to make informed food choices, contributing to their overall well-being.

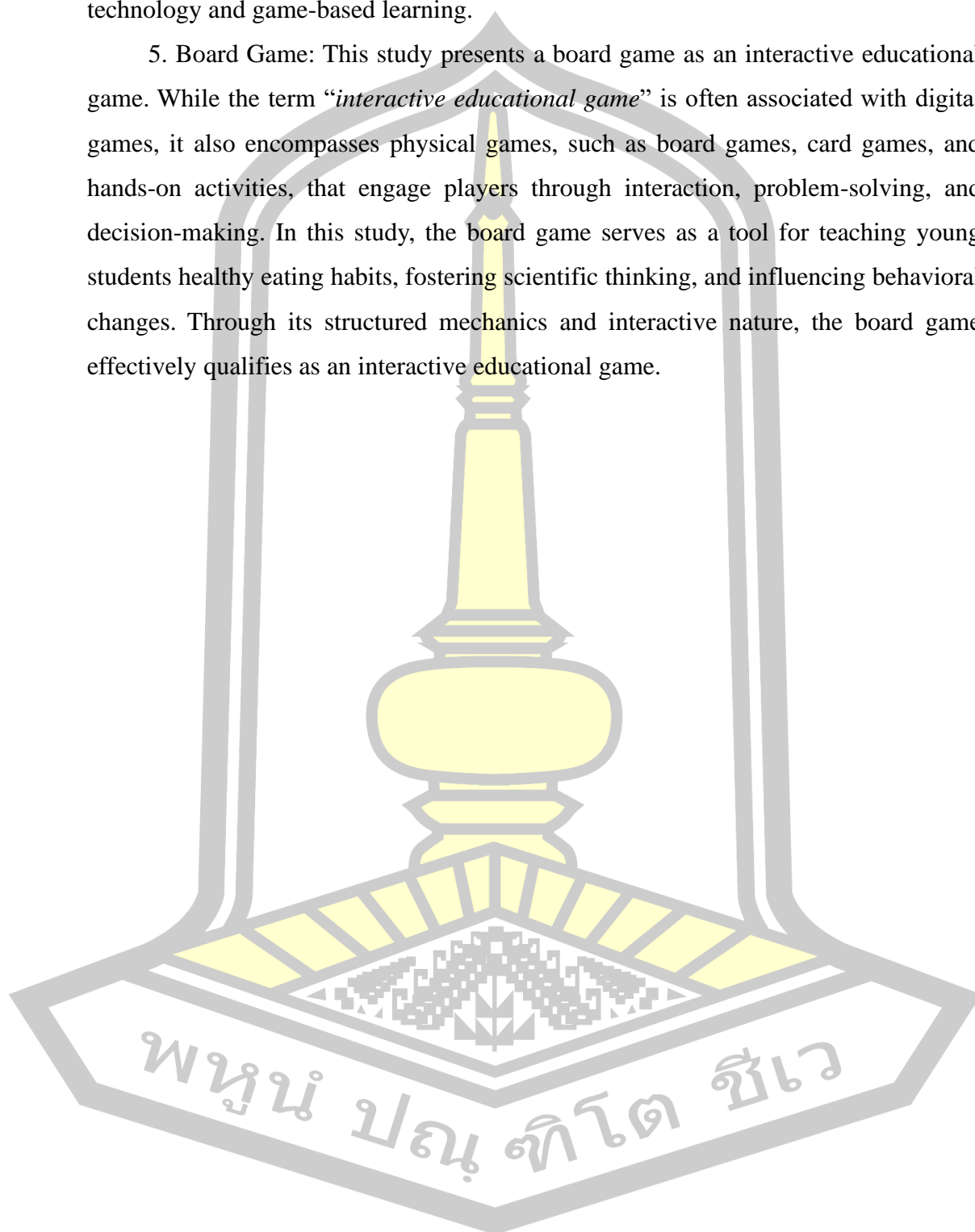
2. Game-Based Learning: In this study, it is to implement GBL to promote healthy dietary habits among elementary school students is a strategic approach that combines the engaging power of games with essential health education. This game can significantly enhance students' understanding and adoption of healthy eating behaviors in a fun and interactive manner.3. Imbalanced data: This is a common challenge in multilabel classification, where some labels appear very frequently in the dataset while others are rare, including classifying bug reports into multiple labels (or classes). This imbalance can lead to models that are biased towards the more frequent labels, often at the expense of performance on the less frequent ones.

3. Healthy Diet for Younger Students: A healthy diet for young students should be balanced, diverse, and enjoyable, incorporating a variety of nutrients necessary for growth, development, and energy.

4. Design-Based Research (DBR): DBR is a methodology aimed at improving educational practices through iterative analysis, design, development, and implementation of innovative strategies, often within real-world settings. When applied to the development of educational interactive games, DBR offers a systematic approach to creating effective, engaging, and scientifically grounded educational experiences. Also, applying DBR to the creation of educational interactive games ensures that the design is grounded in real-world educational needs and challenges, iteratively refined based on empirical evidence, and evaluated for its impact on learning outcomes. This approach not only enhances the quality and effectiveness of

educational games but also contributes valuable insights to the field of educational technology and game-based learning.

5. Board Game: This study presents a board game as an interactive educational game. While the term “*interactive educational game*” is often associated with digital games, it also encompasses physical games, such as board games, card games, and hands-on activities, that engage players through interaction, problem-solving, and decision-making. In this study, the board game serves as a tool for teaching young students healthy eating habits, fostering scientific thinking, and influencing behavioral changes. Through its structured mechanics and interactive nature, the board game effectively qualifies as an interactive educational game.



CHAPTER II

LITERATURE REVIEW

2.1 Overview of the Obesity Epidemic

2.1.1 Definition of Adipose

As the disease spreads throughout the world, America's obesity pandemic has become a worldwide health issue. The World Health Organization has claimed that around 1.6 billion individuals are overweight or obese [19]. The primary cause of the global obesity pandemic is a Western-influenced society that promotes excessive caloric consumption while discouraging physical exercise [20]. Americans' lifestyles, including technological advancements and the food business, have resulted in decreased physical activity and increased intake of high-calorie, nutrient-poor meals [21].

Overweight and obesity are characterized according to body mass index (BMI), which is calculated by dividing a person's weight in kilograms by their height in meters squared. This is the most widely used measure of obesity. It is often used to describe obesity throughout infancy and adulthood. Body mass index (BMI) is a body fat measurement based on a person's height to weight ratio. The following BMI categories were established: underweight (BMI < 18.5), normal weight (BMI 18.5-24.9), overweight (BMI 25-29.9), and obese (BMI > 30.). Obesity is classified into three categories: Class I (BMI > 30. ~ 34.9), Class II (BMI 35. ~ 39.9), and Class III (BMI > 40). These categories can be used to assess health-related illness risk [22].

2.1.2 Childhood Obesity

The prevalence of overweight in children is rising at an alarming rate in the United States. The prevalence of obesity has increased, according to data from NHANES surveys conducted between 1976 and 1980 and 2003 and 2006: the prevalence increased from 6.5% to 17.% among those aged 6 to 11 years; and from 5.% to 17.6% among those aged 12 to 19 years [23]. The incidence of obesity among children aged 6 to 11 years has increased by twofold, while it has tripled among adolescents aged 12 to 19 years [24].

The detrimental health effects of obesity are both immediate and long-lasting, and they can persist into maturity [25]. Around 60% of obese adolescents between the ages of 5 and 10 have at least one risk factor for cardiovascular disease, including elevated levels of triglycerides, insulin, total cholesterol, or blood pressure. A prevalence of two or more of these risk factors in 25% of the children has been reported [26]. A number of weight-related disorders that were previously prevalent in adults are now being identified more frequently in adolescents [27]. The risk factors for cardiovascular disease and type 2 diabetes are encompassed within these conditions.

Children and adolescents who are overweight are more likely to develop into overweight or obese adults [24]. If childhood obesity remains, this generation will be the first to have a lower life expectancy than their parents [28]. Obese and overweight kids may experience psychological costs such as self-blame, shame, and low self-esteem, all of these can hinder and degrade scholastic and social progress [29].

Overweight often leads to diabetes. Type 2 diabetes is increasingly spreading among children and adolescents. According to estimates from 2000, 30% of boys and 40% of girls born in the United States are at risk of developing type 2 diabetes at some time in their life. The future expense of weight-related health care might be enormous and a significant burden [21].

2.1.3 Current Overweight Situation in China

Analysis of overweight and obesity trends in adult males and females in China between 2000 and 2018. Children under 6 years old had an overweight and obesity incidence of 10.4%, while teenagers between 6-17 years old had a rate of 19%. Among residents aged 18 and above, the prevalence of overweight was 34.3% and obesity was 16.4%. Over half (50.7%) of adult inhabitants are overweight or obese. From 2000 to 2018, there was a noticeable rise in rates of obesity among adults. Quicker than the rise in rates of weight gain. Weight gain rates have risen significantly in rural areas compared to metropolitan areas.

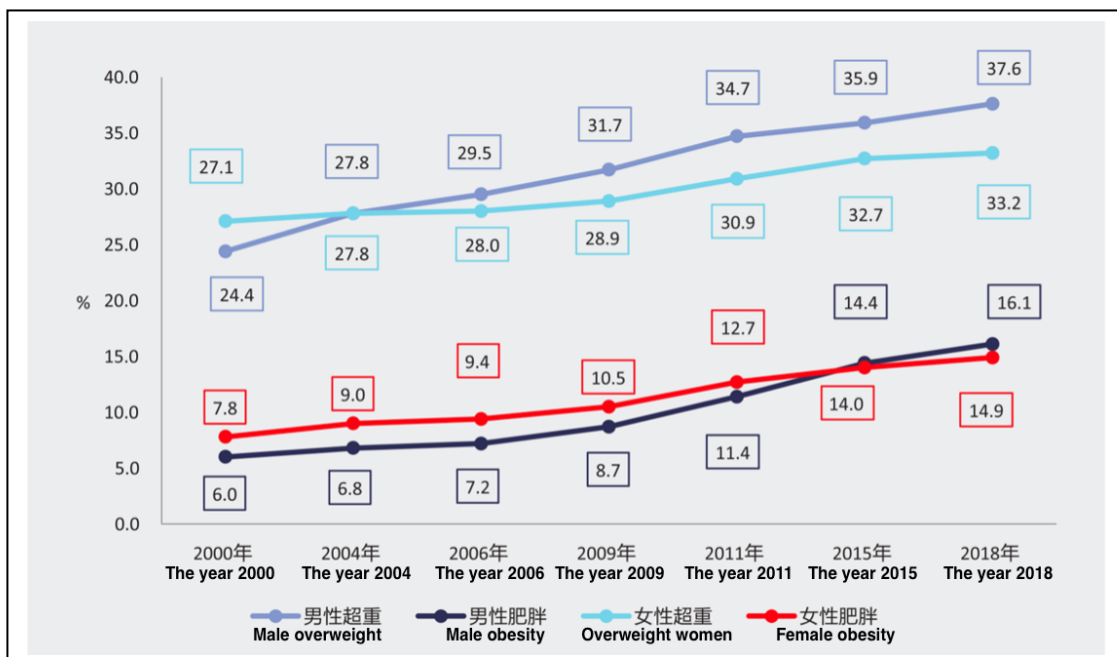


Figure 2.1 Changes in the prevalence of overweight and obesity among adult males and females in China from 2000 to 2018

From: <https://www.cpc.unc.edu/projects/china>

As to the 2020 Report on Nutrition and Chronic Diseases among Chinese Residents, individuals must be 18 years old. In adults, the incidence of hypertension was 27.5% and diabetes was 11.9%. Cholesterol had a prevalence of 8.2% [30].

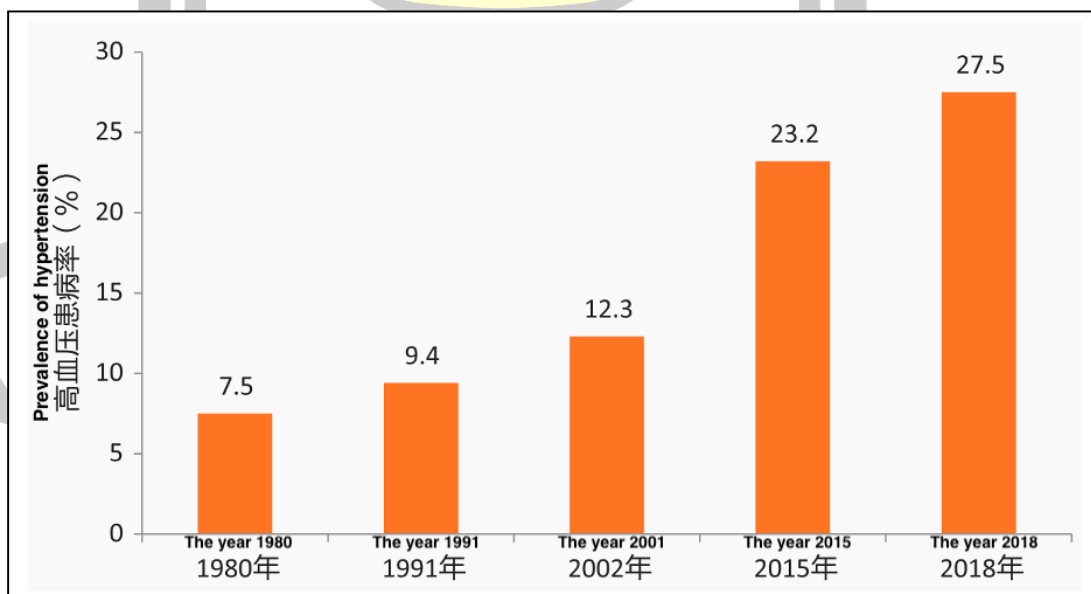


Figure 2.2 Prevalence of Hypertension in the Chinese people

From: <https://www.cpc.unc.edu/projects/china>

Prevalence adjusted for age differences in the population. In each study, the diagnostic criteria for hypertension were $SBP \geq 141 \text{ mmHg}$ and/or $DBP \geq 91 \text{ mmHg}$ in 1979-1980, without considering treatment within two weeks. In 1991, 2002, 2015, and 2018, individuals with systolic blood pressure (SBP) equal to or more than 140mmHg and/or diastolic blood pressure (DBP) equal to or greater than 90mmHg were included. Survey population: Individuals aged 15 years and older in 1980, 1991, and 2002, and individuals aged 18 years and older in 2015 and 2018. Prevalence rates in 1980, 1991, and 2002 were reported in the “2002 Comprehensive Report of one of the Survey Reports on Nutrition and Health Status of Chinese Residents.” The prevalence rate in 2015 was reported by Wang et al. [31] Analysis of hypertension prevalence in China based on the China Hypertension Survey conducted from 2012 to 2015.

The “China Cardiovascular Health and Disease Report 2019” [32] pertains to individuals in China who are 15 years of age and older. Coronary heart disease was found in 10.2% of the whole population and in 27.8% of individuals aged 60 and older. There was a considerable rise in the prevalence of dyslipidemia among inhabitants aged 18 years and older, rising from 18.6% in 2002 to 40.4% in 2012. In 2013, the prevalence of stroke in those aged 40 and above was 2.1%, along with diabetes, hypertension, and cardiovascular and cerebrovascular diseases. Incidence of chronic disorders like vascular diseases is increasing. Chronic disorders are linked to prolonged nutritional imbalance and excessive consumption of oil and salt. (National Center for Cardiovascular Diseases, 2019).

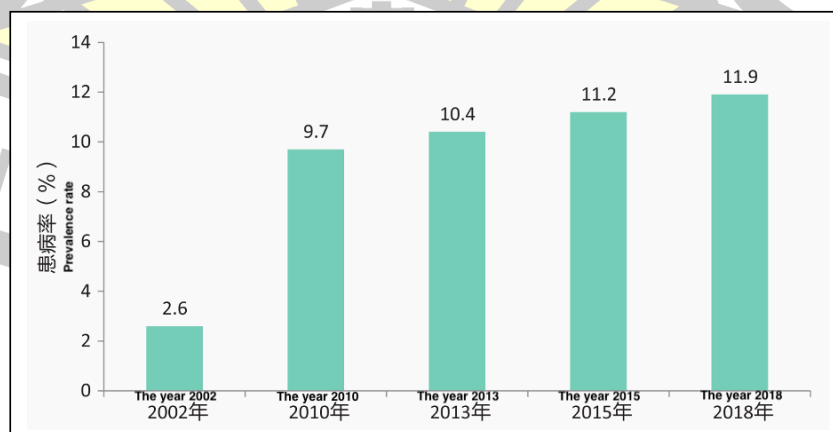


Figure 2.3 Prevalence of diabetes in adults aged 18 years and above in China
From: <https://www.cpc.unc.edu/projects/china>

Prevalence rates in 2010 and 2013 were reported in the China Chronic Diseases and Risk Factors Monitoring Report. Prevalence rate in 2015, National cross-sectional survey conducted by the Diabetes Association [33-34].

2.1.4 The Causes of Obesity

Obesity or overweight is caused by a variety of reasons, including decreased energy expenditure, increased energy intake, and increased consumption of processed foods that are high in calories but low in nutrients [24]. Without a deeper knowledge of these reasons, researchers struggle to build effective obesity-fighting treatments.

Another important reason of obesity might be the estimated 10-15% increase in calorie consumption since the 1980s [35]. In 2002, Putnum et al [36] observed that calorie intake rose by roughly 12% between 1985 and 2000, mostly owing to increasing consumption of cereals, added fats, and added sugars. According to the CDC, calorie consumption was steady from 1971 to 1980, but grew by 7.3% for males and 23.3% for women between that time and 2000 [37]. Carbohydrates, particularly simple sugars found in soft drinks, fruit juices, and white flour, account for the majority of the increase in energy consumption. In 1997, the average American consumed 53 gallons of soft drinks and 17 gallons of juice or other high-calorie beverages, a 51% and 40% increase, respectively, over 1980 [38]. The rise in energy was ascribed to an increase in snacking. While there is significant diversity in research on snacking patterns, many studies indicate that greater snacking leads to higher calorie consumption. Cutler et al. [39] discovered that increases in snack calories were responsible for the total increase in women's energy consumption over the 1970s and 1990s, but snack calories accounted for 90% of the increase in men's energy intake. The Chinese health survey data indicates that this issue is growing increasingly serious in our nation [40].

Preferences of children for foods that are high in fat, sodium, and/or sugar, as opposed to fruits and vegetables, which are healthier alternatives, impede the effectiveness of interventions aimed at improving the nutritional status of children. Due to the fact that children's food preferences are frequently influenced by hedonic factors such as flavor rather than health and nutrition, educational approaches are unlikely to be effective on their own.

2.1.5 The Main Risk Factors for Chronic Illnesses

The prevalence of high oil and sodium ingestion persists, while the consumption of sugar-sweetened beverages continues to increase annually. As per the findings of the 2015 survey, the mean daily consumption of culinary salt per individual in households was 9.3g, indicating a progressive reduction over time. The average daily consumption of cooking salt decreased by 4.6g/d since 1992, with an average reduction of 2g/d every 10 years. Despite this decline, the average daily consumption of cooking salt remained above the threshold of less than 6g advocated by the Chinese Nutrition Society [40].

There is continued prevalence of high oil and sodium ingestion, and the consumption of sugar-sweetened beverages is increasing annually. The 2015 survey found that the mean daily salt consumption for household cooking was 9.3g per individual. This figure indicates a consistent decline over time, which can be attributed to the successful implementation of the national healthy lifestyle action and nutrition publicity and education initiatives. The per capita culinary salt decreased by 4.6g/d since 1992, with a ten-year average decline of 2g/d. Despite a decline in the mean consumption of culinary salt, it remained in excess of the threshold advocated by the Chinese Nutrition Society. The consumption of culinary oil remains substantial, with a particularly pronounced increase observed among individuals residing in rural areas [41].

Eating out is a prevalent practice, especially among the youth. The investigation revealed that the most commonly bought dishes include mostly of fried food and animal-based foods. Individuals who frequently sell or consume meals outside tend to have high intake of oil and salt, as well as an imbalanced nutritional pattern.

Sales of sugar-sweetened drinks have been rising annually, and 42.1% of the urban population's free sugar consumption is from sugar-sweetened beverages and milk beverages. Children and adolescents consume sugar-sweetened milk drinks and beverages at a rate above 30% and 25%, respectively, which is notably higher than the consumption rate among adults. Currently, the average sugar intake among Chinese residents is not high, with only 1.9% of people having an energy supply ratio exceeding 10%. However, children and adolescents consume more sugary drinks than

adults, and the sugar supply to energy ratio for children aged 3 to 5 is as high as 4.8%, warranting significant attention [42].

Insufficient dietary intake of whole grains, dark leafy vegetables, fruits, dairy products, fish, shrimp, and legumes. Chinese residents mostly consume refined rice noodles as their major source of grains, lacking enough consumption of whole grains and cereals. Approximately 20% of persons may consume above 50g per day. The predominant crops are millet and corn, which should be more plentiful. Light vegetables make up the majority of the vegetable kinds, with dark vegetables comprising around 30% of the total, falling short of the desired threshold of over 50%. The per capita fruit intake is low, with urban people consuming just 55.7g/day [43]. There is a significant disparity between dietary needs and actual consumption. Chinese citizens have a low average consumption of milk and its products across all age categories. Children and adolescents consume more milk than adults, but overall consumption is below the recommended levels. The primary cause of inadequate calcium intake among Chinese inhabitants is a lack of milk consumption. The mean consumption of fish and shrimp is 24.3g per day, showing no substantial rise over time. Additionally, less than one-third of adults manage to consume above 40g of fish and shrimp daily on average. Soybean food is a traditional and healthful cuisine in China, but the current consumption rate is low. Approximately 40% of individuals do not regularly consume soybean products [44].

Insufficient dietary intake of grains, whole grains, dark vegetables, fruits, dairy products, fish and crustaceans, and seafood [43]. The proportion of cardiovascular metabolic disease-related fatalities among Chinese citizens attributable to adverse dietary factors is depicted in Figure 2.4.

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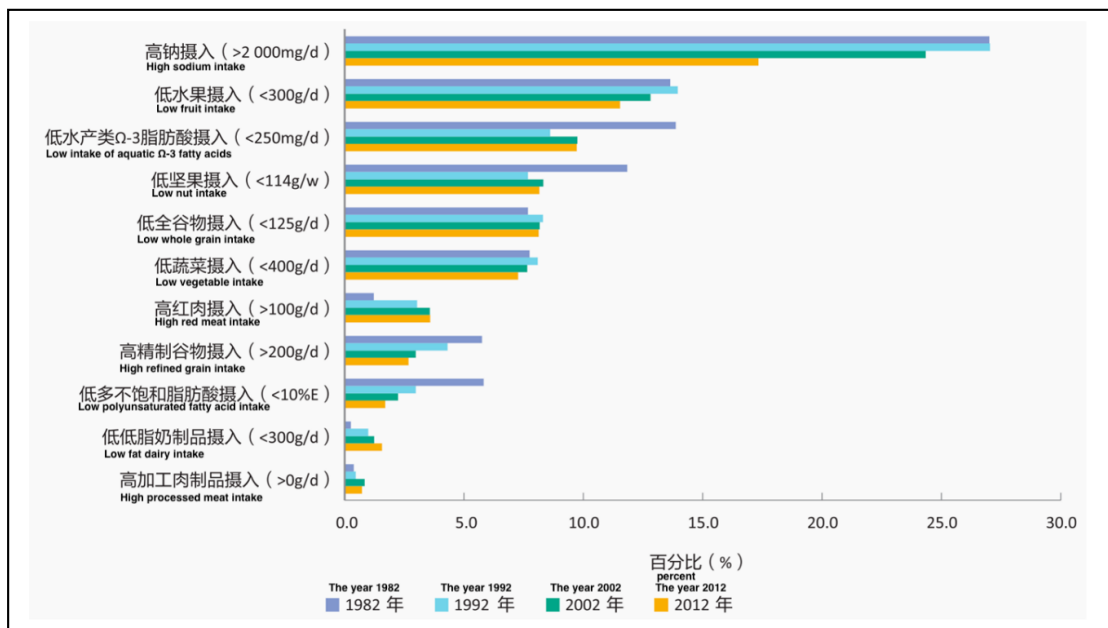


Figure 2.4 Percentage of cardiovascular metabolic disease-related fatalities among Chinese citizens attributable to adverse dietary factors
From: <https://www.cpc.unc.edu/projects/china>

Yuna He, et al. [45] conducted a cross-sectional population-based investigation on the dietary change and its connection to cardiometabolic mortality among Chinese people from 1982 to 2012.

To address the obesity pandemic, a comprehensive and sustained strategy is needed to engage young individuals in their living, educational, and recreational environments. Schools may significantly contribute to reversing the obesity trend. Schools may play a crucial role in collaborating with public, volunteer, and private sector groups to reshape social and physical surroundings. They can provide students with knowledge, resources, and practical tactics to support them. Embrace healthy habits.

พหุบัณฑิต ชีวะ

2.1.6 The Nutrition Problems in Chinese Children

Chinese children's nutrition issues have changed dramatically in recent decades due to larger socioeconomic developments and public health difficulties. An in-depth analysis of child nutrition in China from 1985 to 2015 reveals significant patterns and challenges.

Stunting and Underweight Decline [45]: The prevalence of stunting and underweight among Chinese children has significantly decreased. The prevalence of stunting reduced significantly from 12.21% to 0.97% for children under 5 years and from 12.69% to 0.42% for children aged 5 to less than 7 between 1985 and 2015. The prevalence of underweight fell dramatically throughout the same period.

Socioeconomic Factors [46]: The study gathered socioeconomic data, including GDP per capita and infant mortality rate (IMR), and identified significant relationships between these characteristics and nutritional status markers like height Z-scores. Improved nutritional outcomes were linked to higher GDP per capita and reduced infant mortality rate, demonstrating the influence of wider socioeconomic factors on child health.

Nutritional Transition [47]: There is a dual challenge of undernutrition and overnutrition, representing a worldwide pattern where societies experience both insufficient food intake and a rising occurrence of overweight and obesity. In China, fast economic expansion and urbanization have caused considerable nutritional changes. The shift from traditional diets to more processed meals impacts children's health by leading to undernutrition in certain groups and increasing rates of obesity in others.

These trends indicate substantial advancement in combating undernutrition in Chinese children, perhaps attributed to enhanced socioeconomic situations, public health campaigns, and heightened understanding of dietary requirements. The increasing issue of overnutrition and obesity, associated with shifting dietary habits and lifestyles, presents a complicated nutritional situation that demands sophisticated, comprehensive public health approaches. To tackle these difficulties, it is essential to consistently monitor eating patterns, socioeconomic conditions, and enforce rules that encourage balanced nutrition and promote healthy habits in children.

2.1.7 The Healthy Diet Problem for Elementary School Students in China

The dietary challenge faced by elementary school pupils in China is a component of a larger issue concerning the encouragement of good eating behaviors in children. A comprehensive review and meta-analysis concentrated on instructional methods and tactics that promote healthy eating habits in elementary school students [48].

The healthy diet problem for elementary school students in China can be attributed to rapid socioeconomic changes, urbanization, and shifts in dietary patterns. These changes have led to an increased consumption of processed foods and a decrease in traditional, nutrient-rich diets. Additionally, a lack of nutritional education and awareness among children and their families contributes to the issue, making it challenging to maintain healthy eating habits amidst the availability of convenient, less nutritious food options.

The main points leading to the healthy diet problem for elementary school students in China include rapid urbanization, changes in family structure and lifestyle, increased availability of processed foods, a decline in traditional dietary practices, and insufficient nutritional education. These factors contribute to imbalances in diet, such as high consumption of fats and sugars and low intake of fruits and vegetables, leading to issues like obesity and undernutrition [49].

2.2 Related Theorems

2.2.1 Game-based User-Centered Design (Game-based UCD)

Game-based User-Centered Design (UCD) [50] is an approach that prioritizes the needs, preferences, and limitations of the end-users at every stage of the game design and development process. This methodology involves iterative cycles of designing, testing, and refining game features based on user feedback to create engaging and effective educational games. It emphasizes understanding the user's experience, incorporating their feedback directly into the design to ensure the game is not only educational but also enjoyable and accessible to the target audience. Figure 2.5 presents an overview of UCD.

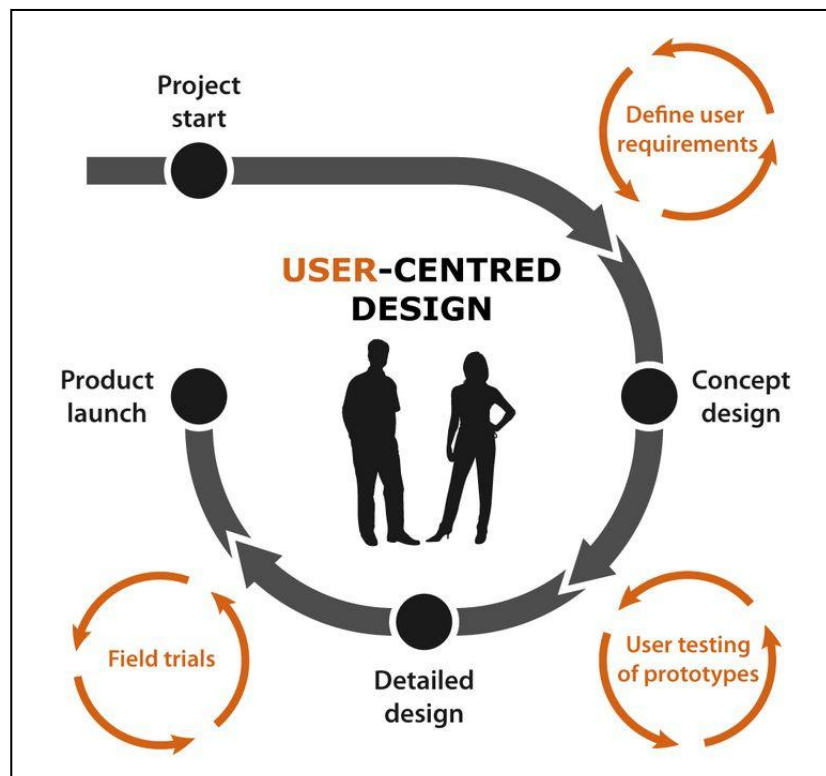


Figure 2.5 An Overview of User-Centered Design (UCD)
 From: <https://id.pinterest.com/pin/142918988154992777/>

To create a game-based UCD, it should be started by researching and defining the target users and their needs. The game is designed with a focus on users by creating prototypes, involving them in testing to receive input, and consistently enhancing the game based on user feedback to improve usability, engagement, and educational value. This method tailors the game to align with the specific interests and educational objectives of its intended audience, hence improving its efficacy as an educational tool. In general, developing a game-based UCD involves a systematic approach [51]:

1. Understanding Problem: This is essential for understanding the educational goals of the game, as well as the requirements and preferences of the target audience.
2. Defining Requirements: Based on research, this is to establish the learning outcomes, user requirements, and objectives of the game.

3. Design and Prototyping: During this stage, prototypes and preliminary game designs are created. In addition, feedback is incorporated in order to enhance the game during this iterative stage.

4. User Testing: This step involves doing usability testing with your target audience to gain input on the game's design and instructional content.

5. Iteration: This step involves refining the game based on user feedback, so boosting usability, engagement, and instructional efficacy.

6. Final Testing and Launch: This step involves running final testing, making any improvements, and ultimately launching the game. Continue collecting user input for future upgrades.

2.2.2 Educational Game Theory

Educational Game Theory [52] explores the intersection of gaming elements and educational practices to create engaging learning experiences. It examines how game mechanics, such as rewards, challenges, and interactivity, can be utilized to enhance motivation, engagement, and knowledge retention in educational settings. The theory aims to understand how games can be designed to achieve specific learning outcomes, making the learning process enjoyable and effective.

Significant concepts in Educational Game Theory include motivation (how games stimulate interest and engagement), feedback (immediate responses to user actions promoting learning), scaffolding (providing support to reach higher levels of understanding), flow (the state of being completely engaged and absorbed in a game), and failure (using mistakes as learning opportunities). These concepts underline how educational games can effectively enhance learning by making it interactive, rewarding, and adaptable to the learner's pace and style. Developing an educational game involves several key steps [53] and a framework of developing an educational game can be shown as Figure 2.6.

1. Identify Learning Objectives: This stage is to precisely outline the educational objectives of the game.

2. Understand Audience: A game developer should be knowledgeable about the age, interests, and learning requirements of their target players.

3. Design Game Mechanics: In this stage, it is to select gaming components that are in line with educational objectives throughout this level.

4. Create Content: This stage is to develop game content that is educational, engaging, and relevant.

5. Prototype and Test: This stage consists of creating a prototype, testing it, and gathering feedback.

6. Iterate Based on Feedback: This step involves refining the game based on test results.

7. Finalize and Launch: This step involves completing development and releasing the game.

8. Evaluate and Update: This step involves evaluating the game's impact and making any required modifications.

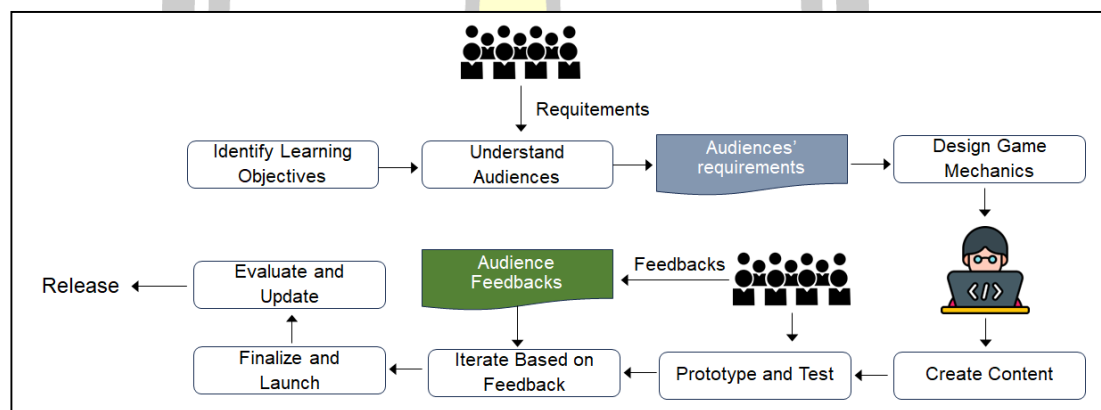


Figure 2.6 A framework of developing an educational game

2.2.3 Interactive Learning Theory

Interactive learning theory [54] is an educational strategy that stresses students' active engagement and participation in the learning process. According to this approach, learners build knowledge through interactions with their surroundings, which include other students, teachers, materials, and tasks. Interactive learning theory is based on the premise that learning is most effective when students actively participate in making meaning of knowledge rather than passively absorbing it. The key principles of interactive learning theory are:

1. Active engagement: Learners engage in the learning process through activities like debates, problem-solving, experiments, and projects.

2. Collaboration: Learners often work together in groups to address challenges, exchange ideas, and gain knowledge from one another.

3. Feedback: It is crucial for students to have regular feedback from teachers, classmates, or self-evaluation in order to track their development and modify their learning approaches.

4. Constructivism: Interactive learning theory is strongly connected to constructivist learning theories, which suggest that learners develop their understanding of topics by actively drawing on their existing knowledge and experiences.

5. Authentic tasks: Learning activities are intended to be meaningful and applicable to learners' lives, frequently replicating real-world circumstances or issues.

6. Reflection: Learners are encouraged to reflect on their learning experiences, examine other views, and relate new knowledge to their previous understanding.

Traditional classrooms, online courses, workshops, and experiential learning environments are all examples of situations where interactive learning can occur. Technology, including as interactive multimedia resources, online forums, and collaborative tools, are frequently used to facilitate learner communication and participation. In summary, the theory of interactive learning acknowledges that active participation, collaboration, and introspection are crucial for fostering profound comprehension and enduring retention of information and abilities.

2.2.3 Gamification Elements Theory

Gamification elements [55] are the building blocks or components used to design and deploy gamified experiences. Gamification is the process of introducing game-like themes and mechanisms to non-game environments in order to engage and encourage users. These features combine game design and psychology principles to produce engaging and immersive experiences that encourage specific behaviors or outcomes. While exact aspects may differ based on the context and objectives of the gamified system, common gamification elements include:

1. Leaderboards [56]: Leaderboards show users' performance rankings relative to one another. They promote rivalry and social comparison, encouraging users to improve their performance in order to move up the ranks.

2. Levels [57]: Levels represent the various stages of progression in a gamified system. As users earn points or achievements, they may progress to higher levels, unlocking additional challenges, content, or privileges along the way.



Figure 2.7 Some Essential Elements in Gamification

From: <https://aristeksystems.com/blog/essential-elements-of-gamification-in-elearning/>

3. Challenges or Quests [58]: Challenges or quests are specific tasks or missions that users must complete within the gamified system. They provide clear objectives and goals for users to pursue, driving engagement and progression.

4. Points [59]: Points are the basic unit of measurement used to monitor progress and reward desired behaviors. They can be gained by performing tasks, meeting milestones, or exhibiting special abilities.

5. Badges [60]: Badges are visual symbols given to users to represent accomplishments, abilities, or achievements. They serve as a type of acknowledgment and might inspire users to strive for greater success.

6. Maps [61]: Maps are crucial in adventure games and can serve as powerful incentives for pupils on their learning journey. Maps can come in several formats. The journey from one end to another might be completed in a single line, with the progress

being shown on the bar as the player advances in the learning process. A thorough map illustrating the complete learning process for the learner from start to finish. Learners can efficiently understand their duties using a well-designed map system.

7. Certificates [62]: Certificates are similar to badges; except they are typically awarded at the completion of a course or module. Outside of learning platforms, certificates are frequently considered more valuable than badges. If used correctly, they can be a powerful motivator for pupils to complete their coursework.

8. Virtual currencies [63]: Virtual currencies are an important aspect in games, and they can be tailored to a player's learning style based on the type of learning being used. Students can use virtual currencies to gain additional benefits while learning.

9. Daily Check-in [64]: This gamification feature can help learners stay on track with their studies. Daily check-ins are effective when login information is displayed upon entering the learning platform. This element, together with badges and point systems, can help players become more interested in the learning process.

10. Avatars or Characters [65]: Avatars, or characters, represent users in the gamified environment. They can be changed by users and used for personal expression and identification.

11. Virtual Environments [66]: Virtual environments are the constructed settings of learning systems. Players are more interested in studying when the platform is gamer like and participatory. Establishing a virtual environment is optional. Utilizing a virtual environment would increase your chances of optimizing the gamification of your training procedure.

12. Collectibles [67]: Humans have an ability for accumulating various items of value, such as baseball cards, coupons, and other valuable objects. This can enhance the engagement of students in educational venues. Collectibles are sporadically dispersed among many platforms to motivate learners to acquire them. Corporate learners should strive to complete their course library.

13. Rewards: Rewards are rewards offered to users for completing tasks, meeting goals, or engaging in desired behaviors. Rewards might be virtual (points, badges) or physical (discounts, prizes).

14. Progress Bars: Progress bars graphically show a user's progress toward a goal or milestone. They give customers feedback on their progress and urge them to keep going till they reach their goal.

15. Narrative: Narrative elements provide context, storyline, and thematic elements to the gamified experience. A compelling narrative enhances immersion and emotional engagement, making the experience more enjoyable and memorable.

16. Feedback: Feedback mechanisms provide users with information about their performance, progress, and achievements. Timely and relevant feedback reinforces desired behaviors and helps users understand their strengths and areas for improvement.

These gamification elements can be blended and adjusted to meet the gamified system's aims and target audience, whether for education, training, marketing, or behavior change. Effective gamification design analyzes the balance and integration of these factors in order to provide users with interesting and inspiring experiences.

As above, the gamification elements theory [68] is a framework for analyzing and designing gamified experiences. Gamification is the use of game design ideas and mechanisms in non-game environments to engage and encourage people. The Gamification Elements Theory describes the numerous components that can be included into a gamified system to improve user engagement, motivation, and overall experience.

2.3 Interactive Educational Game

Interactive Educational Games (IEGs) [69] are physical or digital games that integrate interactive components with educational content in order to improve learning. These games have been carefully developed to teach or improve particular concepts or abilities via interactivity, thereby providing the player with an engaging and responsible learning experience. By requiring learners to actively engage in the learning process, the interactivity of these games facilitates a more individualized and influential educational encounter. Key features of interactive educational games can be:

1. Engagement: They use compelling narratives, challenges, and rewards to keep learners interested and motivated.

2. **Interactivity:** Players interact with the game environment, making choices, solving problems, and applying knowledge in various scenarios.

3. **Adaptive Learning:** Many such games adapt to the learner's level, offering personalized paths that adjust to their skills and knowledge, ensuring an appropriate challenge.

4. **Immediate Feedback:** Players receive instant feedback on their actions, helping them understand their mistakes and learn from them in real time.

5. **Multisensory Learning:** These games often incorporate visuals, text, audio, and sometimes touch, catering to different learning styles and making complex concepts more accessible.

6. **Goal-Oriented Design:** Games are structured around clear objectives, aligning with specific educational goals to guide learning outcomes.

Interactive educational games can be found across various platforms, including:

1. **Desktop and Laptop Computers:** This kind of IEGs is designed to be accessed via downloadable software or web-based applications.

2. **Tablets and Smartphones:** This kind of IEGs involves the use of mobile learning applications.

Some example of IEGs include:

Puzzle Games [70]: This game emphasizes problem-solving abilities through puzzles that have a definitive solution.

Simulation Games [71]: The game simulates real-world activities and vocations, imparting practical skills.

Adventure Games [72]: This game integrates narrative storytelling to encourage exploration and discovery, promoting critical thinking and comprehension.

Role-Playing Games (RPGs) [73]: For this game, players incorporate people in imaginary environments, gaining knowledge from the storyline and decisions made during the game.

Strategy Games [74]: This game requires tactical and strategic thinking, foresight in planning, and resource management to accomplish goals.

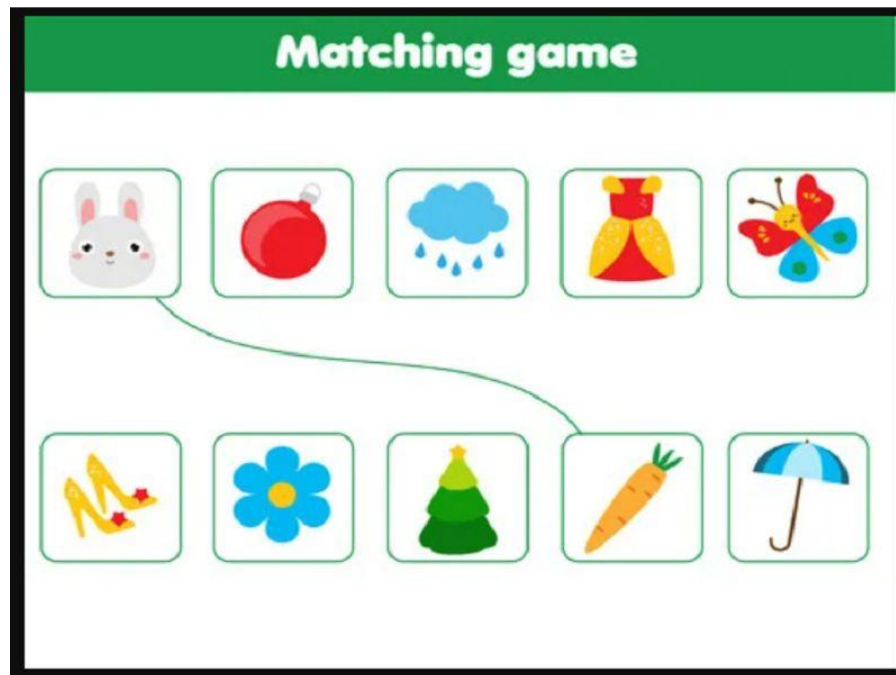


Figure 2.8 An Example of Puzzle Games
From: <https://studiousguy.com/puzzle-games-kids/>



Figure 2.9 An Example of Simulation Games
From: <https://www.digipen.edu/showcase/student-games/game-school-simulator-2015>



Figure 2.10 An Example of Adventure Games

From: <https://www.quora.com/What-are-some-good-adventure-games-for-kids>



Figure 2.11 An Example of Strategy Games

From: <https://rodneyorpheus.medium.com/magical-tabletop-games-for-kids-1cd227cac9fe>



Figure 2.12 A Board Game Example of Strategy Games

From: <https://mosaic-lille.fr/?o=board-game-types-explained-a-beginner-s-guide-to-rr-465oYOI9>

2.3.2 A Generic Framework of Educational Game Development

Developing educational games involves combining pedagogical principles with game design features to produce captivating and efficient learning experiences [75]. Here is a standard foundation for creating educational games [52].

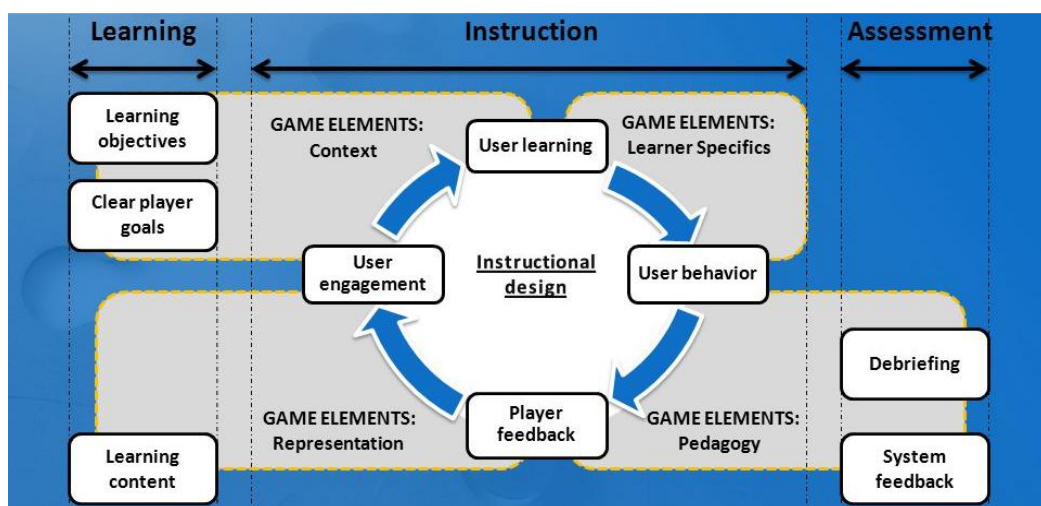


Figure 2.13 A Generic Framework of Educational Game Development

From: <https://slideplayer.com/slide/3124065/>

1. Needs Assessment and Learning Objectives - A game developer must first identify the target audience, their learning needs, and the educational objectives to be achieved through the game. Subsequently, a comprehensive needs assessment should be conducted to grasp the learners' preferences, existing knowledge, and potential obstacles they might face.

2. Curriculum Alignment - This stage of game creation aims to verify that the educational game complies with pertinent curricular requirements or learning objectives to offer significant educational benefits. Later, it should outline the particular concepts, skills, or subjects that the game will cover within the curricular framework.

3. Game Conceptualization – This stage is necessary to brainstorm and conceptualize the game idea, considering how it will effectively convey educational content while maintaining engagement, and then determine the game genre, mechanics, and overall design elements that best suit the learning objectives and target audience.

4. Pedagogical Design - This step involves integrating instructional tactics, learning theories, and pedagogical approaches into the game design. It comprises designing learning activities, challenges, and evaluations to encourage active learning, critical thinking, and skill development.

5. Prototyping and Iterative Design - This stage involves creating a prototype of the instructional game to test its practicality and usefulness. It also seeks feedback from players, subject matter experts, and potential users to improve the game mechanics, material presentation, and user experience through iterative design cycles.

6. Accessibility and Inclusivity - This stage involves ensuring that the game is accessible to a varied range of learners, including those with disabilities or special needs, as well as designing features and modifications to suit different learning styles, preferences, and levels of aptitude.

7. Technology Selection and Development - This stage involves selecting relevant technology platforms, tools, and development frameworks for producing the game. The process includes creating game mechanics, user interfaces, and interactive aspects utilizing computer languages, game engines, or authoring software.

8. Content Creation and Integration - This step involves creating instructional content, such as text, pictures, audio, and video assets, that aligns with the learning objectives and game mechanics. It also smoothly integrates instructional content into the gaming environment, ensuring that it is coherent and relevant to the gameplay experience.

9. Testing and Evaluation - This stage involves conducting extensive playtesting and usability testing to evaluate the game's functionality, usability, and instructional effectiveness. This strategy also assesses the game's impact on learning outcomes using formative and summative evaluation approaches such as pre-post examinations, questionnaires, and observational studies.

10. Deployment and Distribution - This stage involves preparing the game for deployment on the proper platforms, such as web browsers, mobile devices, or desktop computers. The game will be distributed to educational institutions, online learning platforms, and other means to reach its intended audience and maximize its instructional impact.

11. Maintenance and Updates - This stage involves providing continuous support, maintenance, and updates to address technological difficulties, improve features, and ensure the game's relevance and effectiveness in the long term. Feedback from users and stakeholders is required for future revisions and improvements to the game.

2.3.3 Computer Game vs. Board Game

Both computer games [91] and board games [92] serve as interactive entertainment and educational tools, but they differ significantly in format, mechanics, and user experience. Below is a detailed breakdown of their characteristics, advantages, and limitations.

2.3.3.1 Computer Games [93]

A computer game is a digital, interactive experience played on computers, consoles, mobile devices, or other digital platforms. It typically involves real-time processing, graphics, and often artificial intelligence to create dynamic gameplay.

Characteristics:

1) Digital Format – Played on electronic devices with graphics, sound, and animation.

2) Automated Rules – The system enforces game mechanics, eliminating the need for manual rule-following.

3) Single-player & Multiplayer – Can be played alone, with AI, or with other players online.

4) Adaptive Difficulty – Adjusts based on player performance, making challenges more dynamic.

5) Immersion & Engagement – Often features story-driven content, interactive simulations, and realistic environments.

2.3.3.2 Board Games [92]

A board game is a physical, tabletop game where players use cards, dice, game boards, and tokens to play based on a set of rules. It is often turn-based and relies on manual interaction rather than automated mechanics.

Characteristics:

1) Physical Components – Uses tangible items such as game pieces, boards, dice, and cards.

2) Turn-Based Play – Players take turns making decisions rather than reacting in real-time.

3) Manual Rule Enforcement – Players must track progress, enforce rules, and resolve conflicts themselves.

4) Face-to-Face Interaction – Played in physical settings, promoting social engagement.

5) Fixed Gameplay – Unlike digital games, mechanics do not change dynamically.

2.4.3 Educational Game Evaluation using Sentiment Analysis

Evaluating educational games using sentiment analysis [77] is an innovative approach that leverages the power of natural language processing (NLP) to understand and quantify the emotions and opinions expressed by players about the game.

By collecting comments from game players, we may examine the trend of players' sentiment towards the game using sentiment analysis. This study will utilize *k*-means clustering to categorize players' emotion (or sentiment) as either positive or negative [78]. The overview of sentiment analysis method can be shown as Figure 2.14.

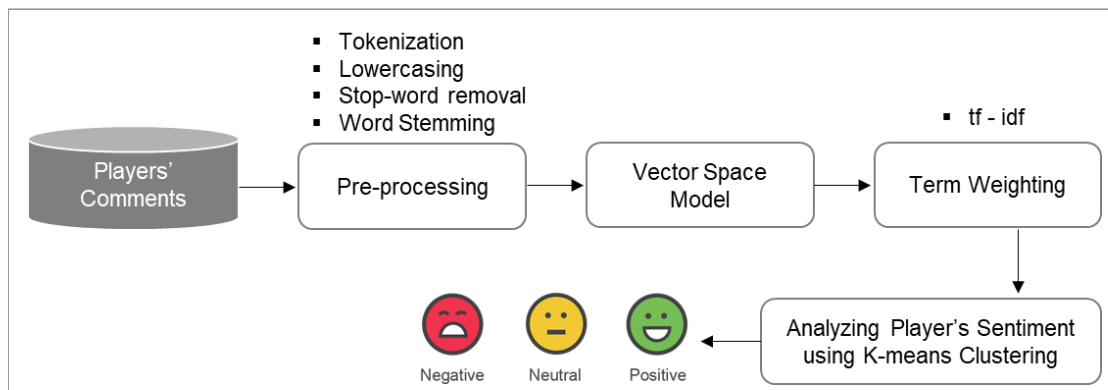


Figure 2.14 The overview of identifying players' sentiment by sentiment analysis method

This task will be performed through the use of Python and its libraries (e.g. NLTK and scikit-learn). Each processing step of identifying game player sentiment can be described as follows.

Step 1: Pre-processing

Text pre-processing is a critical step in natural language processing (NLP) and sentiment analysis workflows, aiming to clean and prepare text data for further analysis or machine learning model training. This process involves several techniques to transform raw text into a more manageable and analyzable format [79]. An outline of common text pre-processing stages used in this study can be provided below:

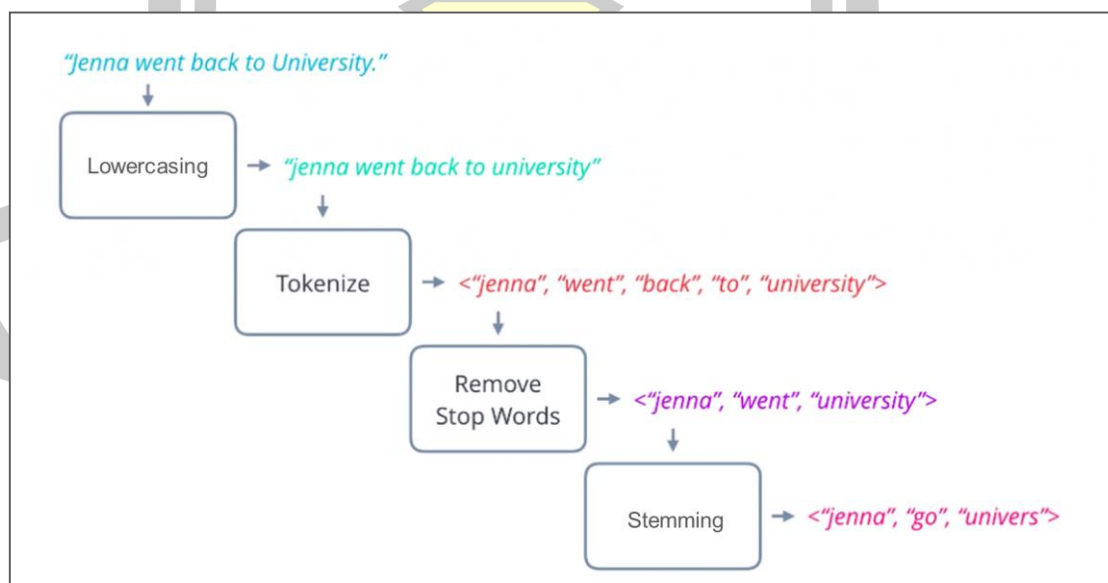


Figure 2.15 An example of text pre-processing

Tokenization: This is to split text into individual words, phrases, or symbols, known as tokens. This is the first step in turning unstructured text into a format that can be analyzed.

Lowercasing: This is to convert all characters in the text to lowercase to ensure that the algorithm does not treat the same words in different cases as different words (e.g., “Like” → “like”).

Stop-word Removal: Common words such as “is,” “and,” and “the” are commonly employed in language but typically lack substantial significance for analysis.

Stemming: Stemming is reducing words to their base form by truncating the ends of words. This approach is rudimentary and may not consistently produce real words, for example, changing “funning” to “fun”.

Step 2: Vector Space Model

The Vector Space Model (VSM) is a foundational concept in natural language processing (NLP) and information retrieval, used to represent text documents as mathematical vectors of identifiers, such as, but not limited to, terms or words from the document. The core idea is to map the textual information into a geometric space, where each dimension corresponds to a specific term or concept within the corpus (the collection of all documents). By representing text in this manner, various mathematical and statistical techniques can be applied to analyze and compare documents. An example of text representation by VSM can be shown as Figure 2.16.

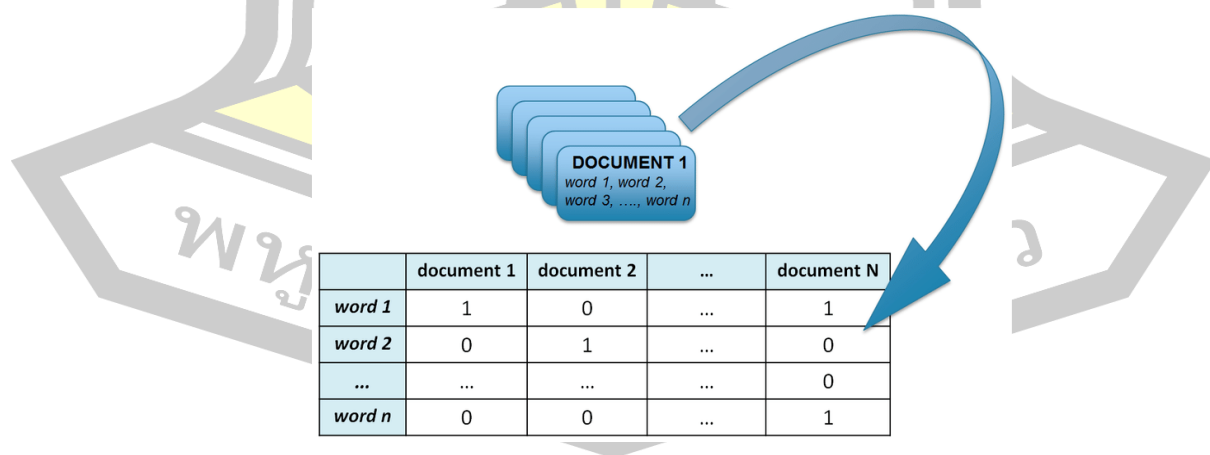


Figure 2.16 An example of text representation by Vector Space Model

From: https://www.researchgate.net/figure/Example-of-representation-with-vector-space-model_fig2_318637064

Step 3: Term Weighting

Term Frequency-Inverse Document Frequency (tf-idf) is the product of TF and IDF scores of a term. It balances the term's frequency in a document against its frequency across all documents, highlighting words that are distinct to a particular document.

Let's create a simple example to illustrate how *tf-idf* works. Suppose we have a small corpus of 3 documents as follows:

Document-1: The cat sat on the mat.

Document-2: The dog sat on the log.

Document-3: The cat danced on the log.

It can calculate the *tf-idf* for a few terms across these documents to demonstrate the process.

Step 1: Calculate Term Frequency (tf) - tf is calculated as the number of times a term appears in a document divided by the total number of terms in the document. For example, the tf for "cat" in Document 1 is calculated as follows:

- "cat" appears 1 time in Document 1.
- Total number of words in the Document-1 is 6.
- *tf* for "cat" in Document 1 = $1/6$.

Step 2: Calculate Inverse Document Frequency (idf) - idf measures how important a term is within the entire corpus. It is calculated as the logarithm of the ratio of the total number of documents to the number of documents containing the term. For example, the idf for "cat" can be calculated as follows:

- Total number of documents = 3.
- Number of documents containing "cat" = 2
(Documents-1 and Document-3).
- *idf* for "cat" = $\log(3/2)$.

Step 3: Calculate tf-idf – tf-idf is simply the product of TF and IDF for each term. Let's calculate the TF-IDF for "cat" in Document 1:

- *tf* for "cat" in Document 1 = $1/6$.
- *idf* for "cat" = $\log(3/2)$.
- *tf-idf* for "cat" in Document 1 = $(1/6) * \log(3/2)$.

We will perform these calculations for “cat” in Document-1, “dog” in Document-2, and a common term “the” across all documents to illustrate the difference in their *tf-idf* scores, which reflect their relative importance in the context of the corpus.

Suppose *tf-idf* of “cat” in Document-1 is 0.68, *tf-idf* of “dog” in Document-2 is 0.183, and *tf-idf* of “the” in both documents is 0. This can be interpreted that the *tf-idf* score for “dog” in Document-2 is higher than that for “cat” in Document-1, reflecting “dog”’s relative importance in Document-2 compared to “cat” in Document-1 within the context of the entire corpus. This is because “dog” appears only in one document, making it more unique than “cat,” which appears in two documents. It is noted that the term “the” has a *tf-idf* score of 0 in both documents, indicating it is not useful for distinguishing between documents due to its high frequency across the corpus.

Step 4: Sentiment Analysis by *k*-means clustering

After performing step (3) and (4), the obtained vector representations allow for calculating the similarity between documents using distance measures like cosine similarity, enabling applications in document clustering by the *k*-means clustering algorithm.

Sentiment analysis using *k*-means clustering is an unsupervised learning approach that can be used to group text data into clusters based on the similarity of their sentiment or underlying semantic content. Unlike traditional sentiment analysis, which often relies on pre-labeled data to train a classifier, *k*-means clustering attempts to discover patterns or groupings in the data without prior labeling. This can be particularly useful for exploring sentiment in large datasets where manual labeling would be impractical. In this study, we assign the value of *k* as 3 to represent positive, neutral, and negative sentiment of players.

Let’s walk through a simplified example of performing sentiment analysis using *k*-means clustering. This example will demonstrate how to cluster a small set of text data into groups that could potentially represent different sentiments.

For this example, we will use a hypothetical dataset of short text reviews about a product. The goal is to cluster these reviews into groups that might represent positive, negative, and neutral sentiments. Following comments are our example texts.

1. Love this product, it works great!

2. Not happy with the purchase.
3. It's okay, but not what I expected.
4. Absolutely fantastic, exceeded my expectations!
5. Poor quality, broke after a week.
6. Moderately satisfied, could be better.

After performing pre-processing, vector space model, and term weighting, the vectors will transform to the stage of sentiment analysis using k -means clustering, where k is assigned as 3 and we use common formula for similarity analysis in this algorithm, known as Euclidean Distance.

$$dis(x, y) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2} \quad (2.3)$$

where x_i and y_i are the coordinates of x and y in the i -th dimension.

An example of for similarity analysis by Euclidean Distance can be illustrated as follows. Imagine we have a dataset with four points in a 2-dimensional space, and we want to cluster these points into two clusters ($k = 2$). For illustration, the data points are A(1, 2), B(2, 3), C(10, 11), and D(11, 12).

The first step is to choose the initialize cluster centroids. In this case, we have:

- Centroid 1 (Initial): A (1, 2)
- Centroid 2 (Initial): C (10, 11)

Afterwards, it is to calculate Euclidean Distances from each point to each centroid. The Euclidean distance between two points (x_1, y_1) and (x_2, y_2) is given by:

$$dis = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (2.4)$$

Let's calculate the distances for each point to each centroid, and then assign each point to the cluster with the nearest centroid.

After calculating the Euclidean distances between each point and the centroids, we get the following results:

Distances to Centroid 1 (Initial: A (1, 2)):

- A: 0.
- B: 1.414
- C: 12.728

- D: 14.142

Distances to Centroid 2 (Initial: C (10, 11)):

- A: 12.728
- B: 11.314
- C: 0.
- D: 1.414

Based on these distances, we assign each point to the nearest centroid:

- Points A and B are closer to Centroid 1 (A), so they are assigned to Cluster 1.
- Points C and D are closer to Centroid 2 (C), so they are assigned to Cluster 2.

However, we will now return to the following comments.

1. Love this product, it works great!
2. Not happy with the purchase.
3. It's okay, but not what I expected.
4. Absolutely fantastic, exceeded my expectations!
5. Poor quality, broke after a week.
6. Moderately satisfied, could be better.

```
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.cluster import KMeans

# Sample text data
reviews = [
    "Love this product, it works great!",
    "Not happy with the purchase.",
    "It's okay, but not what I expected.",
    "Absolutely fantastic, exceeded my expectations!",
    "Poor quality, broke after a week.",
    "Moderately satisfied, could be better."
]

# Vectorize the text data
vectorizer = TfidfVectorizer(stop_words='english')
X = vectorizer.fit_transform(reviews)

# Apply K-means clustering
kmeans = KMeans(n_clusters=3, random_state=42)
kmeans.fit(X)

# Print cluster assignments
print("Cluster assignments:", kmeans.labels_)
```

Figure 2.17 An example code for sentiment analysis by the *k*-means clustering

After running the k -means clustering, we may get the following clusters (the exact clustering might vary due to the initialization randomness of k -means):

Cluster 1 (Positive Sentiment):

Love this product, it works great!

Absolutely fantastic, exceeded my expectations!

Cluster 2 (Negative Sentiment):

Not happy with the purchase.

Poor quality, broke after a week.

Cluster 3 (Neutral Sentiment):

It's okay, but not what I expected.

Moderately satisfied, could be better.

2.4 Evaluation Metrics

Evaluating interactive learning relevant to a healthy diet for elementary school students using educational games requires a combination of quantitative and qualitative metrics. These metrics assess the effectiveness of the game in enhancing students' knowledge, engagement, and interaction with the learning content. The evaluation focuses on how well the educational game facilitates learning, promotes active participation, and supports knowledge retention. By employing appropriate assessment techniques, we can measure both learning outcomes and user experience to ensure that the game meets educational objectives.

2.4.1 Evaluation Metrics the K-Means Clustering Method

Two evaluation metrics (i.e., Silhouette Score [94] and Davies-Bouldin Index [95]) can be used to assess the quality and effectiveness of the clusters. Since the dataset involves educational game reviews, the focus will be on how well the clustering captures meaningful patterns and sentiments in the reviews. [96]

The Silhouette Score (S.S.) measures how similar a data point is to its own cluster compared to other clusters. The Silhouette Score ranges from -1 to 1, where a higher value indicates better-defined clusters. The formula is:

$$S(i) = \frac{b(i) - a(i)}{\max(a(i), b(i))} \quad (2.5)$$

where $a(i)$ is the average distance between data point i and all other points in the same cluster, and $b(i)$ is the average distance between data point i and all points in the nearest cluster. This evaluation metric helps determine how well-separated and cohesive the clusters are in the context of review data.

For the Silhouette Score, perfect clustering occurs when reviews are well-matched within their respective clusters and are distant from others, indicating strong separation between clusters. A score of 1 represents this ideal scenario. Conversely, a score of 0 suggests that the reviews lie between clusters, signifying weak clustering. Negative values indicate that reviews may be incorrectly clustered, implying that the clustering algorithm has grouped them inappropriately. Generally, a score between 0.3 and 0.5 is considered moderate clustering quality, especially for small datasets.

The Davies-Bouldin Index (DBI) measures the average similarity ratio of each cluster to its most similar cluster. Lower values indicate better clustering.

$$DB = \frac{1}{k} \sum_{i=1}^k \max_{j \neq i} \left(\frac{\sigma_i + \sigma_j}{d(c_i, c_j)} \right) \quad (2.6)$$

where σ_i and σ_j are the average distances between data points in clusters i and j to their respective centroids, and $d(c_i, c_j)$ is the distance between the centroids of clusters i and j . This evaluation metric is suitable for assessing the compactness and separation of clusters in the review dataset. The DBI scores typically range from 1 . to 3 ., with lower values indicating better cluster separation and higher values suggesting more overlap or less distinct clusters.

The DBI score measures the ratio of within-cluster dispersion to between-cluster separation, with lower values indicating better clustering. A DBI closer to 0 reflects better separation, while values above 2.5 typically suggest significant overlap between clusters.

2.4.2 N-GUT Scale Calculation

The N-GUT Scale (Nutrition Game Applicability Tool) [97] is a standardized evaluation metric used to assess the applicability of educational nutrition games. It measures multiple dimensions (or aspects) such as *scientific accuracy*, *knowledge coverage*, *adaptability*, and *Applicability of Behavioral Interventions* using a Likert-

scale rating system (e.g., 1 to 5 points). It is an expert-based evaluation metric used to assess the applicability of nutrition-related educational games.

The overall N-GUT score ($N-GUT_{total}$) can be computed as:

$$N - GUT_{total} = \frac{\sum_{i=1}^n W_i S_i}{n} \quad (2.7)$$

Where:

S_i = Score given by expert

W_i = Weight assigned to each criterion (optional, default is equal weight)

n = Number of experts

If Cronbach's alpha (α) is reported ($\alpha=0.87$ in this case), it suggests the scale's internal consistency and reliability.

An example of the N-GUT Scale calculation can be illustrated as follows.

Step 1: Define the Evaluation Criteria

Assume we have 4 evaluation aspects: Scientific Accuracy, Completeness of Knowledge Coverage, Educational Content Adaptability, and Applicability of Behavioral Interventions. Each criterion is rated on a 5-point scale, where:

1 = Poor

2 = Fair

3 = Moderate

4 = Good

5 = Excellent

Step 2: Collect Expert Ratings - Suppose 5 experts provide the following ratings.

Expert	Sci. Accuracy	Knowledge Coverage	Adaptability	Feasibility
Expert 1	5	4	3	4
Expert 2	4	4	4	3
Expert 3	5	5	3	4
Expert 4	4	4	4	4
Expert 5	5	5	4	3

Figure 2.18 Examples of expert's rating collection

Step 3: Compute the Average Score per Aspect

$$Aspect\ Score = \frac{\sum_{i=1}^n S_i}{n} \quad (2.8)$$

Therefore, four dimensions (or aspects) can be calculated as follows.

$$\text{Scientific Accuracy} = \frac{5 + 4 + 5 + 4 + 5}{5} = 4.6$$

$$\text{Completeness of Knowledge Coverage} = \frac{4 + 4 + 5 + 4 + 5}{5} = 4.4$$

$$\text{Educational Content Adaptability} = \frac{3 + 4 + 3 + 4 + 4}{5} = 3.6$$

$$\text{Applicability of Behavioral Interventions} = \frac{4 + 3 + 4 + 4 + 3}{5} = 3.6$$

Step 4: Compute the Overall N-GUT Score

$$N - GUT_{total} = \frac{4.6 + 4.4 + 3.6 + 3.6}{4} = 4.5$$

Thus, the N-GUT Score for this evaluation is 4.5/5, indicating high applicability of the game.

In summary, the N-GUT scale is derived from the average expert ratings across multiple evaluation criteria, ensuring a comprehensive assessment of the educational game's applicability. The reliability of this evaluation is supported by Cronbach's alpha ($\alpha = 0.87$), confirming the consistency of expert judgments. Additionally, if weights (W_i) are applied, criteria deemed more important can have a greater influence on the final score. Ultimately, the final N-GUT score helps determine whether the game is scientifically valid and suitable for real-world use.

2.4.3 Educational Game Evaluation using Pre and Post-Assessment

Evaluating an educational game focused on healthy dietary habits for younger students through pre- and post-assessment [98] involves a careful, engaging process. This approach not only measures the game's impact on students' knowledge and attitudes towards healthy eating but also ensures the assessment is developmentally appropriate and engaging. Here is how to effectively implement this process:

Step 1: Define Learning Objectives

Identifying specific dietary knowledge and behaviors to focus on is the initial step. This may involve tasks such as distinguishing between healthy and harmful foods, comprehending food groups, and selecting nutritious snacks. The game should establish unambiguous and quantifiable objectives regarding the knowledge and skills that students ought to possess upon completion, guaranteeing

their congruence with more comprehensive educational benchmarks concerning health and nutrition.

Step 2: Develop Age-Appropriate Assessment Tools

At this stage, interactive and captivating assessments are developed, such as categorizing exercises (for instance, discerning between nutritious and impure foods), picture-based quizzes, or straightforward recall inquiries pertaining to nutrition facts.

Step 3: Conduct the Pre-Assessment

This is to introduce the pre-assessment in a playful and friendly method prior to the game's release, elucidating that its purpose is to evaluate the participants' existing knowledge regarding health and diet. For example, having individuals provide illustrations of their preferred meals and identify nutritious components, or having those with limited literacy abilities respond to oral inquiries.

Step 4: Conduct the Post-Assessment

After obtaining the proposed educational game relevant to healthy dietary for younger students, using the same tools as the pre-assessment phase, this phase measures changes in knowledge and attitudes with precision. Enhancements in engagement can be implemented in response to observations made during the pre-assessment. Additionally, reflective inquiries regarding how students can employ the knowledge gained from the game to their eating behaviors should be included.

Step 5: Analyze the Results

The purpose of this is to compare pre- and post-results in order to identify changes in attitudes and knowledge regarding healthful nutrition. An assessment of behavioral intent is imperative, wherein students' willingness to modify their dietary patterns in light of the knowledge acquired must be noted.

2.4.4 Analysis of Gameplayer Behaviors

2.4.4.1 The Mugeda Background Tracking System

Gameplayer behaviors in their interactions with the educational game can be analyzed using the Mugeda background tracking system [99].

The Mugeda background tracking system is an integrated feature within the Mugeda platform, a cloud-based tool designed for creating interactive HTML5 content. This system enables developers and educators to monitor and analyze user

interactions, providing valuable insights into user behavior and engagement. By capturing data on how users interact with various elements, such as button clicks, page views, and time spent on specific sections, the system helps in understanding engagement patterns and optimizing content accordingly.

In the context of educational game development, the Mugada tracking system plays a crucial role in assessing learning engagement, identifying user interaction patterns, and enhancing the effectiveness of game-based learning experiences. It allows educators to track how students interact with different game components, analyze common behavioral trends, and refine the educational material based on data-driven insights. The real-time data collection capability ensures that adjustments can be made promptly, improving the overall user experience.

By leveraging this tracking system, content creators can make data-driven decisions to enhance interactivity, design more intuitive user experiences, and improve educational outcomes. The insights gained help tailor educational games to better meet learning objectives, ensuring that students receive an engaging and effective learning experience. Ultimately, the Mugada background tracking system serves as a powerful analytical tool that supports the continuous improvement of interactive educational content, making it more impactful and user-friendly.

2.4.4.2 Cohen's d

After collecting data of gameplay behaviors by using the Mugada background tracking system, the Cohen's d is applied to analyze their interactions with the educational game [100].

Cohen's d is a statistical measure of effect size, which quantifies the magnitude of difference between two groups. It is commonly used in educational research, psychology, and experimental studies to determine whether an observed difference is practically meaningful. Its formula is:

$$d = \frac{M_1 - M_2}{SD_{pooled}} \quad (2.9)$$

Where:

- M_1 = Mean (average) of the experimental group
- M_2 = Mean (average) of the control group

SD_{pooled} = Pooled standard deviation, calculated as:

$$SD_{pooled} = \sqrt{\frac{SD_1^2 + SD_2^2}{2}} \quad (2.10)$$

where SD_1 and SD_2 are the standard deviations of the two groups.

Cohen's d provides a standardized measure of how much one group differs from another. The general interpretation of effect size is:

Cohen's d Value	Effect Size Interpretation
0.2	Small effect (low practical significance)
0.5	Medium effect (moderate difference)
0.8 or higher	Large effect (strong difference)

Figure 2.19 A standardized measure of Cohen's d

A higher Cohen's d value indicates a greater difference between the two groups.

An example can be illustrated as follows. If we are comparing task completion rates between two groups:

Group	Mean Completion Rate	Standard Deviation
Experimental	83.7%	10.5
Control	61.2%	12.3

Figure 2.20 An example data used for calculating Cohen's d

Step 1: Compute the Pooled Standard Deviation

$$SD_{pooled} = \sqrt{\frac{(10.5^2 + 12.3^2)}{2}} = \sqrt{130.77} = 11.44$$

Step 2: Compute Cohen's d

$$d = \frac{(83.7 - 61.2)}{11.44} = 1.97$$

This value of Cohen's $d = 1.97$ represents a very large effect size, meaning the experimental group performed significantly better than the control group in task completion.

2.5 Related Work

The development of educational games is informed by a rich body of research from various disciplines. Effective educational games are those that successfully integrate pedagogical principles with engaging gameplay mechanics. As technology advances, ongoing research continues to explore innovative ways to enhance learning through games, making it a dynamic and evolving field.

The development of educational games is a growing field that combines insights from educational psychology, cognitive science, and game design to create engaging learning experiences. Below are several foundational and contemporary studies that have shaped the understanding and development of educational games, complete with references for further exploration:

Csikszentmihályi [81] proposed the idea of flow, a state of intense concentration and involvement that games may create, offering a way to comprehend involvement in educational games.

Mayer's work [82] on multimedia learning explored how people learn from words and pictures and provides principles for designing effective educational multimedia, including games.

Gee's research highlighted the correlation between video game design and effective learning settings, drawing on ideas from cognitive science [83].

Habgood and Ainsworth [84] discussed the potential of digital tools, including games, for assessment and the role of learning analytics in understanding and supporting learners.

Shute and Ke [85] discussed the integration of formative assessment in games, highlighting how games can adapt to individual learners' needs and provide personalized feedback.

DiCerbo and Behrens [86] discussed the potential of digital tools, including games, for assessment and the role of learning analytics in understanding and supporting learners.

Wouters et al. [87] conducted a meta-analysis to assess the impact of serious games on cognitive and motivational outcomes, providing evidence-based insights into their educational usefulness.

Ke [88] presented the systematic review that identified effective design principles for integrating learning objectives into the gameplay of educational games. It stressed the importance of aligning game mechanics with educational content to ensure that gameplay directly contributes to learning outcomes.

Hamari et al. [89] investigated the relationship between challenge, engagement, flow, and learning in game-based environments. It emphasized the role of social interaction and collaboration in educational games, suggesting that challenges that promoted social learning can lead to higher levels of engagement and deeper learning.

Clark et al [90] also proposed the meta-analysis that assessed the impact of digital games on learning outcomes in STEM (Science, Technology, Engineering, and Mathematics) education. The findings suggested that games designed with specific educational purposes in mind can significantly improve STEM learning outcomes, especially when they incorporated active, critical learning principles.

Lomas et al [91] explored how elements such as choice, novelty, and suspense within educational games affect learners' intrinsic motivation. The study concluded that personalization and adaptivity — adjusting game difficulty and content based on the learner's performance — could significantly enhance motivation and engagement.

Ifenhaller and Yau [92] focused on the use of learning analytics in higher education to support student success. It highlighted how educational games integrated with analytics tools can provide real-time feedback and assessments, enabling personalized learning paths and identifying areas where students might need additional support.

2.6 What are new challenges for current educational game development?

In late 2023, several new trends and innovations are shaping the future of educational game development. These advancements not only leverage the latest in technology but also incorporate cutting-edge pedagogical strategies to create more effective and engaging learning experiences. Here are some of the noteworthy developments in the field:

2.6.1 Augmented Reality (AR) and Virtual Reality (VR)

The incorporation of augmented reality and virtual reality technologies into educational games enables previously impossible immersive learning experiences. By

enabling students to explore virtual environments, conduct experiments, and hone skills in a secure and regulated environment, these technologies enhance the engagement and effectiveness of the learning process.

2.6.2 Artificial Intelligence (AI) and Machine Learning

Personalized learning experiences are being implemented in educational games using AI. Real-time analysis of a student's performance by machine learning algorithms enables the adjustment of the game's level of difficulty and the provision of individualized feedback and recommendations. By allowing for flexibility, the game maintains a balance between difficulty and accessibility, effectively meeting the unique requirements of every learner.

2.6.3 Blockchain for Educational Credentials

While not directly related to game creation, blockchain technology is being investigated for its ability to safely and openly monitor educational achievements and certifications. In the context of educational games, blockchain might be used to verify and award successes across many platforms, giving students a verifiable record of their progress.

2.6.4 Social Learning Platforms

Educational games emphasizing social learning and teamwork are becoming increasingly popular. These games inspire students to collaborate to solve issues, finish projects, and explore topics, taking use of the social side of learning to boost engagement and retention.

2.6.5 Gamification of Assessment

Traditional methods for evaluation are being redesigned through gamification, which incorporates game aspects into tests to make them more entertaining and less stressful for students. This strategy can help teachers gain significant insights into their students' comprehension and skills in a more natural and engaging setting.

2.6.6 Serious Games for Soft Skills

There is a growing emphasis on creating games that teach soft skills like communication, cooperation, empathy, and leadership. These abilities are essential for success in the twenty-first century workplace, and games give an unparalleled chance to practice and improve them in realistic circumstances.

2.6.7 Accessibility and Inclusivity

There is a growing emphasis on making educational games accessible and inclusive for all learners, including those with disabilities. This includes the development of games that are compatible with assistive technologies, as well as the design of game content that reflects a diverse range of cultures, experiences, and perspectives.

2.6.8 Cross-Disciplinary Learning

Educational games are increasingly designed to support cross-disciplinary learning, where students apply knowledge and skills from multiple subjects to solve complex problems. This approach reflects the interconnected nature of real-world challenges and prepares students for the multifaceted problems they will encounter outside of the classroom.

2.7 Theoretical Frameworks of the Study

This research integrates four core theoretical frameworks to inform the design, development, and evaluation of an educational game aimed at promoting healthy dietary habits among elementary school students. The application of multiple frameworks allows for a comprehensive approach that bridges design usability, pedagogical effectiveness, learning interactivity, and motivational engagement. This section presents each theory with reference to existing research that supports its relevance in the context of educational game development.

2.7.1 Game-Based User-Centered Design (UCD)

User-Centered Design (UCD) is a comprehensive design philosophy and methodological framework that prioritizes the needs, characteristics, and limitations of end users at every stage of product development. It emphasizes a participatory and iterative process that involves users in key phases of design, from initial requirements gathering to prototyping and evaluation [107]. In the context of educational technology, particularly in the development of online educational games and applications, UCD serves as a foundation for aligning system functionalities with pedagogical goals and learner characteristics [107][108].

The application of UCD in educational settings ensures that learning interfaces are not only functional but also pedagogically meaningful and personally

relevant to the target learners. For example, Sauv  and Kaufman [107] demonstrated how UCD principles led to the development of engaging and cognitively accessible games for senior learners. Similarly, the systematic review by Al-Sa'di and McPhee [108] highlights how UCD has been successfully employed to tailor educational applications to diverse learning needs and environments, often resulting in enhanced learning performance and user satisfaction.

Core principles of UCD include user research, needs analysis, persona development, prototyping, usability testing, and continuous refinement based on real user feedback. Oviatt [109] emphasized the synergy between UCD and cognitive load theory, arguing that educational systems designed with UCD in mind tend to reduce extraneous cognitive burden, thereby promoting deeper learning and better retention. This is especially critical in multimedia learning environments where interface complexity can easily hinder the learning process.

Moreover, UCD plays a pivotal role in promoting accessibility and inclusivity in educational game design. As illustrated by Zain et al. [110], UCD tools and methods can be adapted to address the specific needs of learners with motor impairments, ensuring that such users are not excluded from digital learning opportunities. Luo [111] further reinforces this point by integrating user-centric design into the creation of inclusive learning environments, thereby supporting equitable access to educational resources for all users regardless of ability.

Beyond interface aesthetics and usability, UCD also extends to instructional design. Traver [112] argues that educational effectiveness can be enhanced by applying UCD not only to the interface layer but also to the structuring of instructional content and learning activities. This integrated approach bridges the gap between human-computer interaction and educational theory, leading to systems that are not only easier to use but also more effective for learning.

Recent discussions in the field, such as those by Gondomar and Mor [113], suggest a movement from traditional UCD toward Human-Centered Design (HCD) and beyond, incorporating philosophical and ethical dimensions of design education. This evolution encourages designers to consider human values and broader social implications, positioning UCD as a catalyst for educational transformation rather than merely a usability framework.

2.7.2 Educational Game Theory

Educational Game Theory provides a robust theoretical framework that informs the integration of pedagogical strategies into the structure and mechanics of digital games. Central to this theory is the concept of flow, a psychological state of deep immersion and enjoyment in an activity, first conceptualized by Csikszentmihalyi and widely applied in educational game design. In this context, flow is achieved when learners are fully engaged in gameplay through the presence of clear goals, immediate feedback, and challenges that are well-matched to their skills [114][115]. These conditions create a state in which learners experience heightened concentration and intrinsic motivation, both of which are critical to effective learning outcomes.

Kiili et al. [114][115] further operationalized these ideas into concrete design principles for educational games. Their work emphasizes the alignment between learning content and game mechanics, advocating for the construction of meaningful, goal-oriented tasks that maintain the learner in the flow channel. The notion of “experiential gaming”, introduced in Kiili’s earlier work [116], frames educational games as environments in which learners actively construct knowledge through interactive problem-solving, supported by immersive and emotionally engaging experiences.

Moreover, Becker [117] argues that many well-designed games inherently embody sound educational principles such as scaffolding, reinforcement, and immediate feedback—elements central to various learning theories including constructivism and behaviorism. Therefore, educational games can be viewed not just as delivery tools for content, but as embodied pedagogies that naturally align with how learners assimilate and apply knowledge.

The Game Cycle Model proposed by Garris, Ahlers, and Driskell [118] adds another critical dimension to educational game theory. This model outlines a repeating cycle of user judgment, behavior, and feedback, which creates a feedback loop that sustains motivation and reinforces learning. The model also underscores the importance of aligning game rules, user actions, and learning goals to create a cohesive and educationally purposeful experience.

A key concept in effective game-based learning is intrinsic integration, as discussed by Habgood [119]. This refers to the seamless embedding of educational content within core gameplay mechanics, rather than tacking on educational elements as external features. Games designed with intrinsic integration are more likely to maintain learner engagement and facilitate deeper understanding, as the act of play itself becomes a learning process rather than a distraction from it.

In designing educational games, another crucial consideration is the alignment of learners' mental models with the internal models of the game. Boyan and Sherry [120] explain that learners enter games with preconceived notions and cognitive frameworks. When educational games are not aligned with these mental models, learners may experience confusion or cognitive dissonance, reducing the effectiveness of learning. Hence, designers must ensure that the structure and logic of the game correspond with the way learners conceptualize the content.

Additionally, the integration of reflective elements into gameplay—such as post-level summaries, in-game journals, or scaffolded discussion prompts—has been identified as a means to deepen learning and foster metacognition. While not all references above address this directly, it is increasingly recognized in the broader literature as a best practice in educational game design.

2.7.3 Interactive Learning Theory

Interactive Learning Theory is grounded in the sociocultural perspective of learning, which emphasizes that meaningful learning occurs through dynamic interaction with others and with the environment. A key theoretical construct within this paradigm is Lev Vygotsky's Zone of Proximal Development (ZPD), which refers to the range between what a learner can achieve independently and what they can achieve with guidance and support [121][124]. Learning is most effective, according to Vygotsky, when learners are provided with structured support—often referred to as scaffolding—that enables them to move through this zone toward greater competence.

Luckin [121] emphasizes the importance of designing educational software that situates learners within the ZPD by enabling them to engage in productive interactivity. This involves facilitating interactions that challenge learners just beyond their current level of competence while simultaneously offering the necessary support to foster understanding. This concept has been particularly influential in the design of

interactive learning environments, such as educational games, that can adapt dynamically to a learner's performance and provide feedback in real time.

Garzotto [122] extended this work by examining the impact of social interaction in digital game-based learning. The study found that children engaging in collaborative gameplay demonstrated significantly greater learning gains than those working individually. This supports the Vygotskian view that cognitive development is enhanced through interaction with more knowledgeable peers or systems, highlighting the role of shared problem-solving and dialogue in educational games.

Luckin and du Boulay [123] further illustrated the application of ZPD through the Ecolab system, a learning environment designed to provide adaptive feedback and scaffolding based on each learner's performance. The system demonstrates how educational technologies can be engineered to simulate the role of a tutor by providing context-sensitive support that aligns with the learner's zone of development. Importantly, their reflection also acknowledges that the effectiveness of scaffolding depends not only on the system's intelligence but also on the learner's capacity to respond to that support, reinforcing the individualized nature of interaction within the ZPD.

From a pedagogical standpoint, Sanders and Welk [124] outlined a set of practical scaffolding strategies rooted in ZPD theory, including modeling, guided questioning, timely feedback, and graduated task difficulty. These strategies have been widely adopted in both classroom settings and interactive digital learning systems to gradually transfer responsibility from teacher (or system) to learner, thereby promoting autonomy and deeper understanding.

Moreover, Gebhard [125] highlighted the continued relevance of Vygotsky's theories in the context of technology-enhanced learning. By embedding ZPD-aligned design principles in software development, educational applications can support learners in socially constructed knowledge-building processes, even in virtual or asynchronous environments [125]. However, despite the potential of such systems, Luckin [121] warns that designing software capable of offering nuanced, adaptive support remains a significant challenge, especially when considering the diversity of learners' backgrounds, abilities, and cognitive styles.

2.7.4 Gamification Elements Theory

Gamification, defined as the integration of game mechanics into non-game environments, has been increasingly adopted in educational settings to enhance student engagement, motivation, and learning outcomes. The fundamental premise is that elements traditionally found in games—such as points, badges, leaderboards, levels, and avatars—can drive learner behavior and improve educational experiences when appropriately implemented [126][127].

Nicholson [128] proposed a User-Centered Theoretical Framework for Meaningful Gamification, emphasizing that gamification should be tailored to users' needs and motivations, rather than simply applying game mechanics superficially. This framework encourages alignment between educational objectives and game elements to foster deeper engagement and learning. Similarly, Limantara et al. [129], in their systematic review, identified that successful gamified learning environments often integrate multiple components such as progress indicators, challenges, social interaction, and personalized feedback, all of which contribute to sustained learner involvement in higher education contexts.

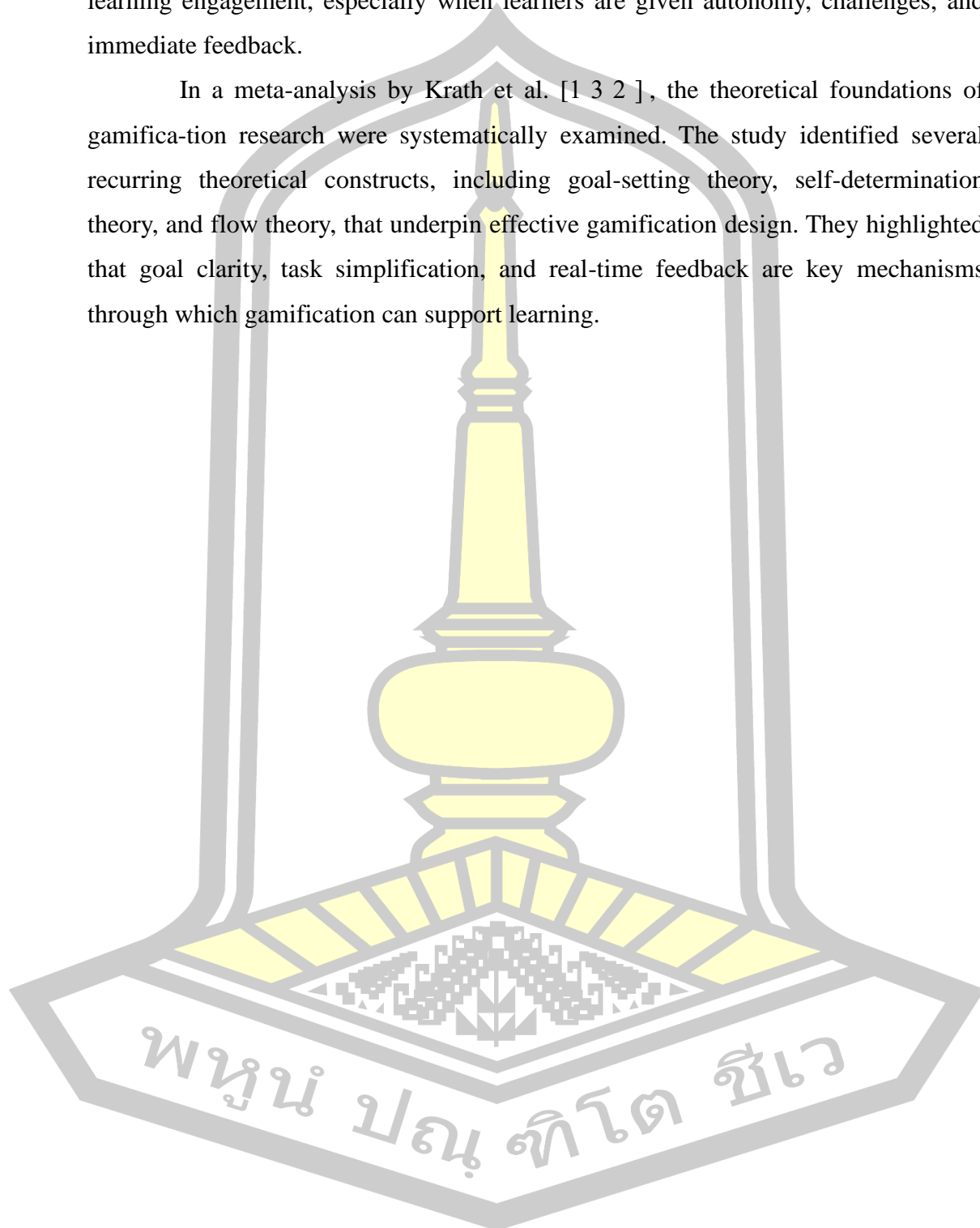
Nah et al. [130] reviewed a broad range of literature and highlighted the educational benefits of gamification, including increased attention, participation, and retention of learning content. Their study also categorized gamification elements into cognitive (e.g., challenges), emotional (e.g., enjoyment), and social (e.g., competition) dimensions, demonstrating the multifaceted impact of gamified learning systems.

However, the application of gamification in education is not without criticism. Mekler et al. [126] conducted an empirical analysis and found that while points, levels, and leaderboards can enhance extrinsic motivation, they may also diminish intrinsic motivation if not properly integrated into meaningful learning activities. This concern is echoed by Hanus and Fox [131], who conducted a longitudinal study revealing that overreliance on extrinsic gamification elements may lead to reduced motivation, satisfaction, and academic performance over time—particularly when learners perceive the gamified system as manipulative or unrelated to learning goals.

Mao and Terry [127] further emphasized that the effectiveness of gamification depends heavily on contextual factors such as learner characteristics, subject matter, and instructional strategies. Their review highlights that thoughtful

integration of gamification—not mere implementation—can lead to enhanced learning engagement, especially when learners are given autonomy, challenges, and immediate feedback.

In a meta-analysis by Krath et al. [132], the theoretical foundations of gamification research were systematically examined. The study identified several recurring theoretical constructs, including goal-setting theory, self-determination theory, and flow theory, that underpin effective gamification design. They highlighted that goal clarity, task simplification, and real-time feedback are key mechanisms through which gamification can support learning.



CHAPTER III

RESEARCH METHODOLOGY

The purpose of this section is to present a proposed method to develop an interactive educational game that focuses about healthy diet for students in elementary school.

3.1 Participants and Data Sources

This study utilizes both primary data and secondary data to develop, implement, and evaluate an interactive educational game for promoting healthy dietary habits among elementary school students. The participants and data sources are described in two parts: (1) student participants involved in the intervention, and (2) online user reviews used for design and sentiment analysis purposes.

3.1.1 Student Participants and Group Assignment

3.1.1.1 Population and Sample

The population for this study comprises all Grade 2 students (typically aged 8–9 years) enrolled at Huanhu Primary School during the academic year of the study. From this population, a sample of 46 students was selected using a purposive sampling method. The selection was based on the following criteria:

- Students were currently enrolled in Grade 2, specifically Class 5, to maintain classroom integrity and scheduling consistency.
- Students were between 8 and 9 years old.
- Students had not received prior formal nutrition education.
- Informed consent was obtained from parents or legal guardians.
- Students were able to participate in both physical (tabletop) and digital (PC-based) game formats.

These criteria ensured that participants were developmentally appropriate for the game content and represented a relevant target group for evaluating learning impact.

3.1.1.2 Group Assignment

The selected sample ($n = 46$) was randomly divided into two equal groups to facilitate a quasi-experimental design:

Experimental Group ($n = 23$): These students participated in the learning intervention using the developed interactive educational game in both tabletop and PC-based formats. The game sessions were conducted during regular class hours over a period of 2 weeks.

Control Group ($n = 23$): These students received conventional instruction on nutrition topics using standard worksheets and teacher-led explanations, without any gamified or interactive components.

To ensure fairness and comparability, students were assigned to the groups through simple randomization, using a lottery-drawing method conducted by the class teacher. The demographic characteristics (e.g., age, gender, digital literacy) of the two groups were reviewed and found to be statistically similar before the intervention began.

3.1.1.3 Rationale for Group Design

This division allowed for a clear comparison between traditional and game-based learning methods, enabling the researchers to isolate the impact of the educational game on learning outcomes, behavioral engagement, and user satisfaction. The randomized group assignment enhanced internal validity by minimizing selection bias and controlling for confounding variables.

The randomized group assignment enhanced internal validity by minimizing selection bias and controlling for confounding variables. In addition to the primary user group of Grade 2 students (aged 8–9), the study also gathered feedback from their parents, who are considered key stakeholders in children's learning and digital engagement. This dual-group approach provides richer insights into the effectiveness and acceptance of the educational game across different age groups, especially by comparing perspectives between children and adults.

3.1.2 Online Educational Game Review Data

In addition to student participants, the study incorporates secondary data consisting of publicly available user-generated reviews of popular educational games.

These reviews were collected via web scraping from platforms such as Common Sense Media, Google Play, and App Store between 2020 and 2022.

The review authors include anonymous users, primarily students, parents, and educators, who voluntarily shared their feedback about educational games like Endless Alphabet, Prodigy Math Game, and Minecraft: Education Edition.

The inclusion criteria for selecting reviews were:

- Text-based reviews written in English
- Minimum length of 10 words
- Publicly accessible without authentication

A total of 1,500 cleaned reviews were used for two main purposes:

1. K-Means Clustering to extract common themes (e.g., engagement, motivation, usability) for game design inspiration
2. Sentiment Analysis to understand user experiences and preferences regarding educational games

These reviews were used as textual data, not as direct human subjects of experimentation. Since all content was anonymized and publicly available, ethical concerns were mitigated, and no personally identifiable information (PII) was collected.

By combining controlled experimentation with student participants and real-world feedback from educational game users, the study adopts a mixed-methods approach to design, test, and validate the proposed game. The primary data captures measurable learning impact, while the secondary data informs user-centered game design and evaluates overall user sentiment.

3.2 Overview of the Proposed Framework

Developing an interactive educational game focused on healthy dietary habits for elementary school students requires a comprehensive approach that integrates educational content with engaging gameplay. A game-based User-Centered Design (UCD) framework is well-suited for this purpose, as it prioritizes the needs and experiences of the target audience—elementary school students—throughout the development process. The framework incorporates Educational Game Theory, Interactive Learning Theory, and Gamification Elements Theory, ensuring that the

game is not only educational but also engaging and effectively supports learning objectives. Figure 3.1 illustrates the proposed framework.

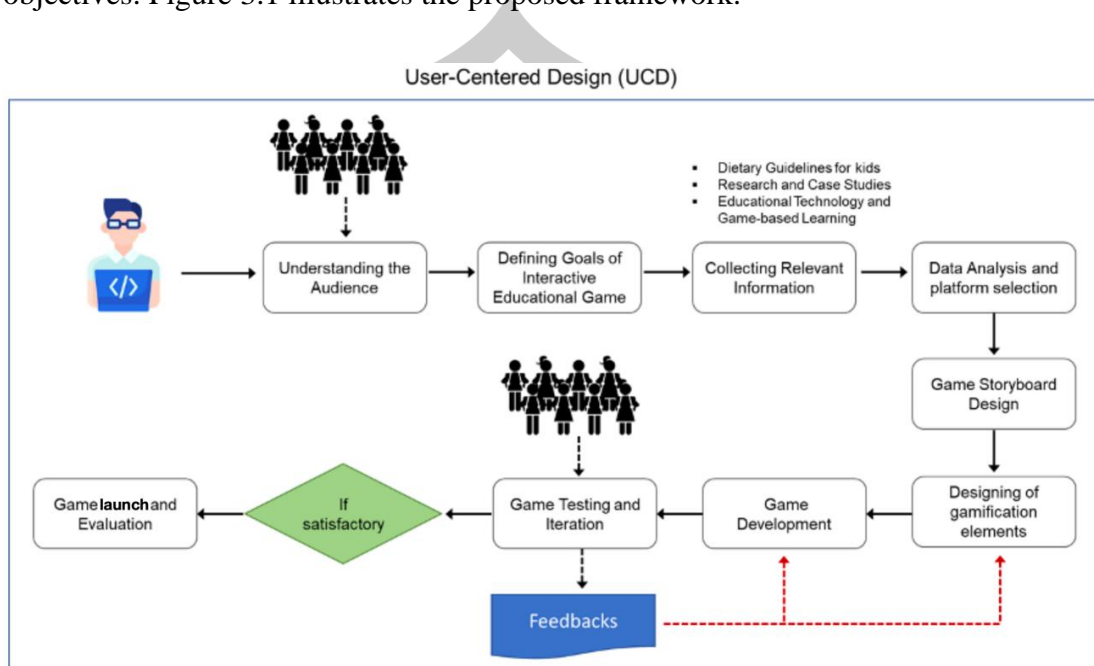


Figure 3.21 The proposed framework overview of developing an interactive educational game that focuses about healthy diet for students in elementary school.

Here is a detailed plan to develop such a game:

3.2.1 Understanding the Audience

Understanding the audience's dietary habits is a critical step in developing an interactive educational game for elementary school students focused on healthy eating. This knowledge helps tailor the game's content, design, and educational strategies to the specific needs, preferences, and challenges faced by the target demographic. Knowledge of the audience's dietary habits allows for the customization of game content to make it more relevant and engaging for the students. For instance, if a large portion of the target audience consumes a high number of sugary snacks, the game can include specific challenges and rewards related to reducing sugar intake. Also, understanding dietary habits helps ensure the game respects cultural food practices and preferences, making the educational content more inclusive and relatable. Three considerations are important at this stage:

1. It is imperative to identify prevalent nutritional deficiencies or misconceptions among the target demographic. In order to rectify these concerns,

developers may devise game levels or activities that educate children about the significance of particular nutrients and the proper methods to incorporate them into their diets.

2. Understanding dietary preferences facilitates the development of content that promotes a well-rounded diet by emphasizing the importance of a diverse range of foods for optimal health.

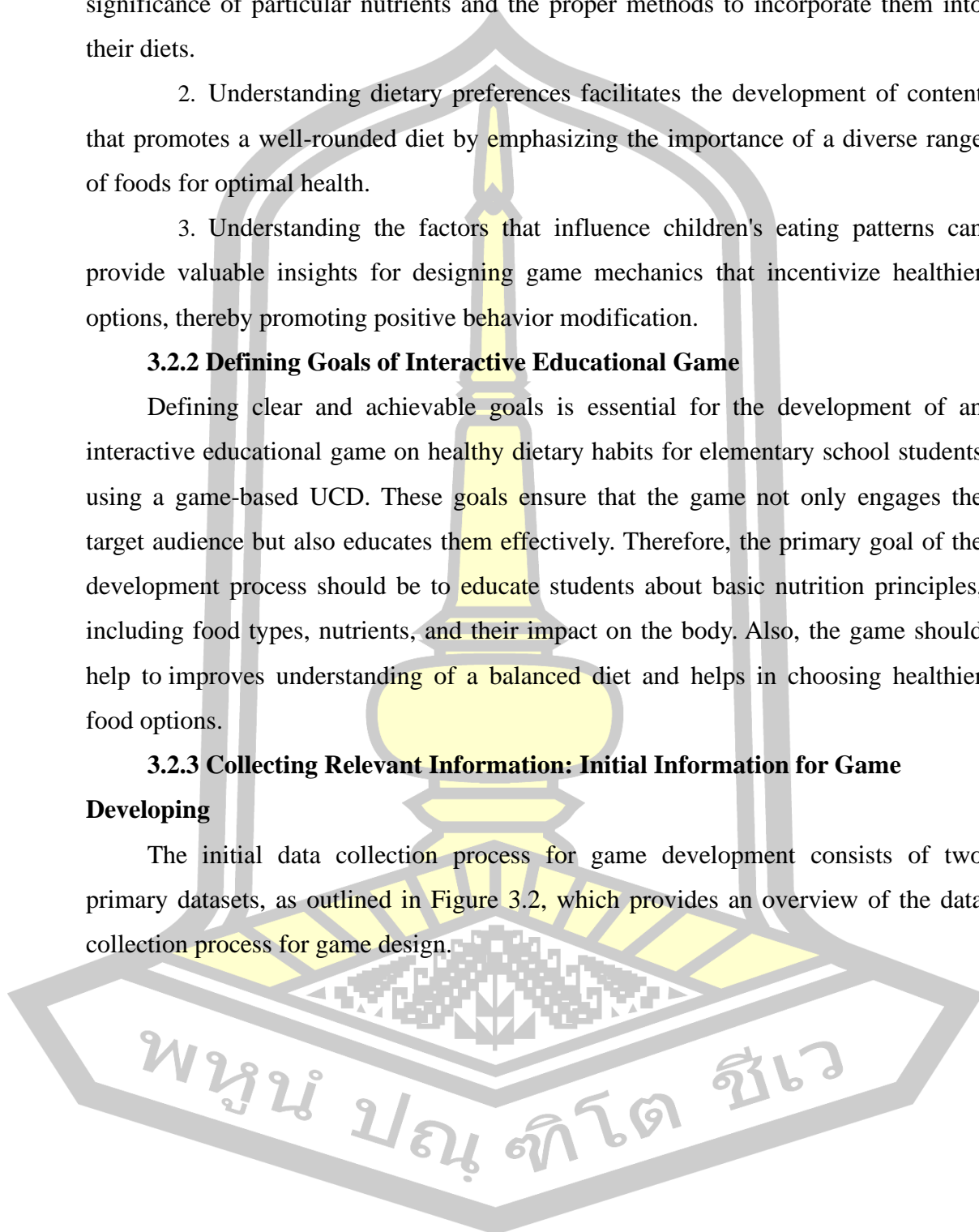
3. Understanding the factors that influence children's eating patterns can provide valuable insights for designing game mechanics that incentivize healthier options, thereby promoting positive behavior modification.

3.2.2 Defining Goals of Interactive Educational Game

Defining clear and achievable goals is essential for the development of an interactive educational game on healthy dietary habits for elementary school students using a game-based UCD. These goals ensure that the game not only engages the target audience but also educates them effectively. Therefore, the primary goal of the development process should be to educate students about basic nutrition principles, including food types, nutrients, and their impact on the body. Also, the game should help to improve understanding of a balanced diet and helps in choosing healthier food options.

3.2.3 Collecting Relevant Information: Initial Information for Game Developing

The initial data collection process for game development consists of two primary datasets, as outlined in Figure 3.2, which provides an overview of the data collection process for game design.



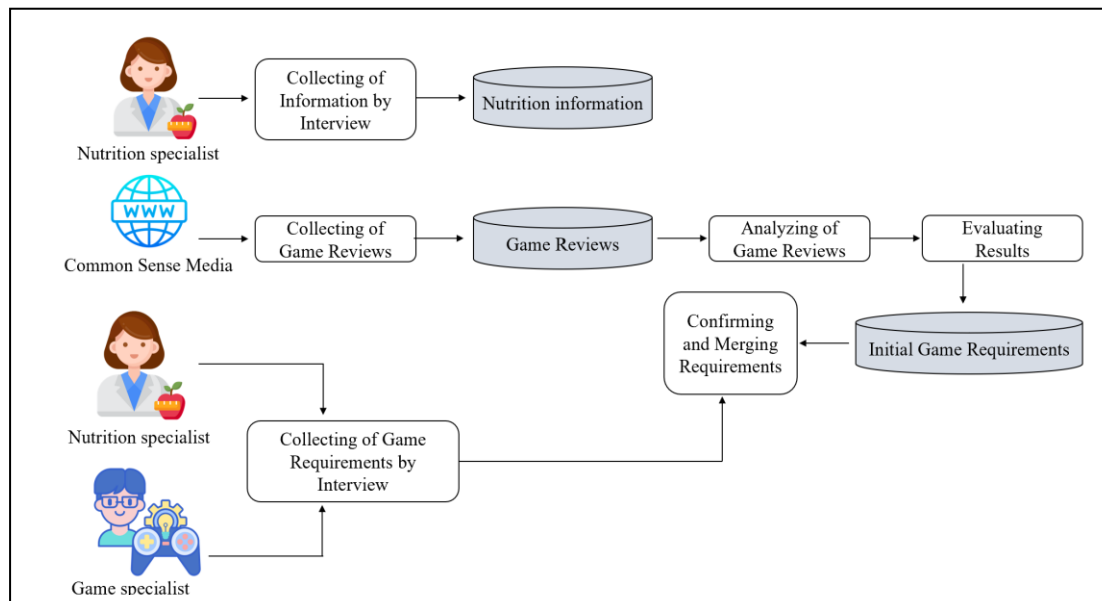


Figure 3.22 An Overview Process of the Initial Data Collection for Game Design

The first dataset involves collecting essential nutritional information for early childhood, which is sourced from experts in nutrition and child development. This data ensures that the game provides accurate, evidence-based, and age-appropriate dietary guidance, effectively supporting young children in developing healthy eating habits.

The second dataset focuses on interactive game design principles tailored for children, specifically to create a nutrition education experience through engaging gameplay. To achieve this, the study adopts a data-driven approach, analyzing user feedback and reviews to identify key factors that contribute to the success or failure of educational games. Reviews of popular educational games from Common Sense Media are examined using *k*-means clustering, which categorizes similar reviews and extracts meaningful insights. The clustering results, validated using *Silhouette Scores* and *Davies-Bouldin Index* metrics, reveal distinct themes in user feedback, identifying critical areas for enhancing educational game design. The findings demonstrate that clustering user reviews effectively differentiates between positive and mixed feedback, providing actionable insights for game developers. This study highlights the importance of systematic user feedback analysis in the game development process, offering a structured, evidence-based approach to creating games that are both engaging and educationally effective. To develop a comprehensive understanding of

user needs, these insights will be combined with survey responses and interview data collected from children who have played educational games, their parents, and caregivers. The integrated dataset will then be analyzed alongside expert recommendations from child development specialists and game design professionals to ensure that the proposed game effectively fosters healthy eating habits among young learners. By incorporating multiple perspectives, this study seeks to establish a well-informed, research-backed framework for designing an educational board game that not only enhances children's understanding of nutrition but also provides a highly engaging and interactive learning experience.

To gather initial information for game design from Common Sense Media, the process of leveraging insights from educational game reviews using k-means clustering can be explained as follows.

1. Benefits of Collecting Initial Information from Game Reviews on Common Sense Media for Game Design

Collecting initial information from game reviews on Common Sense Media offers several advantages in the educational game design process. As a trusted platform that aggregates user-generated feedback from parents, educators, and children, Common Sense Media provides valuable insights into how educational games are perceived in terms of engagement, learning effectiveness, and usability.

One of the primary benefits of analyzing these reviews is the ability to identify key factors that contribute to the success or failure of educational games. By examining patterns in user feedback, developers can gain a deeper understanding of what makes a game engaging, educationally effective, and suitable for different age groups. This allows for a data-driven approach to game design, ensuring that the new educational game incorporates elements that have been positively received while addressing common concerns or limitations reported in previous games.

Additionally, clustering user reviews enables the categorization of player experiences into meaningful themes, such as game mechanics, difficulty levels, learning outcomes, and engagement factors. This categorization helps developers refine game mechanics to ensure that they align with cognitive and developmental needs while maintaining an interactive and enjoyable experience for young learners.

Another significant advantage is that analyzing reviews from Common Sense Media provides real-world user perspectives, which may not always be captured through expert opinions alone. While subject-matter experts contribute essential theoretical insights, user reviews reflect practical, hands-on experiences, revealing usability challenges, motivational aspects, and potential areas for improvement that might not be evident from a purely academic or theoretical standpoint.

Ultimately, leveraging user feedback from Common Sense Media allows for a more structured, user-centered approach to game development, ensuring that the final educational game is not only pedagogically sound but also engaging and enjoyable for its target audience. By integrating these insights into the design process, developers can create a more effective and impactful educational tool that enhances learning outcomes while addressing the needs and preferences of both children and their caregivers.

2. Method of Leveraging Insights from Educational Game Reviews by the k-means Clustering

(1) Datasets

This study utilized educational game reviews from Common Sense Media (<https://www.commonsensemedia.org/game-reviews>). Common Sense Media is a widely respected platform offering detailed reviews and ratings of educational content, including games, movies, books, and apps, specifically targeted at children and families. The game reviews are conducted by experts in education and child development, focusing on each game's educational value, age appropriateness, and content quality. Assessments include the game's support for learning objectives, such as the skills it encourages (e.g., math, literacy, critical thinking), its intuitive and user-friendly nature for the target age group, its capacity to engage and maintain children's interest, and the quality of its content, graphics (i.e. color tone and font), game levels, and award system.

Table 3.1 Characteristics of Data

Components	Definition
Game Title	The name of the educational game.
Age Rating	Recommended age group for the game.
Overall Rating	A star rating (out of 5) summarizing the overall quality of the game.
Detailed Reviews	Narrative reviews that discuss the educational aspects, gameplay, and content quality.
Pros and Cons	Highlighted strengths and weaknesses of the game.
Educational Topics	Specific subjects or skills that the game focuses on (e.g., math, science, reading).
User Ratings	Reviews and ratings provided by parents, teachers, and sometimes children.

This study utilized educational game reviews for Endless Alphabet, Prodigy Math Game, and Minecraft: Education Edition. These games are suitable for children aged 3 and up, 6 and up, and 8 and up, respectively. These examples illustrate the specific information provided by Common Sense Media reviews, offering valuable insights into the educational value and overall quality of each game.

Reviews of these educational games were selected for this study because Prodigy Math Game is well-liked for its curriculum alignment and engaging gameplay, while Endless Alphabet is renowned for its simplicity and effectiveness in teaching early reading. Minecraft: Education Edition is widely appreciated for its adaptability and educational potential across various subject areas. The educational game reviews were downloaded on May 30, 2024. An example of an educational game review is illustrated in Figure 3.1.

Table 3.2 Summary of Dataset

Games	Total number of reviews
Endless Alphabet	200
Prodigy Math Game	500
Minecraft: Education Edition	800

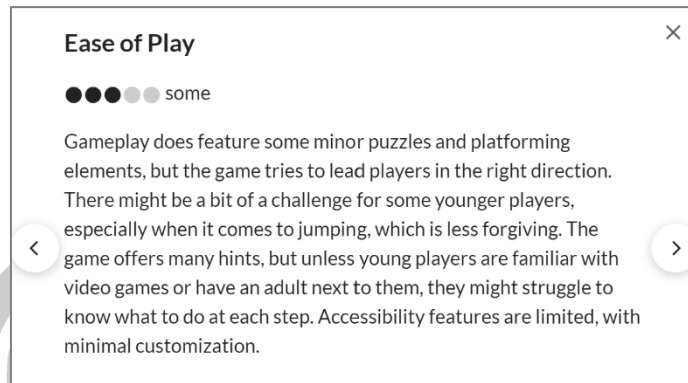


Figure 3.23 An example of educational game review

(2) Method

This section provides a comprehensive explanation of each stage involved in identifying positive reviews that contain user-expressed preferences, which can assist in the design of educational games. This study employed Python and associated libraries, such as NLTK and Scikit-learn.

A. Collecting game reviews – This study applied Web Crawling to collect game reviews from the websites. Web crawling is an essential technique for automated data extraction from websites. One of the most efficient and widely used frameworks for this purpose in Python is Scrapy. It enables the systematic extraction of structured data, making it highly suitable for collecting user-generated content such as reviews, ratings, and comments from websites. In this context, Scrapy can be used to extract user reviews from Common Sense Media for three popular educational games: Prodigy Math Game, Endless Alphabet, and Minecraft: Education Edition.

Scrapy is particularly beneficial for large-scale web scraping tasks due to its asynchronous architecture, which allows multiple web pages to be crawled efficiently. It is faster than traditional scraping libraries because it handles requests concurrently, reducing the overall time required for data collection. Additionally, Scrapy provides built-in mechanisms for data storage, enabling seamless export of extracted information in formats as CSV. To extract user reviews from Common Sense Media for the targeted educational games, a structured approach is required:

a. Identifying Target URLs: The first step involves determining the exact web pages where the reviews are located. Each game has a dedicated review page containing user-generated feedback, ratings, and textual reviews.

b. Setting Up a Web Crawler: A Scrapy spider (a specialized program for crawling web pages) is designed to systematically visit these pages, extract the relevant information, and store it in a structured format.

c. Extracting Review Data: The crawler focuses on retrieving key elements such as game titles, user ratings, and detailed review texts. This extracted information provides insights into user experiences and perceptions of the games.

d. Handling Pagination: Since user reviews may span multiple pages, the web crawler must be capable of navigating through different sections to ensure comprehensive data collection.

e. Data Storage and Processing: Once collected, the review data is stored in an appropriate format, such as a structured database or a JSON file, for further analysis.

B. Pre-processing of educational game reviews - Pre-processing of educational game reviews refers to the series of steps taken to clean, normalize, and prepare text data (in this case, reviews written about educational games) for further analysis, such as clustering. The goal of pre-processing is to convert raw text into a structured and consistent format that can be easily analyzed by clustering algorithms. The following is a comprehensive explanation of each stage of text data pre-processing, along with examples:

Lowercasing: This task converts all characters in the text to lowercase to ensure uniformity. This step helps avoid treating words like “*Game*” and “*game*” as different tokens, which would otherwise introduce redundancy.

Punctuation Removal: This task removes punctuation marks, as they generally do not add semantic value to the text in NLP tasks. This step also reduces noise in the data. For an example,

Input: “Amazing game, highly recommended!”

Output: “Amazing game highly recommended”

Numbers Removal: This task is used to remove numbers unless they are contextually significant (e.g., “*3D games*” might be kept, but “*1234*” might be removed). This step reduces irrelevant numerical data that may not contribute to understanding the text.

Special Characters Removal: This task is used to eliminate special characters (e.g., @, #, \$, %, &) that do not contribute to the semantic meaning of the text. This step helps further clean the data by removing unnecessary symbols.

Prodigy Math Game			
Game	User	Rating	Review Text
Prodigy Math Game	SarahM123	★★★★★ (5/5)	My child absolutely loves Prodigy! It makes math fun and engaging, and I've noticed a big improvement in her problem-solving skills.
Prodigy Math Game	JohnD456	★★★★★ (4/5)	A great way to get kids into math, but some of the premium features feel a bit unnecessary. Wish more was free.
Prodigy Math Game	EmilyK789	★★★★★ (3/5)	My son enjoys it, but he spends more time battling than actually learning. The educational aspect could be stronger.

Endless Alphabet			
Game	User	Rating	Review Text
Endless Alphabet	Parentof2	★★★★★ (5/5)	A wonderful app for teaching vocabulary! The animations are adorable, and my toddler loves it.
Endless Alphabet	Educator99	★★★★★ (4/5)	Great for early learners, but after a while, it gets repetitive. More words would be a nice addition.
Endless Alphabet	DadWithTwins	★★★★★ (5/5)	My kids are learning new words so quickly! It's a fantastic tool for preschoolers.

Minecraft: Education Edition			
Game	User	Rating	Review Text
Minecraft: Education Edition	TeacherMike	★★★★★ (5/5)	I use this in my classroom, and students love it! It's an excellent way to teach problem-solving and creativity.
Minecraft: Education Edition	GamerDad	★★★★★ (4/5)	Great for kids, but the controls can be a bit tricky for younger players. Still, an amazing learning tool.
Minecraft: Education Edition	ScienceFan2024	★★★★★ (5/5)	I love how it incorporates science and engineering concepts into gameplay. Definitely worth using in schools.

Figure 3.24 Example Results of Web Crawling

Tokenization: This task is used to break down the text into individual words or tokens, which can then be analyzed separately. This step is crucial for further processing, such as removing stop words or applying algorithms. For an example,

Input: "Great game, very engaging"

Output: ["great", "game", "very", "engaging"]

Stop-word Removal: English stop words, such as “the,” “and,” and “is,” which do not carry significant meaning, should be removed. This step helps reduce the dimensionality of the data and focuses on the more meaningful words in the text.

Stemming: Stemming is the process of reducing words to their root or base form, often by removing prefixes or suffixes. This study employed the Snowball Stemmer.

C. TF-IDF Vectorization - This study employed TF-IDF vectorization. TF-IDF stands for Term Frequency - Inverse Document Frequency and is a powerful technique for converting text data into numerical form, capturing the importance of terms in documents relative to the entire corpus. This process involves calculating TF-IDF scores for each term in the corpus, resulting in a matrix that can be used for various NLP tasks, such as clustering.

Term Frequency (TF): It calculates the frequency of a term's occurrence in a document, typically by dividing the frequency of a word's occurrence in the document by the total number of words in that document.

$$TF(t, d) = \frac{\text{Number of times term } t \text{ appears in a document } d}{\text{Total number of terms in document } d} \quad 3.1)$$

Inverse Document Frequency (IDF): It measures the importance of a term across the entire corpus, reducing the weight of terms that appear frequently across many documents.

$$IDF(t, d) = \log \left(1 + \frac{\text{Total Number of document } |D|}{\text{Total number of terms in document } d} \right) \quad 3.2)$$

Therefore, *TF-IDF* is the product of TF and IDF highlights words that are significant in a particular document while downplaying common words across all documents. The TF-IDF vector can be used as input for clustering algorithms like k-means to group similar reviews.

D. The Clustering Approaches: k-means Clustering - We employed the k-means approach for this study. This algorithm assigns each review to one of several clusters based on similarity in the feature space. We selected the k-means algorithm for our study due to its unsupervised learning capabilities, which eliminate the need

for pre-labeled data. This makes it advantageous when working with an unlabeled dataset.

The k-means algorithm is a widely used clustering technique that partitions a dataset into k clusters, where each data point belongs to the cluster with the nearest mean (centroid). The algorithm aims to minimize within-cluster variance, defined as the sum of squared distances between data points and their respective cluster centroids. k-means can be particularly useful in analyzing educational game reviews to uncover key themes or insights by grouping similar reviews together. After selecting the number k , the algorithm randomly chooses k initial centroids from the dataset. It then assigns each data point to the nearest centroid, typically measured by Euclidean distance.

$$d(x_i, \mu_j) = \sqrt{(x_{il} - \mu_{jl})^2} \quad (3.3)$$

where n is the number of features.

In this clustering, the objective function is used to minimize the within-cluster sum of squares (WCSS), also known as inertia:

$$WCSS = \sum_{j=1}^k \sum_{x_i \in C_j} \|x_i - \mu_j\|^2 \quad (3.4)$$

where C_j is the set of points in cluster j . $\|x_i - \mu_j\|^2$ is the squared distance between a point x_i and the centroid μ_j .

Afterward, the algorithm recalculates the centroid of each cluster by averaging the features (e.g., average TF-IDF scores) of all reviews in that cluster. The k-means algorithm repeats the assignment and update steps until the centroids stabilize. Convergence is reached, and the clusters are finalized when the centroids no longer undergo significant changes.

In summary, k -means clustering works by iteratively assigning data points to clusters and recalculating centroids to minimize within-cluster variance. The objective is to partition the data into k clusters, where each point is closest to its cluster's centroid. This algorithm is particularly useful for analyzing educational game reviews to uncover key themes or insights by grouping similar reviews together.

This study modified the k-means algorithm by adding a constraint. The constraint requires determining the value of k based on design features defined by a domain expert. These features include (1) characteristics of the game content that may enhance comprehension, (2) the number of stages in the game, (3) the game's color scheme, (4) fonts used in the game, (5) characteristics of game items, and (6) the reward system. Based on these features, k is set to 6. Additionally, the domain expert provides review data to serve as the initial centroids for each cluster.

We expect this will enable us to identify themes more effectively, serving as a foundation for the game design process.

Why This Work Can Be Considered as User-Centered Design (UCD)?

This study aligns with User-Centered Design (UCD) principles because it prioritizes user feedback and experience in shaping the development of an educational game. UCD is a design approach that involves users at every stage of the development process, ensuring that the final product meets their needs, preferences, and usability expectations.

1. Incorporating Real-World User Feedback into Game Design - A key characteristic of UCD is designing based on actual user needs, behaviors, and experiences rather than relying solely on theoretical frameworks. This study analyzes user reviews from Common Sense Media, a platform where parents, educators, and children share their experiences with educational games. By clustering these reviews, the study identifies patterns of user engagement, learning effectiveness, usability issues, and game mechanics preferences, ensuring that the game is designed with direct input from its target audience.

2. Data-Driven Refinement Based on User Experience - Instead of making assumptions about what makes an educational game effective, this approach leverages user-generated data to refine the game mechanics. By using k-means clustering, the study categorizes user feedback into meaningful themes such as difficulty levels, motivation, interaction quality, and educational value. This iterative process—where insights from users drive game adjustments—mirrors the user-centered design cycle of research, prototype, testing, and refinement.

3. Addressing User Needs and Pain Points - UCD emphasizes designing solutions that solve real problems for users. By examining user feedback,

this work directly identifies common frustrations and limitations in existing educational games. Issues such as engagement gaps, ineffective learning strategies, or poor usability are systematically addressed, ensuring that the game is both pedagogically sound and enjoyable for young learners.

4. Enhancing Usability Through Iterative Design - A critical aspect of UCD is iterative design, where user feedback is continuously incorporated to refine the product. In this study, findings from game reviews will be further integrated with survey responses and interviews from children, parents, and caregivers to deepen the understanding of user expectations. Expert recommendations from child development specialists and game design professionals will also be incorporated, ensuring that the final product aligns with both scientific principles and real-world usability.

In summary, this work exemplifies UCD by systematically involving real user feedback, iterative refinement, and data-driven decision-making in the game development process. By integrating insights from children, parents, educators, and experts, the study ensures that the final game is engaging, educationally effective, and tailored to the needs of its young audience.

E. Confirming and Merging Game Requirements by Specialists - After gathering relevant information for game design through web crawling, game specialists, and nutrition specialists, the collected data was carefully reviewed and refined by experts in both game development and nutrition to ensure its accuracy, relevance, and effectiveness for the intended audience. This expert-driven refinement process helped align the game's design with educational and nutritional objectives, ensuring that it meets both engagement and learning criteria. A summary of the initial information for game design is presented in Table 3.3.

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Table 3.3 A summary of the extracted initial information for game design in this study

Aspects	Key Findings	Design Recommendations
Information related to Content (Engagement & Learning Value)	Games should balance education and fun, avoid repetitiveness, and have adaptive difficulty.	<ul style="list-style-type: none"> • Keep learning objectives clear. • Introduce variety in challenges. • Provide interactive explanations.
Information related to Graphics (Color & Font)	Bright colors work well for young learners, but overstimulation and readability should be considered.	<ul style="list-style-type: none"> • Use soft or dynamic color tones depending on age groups. • Allow font customization for accessibility.
Information related to the Award System (Motivation & Progress Tracking)	Meaningful rewards improve engagement, but over-reliance on premium content can be problematic.	<p>Use achievement-based rewards.</p> <p>Implement progress tracking to maintain long-term motivation.</p> <ul style="list-style-type: none"> • Offer customizable incentives like avatars or new content.
Information related to Game Levels	The number of game levels	Between 5 and 10 levels
General information	Overall user impressions, general gameplay experience, ease of use, user engagement, and broad comments that do not fit into specific categories like content, graphics, rewards, or game levels.	-

3.2.4 Key Insights for Implementing Nutrition Knowledge in a Healthy Eating Game for Young Children

The core idea behind integrating nutrition knowledge into the educational game for young children is to ensure that scientific dietary guidelines are effectively transformed into engaging, interactive gameplay elements. This is achieved through constructivist learning principles, data-driven design, and behavioral reinforcement mechanisms.

- *Data-Driven Knowledge Structuring*
 - CHNS Data Mapping: Nutritional guidelines are tailored to regional dietary patterns (e.g., addressing the low intake of fruits and vegetables in South China). Game tasks, such as achieving 70% of CHNS-recommended fruit and vegetable intake, reinforce real-world nutritional habits.
 - Granularity Grading: Learning progression follows Vygotsky's Zone of Proximal Development, where basic tasks involve simple food classification (e.g., identifying unhealthy "red light foods"), while advanced tasks introduce nutrient calculations (e.g., protein intake estimation).
- *Constructivist-Oriented Task Design*
 - Contextual Problem-Solving: Players engage in real-life-inspired decision-making (e.g., selecting food for a picnic based on activity level and weather conditions). This fosters higher-order thinking and knowledge reconstruction rather than rote memorization.
 - Mis-Choice Boot Mechanic: When a child makes an unhealthy choice (e.g., selecting a high-sugar drink), NPC guidance is triggered, prompting dialogue-based self-reflection rather than direct correction. This encourages children to internalize healthy choices through active learning.
- *Interdisciplinary Integration for Behavioral Change*
- Nutrition-Pedagogical Coupling: Dietary recommendations are embedded into game mechanics (e.g., limiting sodium intake in a kitchen simulation task where the player is restricted to using a salt shaker only three times).
- Cognitive-Behavioral Theory Reinforcement: The stimulus-response-reward system is embedded within the game (e.g., choosing whole grains boosts

character abilities, reinforcing positive dietary behaviors through immediate feedback).

In summary, the primary goal of embedding nutrition knowledge in the game is to immerse children in an interactive learning environment where they actively apply dietary principles through problem-solving, guided feedback, and behavioral reinforcement. By incorporating real-world dietary data, gradual learning progression, and engaging mechanics, the game effectively fosters healthy eating habits in a way that is both educational and enjoyable.

3.1.6 Game Storyline and Sequence of Events

The game uses narrative-driven learning, decision-based gameplay, and interactive challenges to promote healthy eating habits in an engaging and culturally adaptive way. The combination of real-world food decisions, dynamic feedback, and gamified rewards makes the learning process immersive and fun for young players. Below is a structured storyboard outlining the flow of the game:

1. Introduction Scene (Setting the Narrative)

- Title: “*Save the Nutrition Planet!*”
- Background Story: Players assume the roles of young "Nutrition Explorers" tasked with restoring balance to the Nutrition Planet, which is under threat due to unhealthy eating habits.
- Main Goal: Players must complete nutrition-based challenges to collect “*Health Points*” and earn rewards that help their team.

2. Character Selection Scene

- Players choose avatars (e.g., Kid Explorers, Nutrition Scientists, Health Guardians).
- Each character has special abilities based on nutrition knowledge (e.g., “*Dietary Energy Wave*” is activated by choosing the right food).

3. Interactive Learning Challenges

A. Decision-Making Tasks

1) Supermarket Shopping Quest:

- Players are given a budget and must choose healthy foods while balancing nutrition and cost.
- The food pyramid serves as a guide.

- If players buy too much junk food, they trigger the “Health Crisis” event, requiring corrective actions.

2) Family Meal Planning Task:

- Parents can participate as “*Nutrition Consultants*” to co-design meal plans.
- Players classify foods into categories (protein, fiber, vitamins) and create a balanced diet.

B. Cultural Adaptation Challenges: Guangdong Morning Tea Challenge

- Players match traditional Lingnan foods with healthy dietary guidelines.
- Cultural symbols are integrated, reinforcing regional food education.

4. Dynamic Feedback and Game Progression

A. Interactive Story Branching

- Choosing different food cards leads to different game paths.
- Unhealthy choices (e.g., too much fried food) result in “Health Crisis” scenes, requiring players to fix their mistakes before proceeding.

B. Visual Feedback & Performance Metrics

- Players earn Health Points and track progress on a Nutrition Dashboard.
- Health performance is visualized with a “*Vitality Score*” to compare real-life improvements.

5. Rewards & Incentives System

A. Points & Badge System

- Players earn Nutrition Expert Badges (Bronze, Silver, Gold) based on progress.
- Advanced players unlock special skills (e.g., knowledge about fiber-rich foods).

B. Virtual Economy & Social Features

- Players earn Health Coins to buy in-game resources (e.g., rare food cards, character upgrades).
- A leaderboard ranks players based on health coins & quiz scores, encouraging friendly competition.

6. Closing Scene (Game Wrap-Up & Learning Reflection)

- Players receive a summary of their food choices and how they impacted the Nutrition Planet.
- A final nutrition report compares their in-game choices with real-world dietary habits.
- Parents and teachers can review performance metrics, reinforcing real-life behavior change.

3.3 Theoretical Mapping and Process Integration

This section presents the integration of four core theories—Game-Based User-Centered Design (UCD), Educational Game Theory, Interactive Learning Theory, and Gamification Elements Theory—across the research process. Each theory was systematically applied to ensure a conceptually grounded approach to the design, development, and evaluation of the educational game. The relationship between research activities and theoretical foundations is clarified to demonstrate how the outputs from each step contribute to the next, thereby creating a coherent and structured methodological framework.

3.3.1 Game-Based User-Centered Design (UCD)

Game-Based UCD was employed during the initial design phase of the educational game (Section 3.2), ensuring that the prototype responded to the actual needs and preferences of the target users—Grade 2 students. Iterative prototyping and direct observation of student feedback during early playtesting allowed for refinements in usability, interface clarity, and interaction flow. Furthermore, insights from online educational game reviews (Section 3.4) were used to enhance user-centered features. This combination of empirical and design-driven input reinforced the central role of the user in shaping gameplay mechanics and learning interactions.

3.3.2 Educational Game Theory

Educational Game Theory informed the formulation of game content and structure by ensuring that pedagogical principles were embedded within the game's narrative and tasks. As outlined in Section 3.2, game activities were designed to align with learning objectives related to a healthy diet. This theory also guided the incorporation of intrinsic and extrinsic motivators, such as storytelling, challenge

progression, and reward feedback, creating a seamless link between cognitive engagement and educational purpose.

3.3.3 Interactive Learning Theory

Interactive Learning Theory underpinned the design of the game's collaborative and feedback mechanisms, which were evaluated in Sections 4.3 and 5.2. Features such as in-game decision-making, exploration-based tasks, and immediate feedback loops were developed to promote active learning. These elements supported the constructivist principle that learners construct knowledge through interaction with content and peers. Learning effectiveness was measured using pre- and post-tests, as well as observational data, providing empirical support for this theoretical alignment.

3.3.4 Gamification Elements Theory

Gamification Elements Theory guided the selection and implementation of motivational components throughout the game. Clustering of user review data (Section 3.4) revealed high-frequency gamification features such as badges, levels, avatars, and point systems, which were associated with increased engagement and positive sentiment. These findings were used to inform the game's feature set, making gameplay more engaging while reinforcing learning objectives. The presence of these elements was later evaluated to determine their impact on student motivation and sustained interaction.

3.3.5 Integration Workflow

The research process was structured as a multi-stage pipeline in which each phase contributed outputs that were necessary for the next. Theories were mapped to corresponding stages to ensure theoretical grounding and practical alignment. Table 3.1 illustrates the mapping of each theory to the research process and highlights the outputs and benefits of each stage.

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Table 3.4 Mapping of Theories to Research Process Stages

Research Stage	Applied Theory	Key Output	Contribution to Next Stage
Game Review Analysis (Section 3.4)	Gamification, UCD	Clustered user preferences and feature insights	Informs design decisions for game development
Game Design and Prototyping (3.2)	UCD, Educational Game Theory	Game prototype with learning tasks and gamified features	Sent for user testing and refinement
User Testing and Evaluation (4.3)	Interactive Learning Theory, Gamification	Behavioral data, learning performance, engagement	Provides evidence of learning outcomes and user satisfaction
Final Analysis and Reflection (Chapter 5)	All theories	Theoretically grounded interpretation of results	Supports conclusions and future development

3.3.6 Review Clustering and Data Interpretation

In this study, clustering was employed as an unsupervised learning method to analyze user-generated reviews of educational games, with the objective of uncovering implicit patterns in user sentiment and design preferences. Specifically, the K-Means algorithm was applied with $k = 3$, corresponding to three overarching sentiment categories: positive, neutral, and negative. Each review was converted into a TF-IDF vector and grouped into clusters based on semantic similarity. The primary data obtained from clustering includes:

- **Sentiment Grouping:** The reviews were automatically categorized into three sentiment-based clusters. This classification provided insights into the general attitude of users toward educational games without the need for manually labeled data. These unsupervised groupings were later validated through expert interpretation to ensure semantic coherence.
- **Thematic Content Patterns:** Beyond sentiment, the clustering also revealed dominant themes across the dataset. These included frequently mentioned elements

such as game usability, instructional effectiveness, visual appeal, and user engagement. For example, clusters with high-frequency terms like “fun,” “easy to use,” and “interactive” were associated with positive sentiment and high engagement, while clusters with terms like “confusing” or “repetitive” indicated areas needing design improvement.

- **Gamification Feature Preferences:** The clustering highlighted specific gamification features frequently referenced in user feedback, such as point systems, avatars, levels, and rewards. This information was crucial for informing the design of the educational game in this study. Features that appeared consistently in positively clustered reviews were prioritized in the game’s feature set.

The insights gained from this clustering process played a central role in bridging theory and design. By understanding which features and experiences were most associated with positive or negative perceptions, the development process could be better aligned with User-Centered Design (UCD) and Gamification Elements Theory. Thus, clustering not only served as an analytical tool but also as a design-informing mechanism that directly influenced feature selection and iteration in the prototyping phase.

This theoretical mapping clarifies the interdependence of research activities and ensures that the entire process—from data collection to analysis—is grounded in educational theory. By integrating theoretical frameworks at each stage—particularly through the application of clustering to extract user sentiment and design preferences—the study enhances both academic rigor and design relevance. This framework enables a theory-informed, data-driven approach to educational game development that aligns with the learning goals and user needs of the target audience.

3.4 Developing a Board Game for Interactive Learning on Healthy Eating for Elementary School Students

Healthy eating habits play a crucial role in children's growth, cognitive development, and overall well-being. However, traditional nutrition education methods often struggle to fully engage young learners. To make learning about nutrition more interactive and enjoyable, this study focuses on developing a board game that promotes healthy eating knowledge through play-based learning. By

incorporating gamification elements, role-playing, and decision-making tasks, the game encourages students to actively participate in nutrition-related activities. Through hands-on gameplay, students can explore real-world food choices, develop an understanding of balanced diets, and reinforce key dietary principles in an engaging and memorable way. This educational board game aims to enhance children's nutrition knowledge while fostering long-term healthy eating behaviors.

3.4.1 Game Color and Font Specification

To enhance the visual appeal, accessibility, and engagement of the healthy eating educational board game for elementary school students, the color scheme and typography are carefully selected to prioritize readability, cognitive ease, and thematic consistency. The initial specifications for color and font selection are informed by the guidelines outlined in Section 3.1.3.

1. Color Scheme - The game uses a bright, vibrant, and friendly color palette that enhances player engagement while reinforcing the theme of healthy eating. The chosen colors align with nutritional elements and psychological principles of color perception in children:

- Primary Colors: Green, Red, and Orange
- Secondary Colors: Yellow, Blue, and Purple

2. Font Specification - Typography in the game prioritizes clarity, readability, and playfulness, ensuring that young players can easily read the content while maintaining an engaging and fun experience. The recommended fonts include Microsoft Yahei, Orchid ting black, Courage Kid, Kids Komik, Kids Place Font. These fonts were selected based on their readability, visual appeal, and suitability for the educational context of the board game.

By implementing these color and font specifications, the game maintains aesthetic appeal, functional clarity, and an immersive educational experience for elementary school students.

3.4.2 Development of Board Game Items Using Plastic

The development of board game items using plastic allows for the creation of visually appealing, child-friendly, and long-lasting components, making them suitable for both educational and recreational purposes. Additionally, plastic materials offer

flexibility in design, enabling the production of intricate game pieces, interactive elements, and custom features that enhance user engagement.

This study explores the advantages of using plastic materials in board game development, focusing on aspects such as safety, durability, aesthetic appeal, and ease of maintenance. Furthermore, it examines how material selection influences game design and player experience, particularly for young learners and family-oriented games.

The use of plastic in board game development provides practical, aesthetic, and functional advantages, making it an ideal material for producing high-quality, durable, and visually engaging game components. With its versatility, cost-effectiveness, and safety features, plastic remains a preferred choice for both educational and recreational board games, ensuring that players of all ages can enjoy an immersive and long-lasting gaming experience.

Positive reasons for using bright-colored plastic materials in early childhood items are:

- *Safety and Durability* – Plastic materials used for early childhood items are designed to be lightweight, impact-resistant, and free from sharp edges, reducing the risk of injury. Their durability ensures long-term usability, even with frequent handling.

- *Visual Stimulation and Cognitive Development* – Bright colors attract young children's attention, enhance visual perception, and support cognitive development. Exposure to vibrant colors helps in color recognition and memory retention.

- *Engagement and Playfulness* – Vivid colors make learning materials and toys more engaging, encouraging exploration, creativity, and interactive play, which are essential for early childhood learning.

- *Easy Maintenance and Hygiene* – Plastic is easy to clean, making it a hygienic choice for items used by young children. It resists moisture and bacteria, ensuring a safe and sanitary play environment.

- *Versatility in Design* – Plastic materials allow for the creation of a wide variety of shapes, textures, and functionalities, making them suitable for different educational tools, sensory toys, and developmental aids.

3.4.3 Board Game Materials

A well-structured board game consists of several essential components that enhance gameplay, engagement, and learning. The following materials are designed to support an interactive and educational experience focused on nutrition and healthy eating:

A. Core Game Components: Core game components are the essential physical and functional elements required for a board game to operate effectively. These components shape the gameplay experience, ensuring clarity, engagement, and smooth game mechanics. The following are key core game components:

1. *Game Board* – The central playing surface where players navigate challenges, complete tasks, and progress through the game.
2. *Game Cards* – A set of cards containing questions, challenges, or rewards related to nutrition and healthy habits. These encourage interactive learning.
3. *Tokens/Pieces* – Player markers or character pieces used to represent each participant's progress on the board.
4. *Dice* – A game element used to determine movement and introduce an element of chance, ensuring variability in gameplay.
5. *Player Markers* – Individual pieces that indicate each player's position or status within the game.
6. *Coins/Game Currency* – “Health Coins” earned through completing tasks and achieving milestones, which can be used for in-game rewards.
7. *Scoreboard* – A tracking system that displays players' points, achievements, or overall progress throughout the game.
8. *Instruction Manual/Rulebook* – A comprehensive guide outlining the game rules, objectives, and step-by-step instructions on how to play.

B. Game Mechanics Components: Game mechanics components refer to the interactive systems and rules that govern how players engage with a board game. These components dictate game flow, player actions, progression, and decision-making, ensuring an engaging and balanced gameplay experience. In this study, the following are key game mechanics components:

1. *Life System (Gems)* – Players start the game with 10 lives, represented by 10 gems.

- After rolling the dice, one gem is deducted, indicating a reduction in remaining lives.

- This method continues until all lives are used or objectives are completed.

2. *Progression and Reward System* – Various milestones, achievements, and in-game rewards keep players motivated and engaged.

3.4.4 The Proposed Board Game for Interactive Learning Relevant to Healthy Diet for Elementary School Students

This section introduces the development of an interactive educational board game designed to promote healthy eating habits among elementary school students. The game incorporates engaging mechanics, visually appealing elements, and an interactive learning approach to enhance students' understanding of nutrition, food choices, and balanced diets in an enjoyable and meaningful way.

The proposed board game is structured to encourage active participation, strategic thinking, and collaborative learning through a variety of tasks, challenges, and rewards. It features a game board, nutrition-themed cards, tokens, player markers, dice, health coins, and a scoreboard, all carefully designed to align with age-appropriate cognitive and motor skills. The game mechanics are tailored to reinforce key educational concepts while maintaining an element of fun and motivation.

By integrating gamification strategies, this board game aims to transform traditional nutrition education into an interactive experience, fostering better decision-making skills, knowledge retention, and a positive attitude toward healthy eating. The following sections provide an in-depth explanation of the game's design, components, rules, and educational benefits.

The following images displays the equipment used for gaming.

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Figure 3.25 An Overview of Board Game Map for Little Nutrition Explorers



Figure 3.26 Board Game Map for Little Nutrition Explorers



Figure 3.27 Material Textures for Board Game Map



Figure 3.28 Board Game Cards



Figure 3.29 Characters in Board Game



Figure 3.30 Life Gem in Board Game



Figure 3.31 Coins for Scoring in Board Game



Figure 3.32 Dice for Board Game

The following images shows the game in action.



Figure 3.33 Board Game On-Site (1)



Figure 3.34 Board Game On-Site (2)

3.4.5 PC-based Board Game for Interactive Learning Relevant to Healthy Diet for Elementary School Students

This section presents the development of an interactive educational board game designed for Personal Computers (PCs), aimed at promoting healthy eating habits among elementary school students. The digital adaptation of the board game leverages interactive features, engaging visuals, and gamified learning experiences to enhance students' understanding of nutrition, balanced diets, and healthy lifestyle choices in an immersive and dynamic environment.

The proposed PC-based board game incorporates interactive challenges, multimedia elements, and adaptive learning mechanics to foster active participation, critical thinking, and decision-making skills. Key components include a digital game board, animated nutrition-themed cards, virtual tokens, player avatars, a scoring system, and in-game rewards, all designed to ensure an engaging and accessible learning experience.

By utilizing digital gamification strategies, this board game transforms traditional nutrition education into an interactive and adaptive learning tool. The integration of sound effects, animations, and real-time feedback enhances user engagement while reinforcing key nutritional concepts in an age-appropriate and enjoyable manner.

The following images display the screen used for PC-based board gaming.



Figure 3.35 Video Game Interface Design: Page Layout and Scoring Status During Gameplay



Figure 3.36 Video Game Interface Design: Card Flipping During Gameplay



Figure 3.37 Video Game Interface Design: Game End Score Screen

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Figure 3.38 Students playing the PC-based game

3.5 Sentiment Analysis for Educational Game Evaluation

Sentiment analysis [101] is a Natural Language Processing (NLP) technique used to determine the emotional tone, attitude, or opinion expressed in text. It categorizes text into positive, neutral, or negative sentiment and can be applied to various domains such as customer feedback, social media analysis, and educational research.

Sentiment analysis is a powerful tool for evaluating educational games, providing quantitative insights into user experiences. By applying it to student and parent feedback, developers can make data-driven improvements, enhancing game effectiveness in education and engagement.

In this study, sentiment analysis was also applied to assess the perceptions of both students and parents regarding the proposed educational game. The sentiment analysis process followed the same methodology outlined in Section 3.1.3 (2).

To conduct this analysis, interviews were conducted, and the audio responses were transcribed into text. The collected text data was then categorized into three

sentiment groups: Positive Cluster (for participants who expressed a favorable opinion), Neutral Cluster (for those with neutral views), and Negative Cluster (for those who expressed dissatisfaction).

To ensure representative clustering, domain experts selected key opinions to serve as centroids (or center points) for each sentiment group. The K-Means Clustering algorithm was then applied with $K = 3$ to group similar responses. The performance of the sentiment classification was evaluated using recall [102], precision [103], and F1-score [104] to measure its accuracy and effectiveness. [105]

In clustering, precision, recall, and F1-score are used to evaluate how well the clustering algorithm groups similar data points together compared to the actual (ground truth) labels.

Precision in clustering measures the purity of a cluster, meaning how many of the data points in a cluster actually belong to the same true category.

$$Precision = \frac{TP}{TP + FP} \quad (3.5)$$

where:

TP (True Positives) = Data points correctly assigned to the cluster.

FP (False Positives) = Data points incorrectly assigned to the cluster.

Suppose we cluster game reviews into three groups: Positive, Neutral, and Negative using K-Means.

The model assigns 50 reviews to the “Positive” cluster.

However, only 40 reviews actually belong to Positive, while 10 are Neutral or Negative (False Positives).

$$Precision = 40 / (40 + 10) = 0.8 \text{ (80\%)}$$

This means that 80% of the reviews in the "Positive" cluster are truly Positive.

Recall measures how many of the actual data points from a true category were correctly assigned to the right cluster. It answers: “Out of all actual positive reviews, how many were placed in the Positive cluster?”

$$Recall = \frac{TP}{TP + FN} \quad (3.6)$$

where:

TP (True Positives) = Correctly clustered data points.

FN (False Negatives) = Data points that belong to the category but were incorrectly assigned to another cluster.

Example:

There are 60 actual Positive reviews in the dataset.

The clustering algorithm correctly places 40 of them in the Positive cluster, but 20 were wrongly placed in Neutral or Negative clusters (False Negatives).

Recall = $40 / (40 + 20) = 0.67$ (67%)

This means only 67% of all actual Positive reviews were correctly grouped together.

F1-Score is the harmonic mean of Precision and Recall, providing a balanced measure of clustering performance. It helps when there is an imbalance between Precision and Recall.

$$F1 - score = 2 \times \frac{Precision \times Recall}{Precision + Recall} \quad (3.7)$$

Example Calculation (Using Previous Data): Precision = 0.8 (80%) and Recall = 0.67 (67%)

$$F1 - score = 2 \times \frac{0.8 \times 0.67}{0.8 + 0.67} = 0.73 \text{ (73\%)}$$

This means that the overall clustering effectiveness for the Positive cluster is 73%.

3.6 Summary of Evaluation Techniques and Metrics

To provide a comprehensive view of how the effectiveness of each component in the research process was assessed, Table 3.4 summarizes the evaluation techniques applied in Chapter 4, including key metrics and their interpretations.

Table 3.5 Summary of Evaluation Techniques and Metrics

Evaluation Focus	Purpose	Metrics / Tools Used	Result Interpretation
1. Clustering Educational Game Reviews	Identify core themes to inform game design	Silhouette Score Davies-Bouldin Index	Moderate cluster separation. Insights validated by experts to guide content (e.g., game levels, visuals)
2. Expert Validation of Game Design	Evaluate game content accuracy and usability	Using N-GUT Scale Evaluation (Expert Review) Mean scores across 4 dimensions Standard Deviation (SD) % of ratings ≥ 4 Cronbach's $\alpha = 0.87$	High validity and consistency in scientific content, adaptability, and behavioral impact
3. Learning Effectiveness	Measure knowledge gain in nutrition topics	Using Paired Sample T-Test Pre-test & post-test mean scores t -value p -value	Statistically significant improvements ($p < 0.01$) in food classification, nutrients, and meal pairing
4. Behavioral Engagement	Compare engagement patterns (exp. vs control group)	Using Behavior Tracking with Muggeda System + Cohen's d Effect Size Task Completion Rate Daily Login Rate Challenge Retry Count Health Coin Use Variance	Large effect sizes (Cohen's $d > 1.5$) show higher persistence and engagement in experimental group
5. Sentiment Toward Game Formats	Analyze user feedback from students & parents	Precision Recall F1-score Grouped into Positive, Neutral, Negative	Students prefer digital game (positive sentiment); parents prefer tabletop version. F1-scores show classification validity

CHAPTER IV

EVALUATION AND DISCUSSION

This chapter presents the study results, including a multidimensional evaluation. The assessment covers several aspects and can be detailed as follows.

4.1 Evaluation of Information Using the K-Means Clustering Method to Leverage Insights from Educational Game Reviews

This section presents a concise summary of the experimental results. The clustering performance was evaluated using the Silhouette Score and Davies-Bouldin Index. The identified clusters are as follows:

- Cluster-1: Information related to Content (Engagement & Learning Value)
- Cluster-2: Information related to Graphics (Color & Font)
- Cluster-3: Information related to the Award System (Motivation & Progress Tracking)
- Cluster-4: Information related to Game Levels
- Cluster-5: General information

The results are presented in Table 4.1.

Table 4.6 Evaluation of Information Using the K-Means Clustering Method to Leverage Insights from Educational Game Reviews

Clusters	Silhouette Score	Davies-Bouldin Index Score	Information Acceptance Considered by Experts
Cluster-1	0.35	2.20	Accepted
Cluster-2	0.30	2.10	Accepted
Cluster-3	0.35	2.20	Accepted
Cluster-4	0.35	2.20	Accepted
Cluster-5	0.30	2.10	Accepted
Average Scores	0.33	2.16	

The Silhouette Scores for all clusters range between 0.3 and 0.35, indicating a moderate clustering quality. Specifically, Clusters 1, 3, and 4 achieved a score of 0.35, suggesting a slightly better-defined cluster structure than Clusters 2 and 5, which both received a score of 0.3.

A Silhouette Score of 1 represents perfect clustering, while a score of 0 indicates that data points are situated between clusters, leading to weak separation. Scores below 0.3 suggest poor clustering quality, while values between 0.3 and 0.5 are considered moderate, particularly for small datasets. The results suggest that while some meaningful grouping has been achieved, there is still considerable overlap among clusters, indicating that the boundaries between clusters are not strongly defined.

The slightly higher Silhouette Scores of 0.35 for Clusters 1, 3, and 4 suggest that these clusters exhibit a more compact and internally consistent structure compared to Clusters 2 and 5. However, since no cluster achieves a score above 0.5, it indicates that the reviews within each cluster are not well-separated from other clusters, leading to possible misclassifications.

The DBI scores for the clusters range between 2.1 and 2.2, which reflects a relatively high level of cluster overlap. Since lower DBI values indicate better clustering, these results suggest that the clusters may not be well-separated. Ideally, a DBI close to 0 represents distinct, well-separated clusters, while values above 2.5 indicate significant overlap.

In this case, Clusters 2 and 5 have the lowest DBI score of 2.1, suggesting slightly better separation compared to Clusters 1, 3, and 4, which have a DBI score of 2.2. However, the difference is minimal, indicating that all clusters exhibit a similar degree of dispersion and overlap. The relatively high DBI scores reinforce the observation that some reviews may share characteristics across multiple clusters, leading to ambiguity in classification.

The results suggest that the educational game reviews contain overlapping content across multiple aspects, including content engagement, graphics, reward systems, game levels, and general information. The moderate Silhouette Scores and relatively high DBI values indicate that while the K-Means clustering method was

able to group the reviews into five meaningful categories, the clusters are not clearly distinguishable from one another.

However, the insights extracted from the game reviews as an initial dataset for game design were validated by experts. The experts agreed that the extracted information is valuable and can serve as a foundational reference for designing and improving educational games. Their feedback confirms that, despite the moderate clustering quality, the categorized aspects provide meaningful insights that can guide the development process, ensuring that the game aligns with user expectations and educational objectives.

4.2 Expert Evaluation of the Nutrition Educational Game Using the N-GUT Scale

The purpose of this evaluation is to verify the expertise-based evaluation of a nutrition-related educational game using the N-GUT scale (a specialized assessment tool for nutrition game applicability, with a reliability score of $\alpha=0.87$). The goal of this metric used is to assess the applicability of nutrition-related educational games. Four dimensions (or aspects) are evaluated. They are Scientific accuracy, Completeness of knowledge coverage, educational content adaptability, and Applicability of Behavioral Interventions based on the Dietary Guidelines for Chinese Residents. The results of evaluation can be presented as Table 4.2.pd

Table 4.7 Expert Evaluation of the Nutrition Educational Game Using the N-GUT Scale

Evaluation Aspects	Score	S.D.	Percentage of Ratings ≥ 4
Scientific accuracy	4.53	0.61	93.3%
Completeness of knowledge coverage	4.47	0.64	86.7%
Educational content adaptability	4.33	0.72	80.0%
Applicability of Behavioral Interventions	4.20	0.77	73.3%

In Table 4.2, the scientific accuracy aspect emerged as the strongest, receiving the highest score (4.53/5, 93.3%). This confirms that key components, such as dietary pyramid integration and nutrition calculation, are professionally accurate and reliable.

The knowledge coverage aspect also received a high score, indicating that the game content covers 86.2% of the core knowledge points outlined in the dietary guidelines. While this suggests that most essential nutritional knowledge is included, there is still room for minor enhancements to ensure more comprehensive coverage.

One key area for improvement is cultural adaptation. Experts recommended enhancing the representation of regional food cultures, such as incorporating the Lingnan medicinal diet, to make the game more applicable to diverse populations. This highlights a gap in how well the educational material reflects regional dietary habits.

Overall, the assessment confirms the credibility of the game's educational content. It identifies key strengths, including scientific accuracy and knowledge coverage, while also highlighting areas for refinement, particularly in cultural adaptation. These findings serve as a foundation for enhancing the game's relevance and effectiveness in delivering nutrition education.

4.3 Effectiveness of the Educational Game on Health Knowledge: Pre- and Post-Test Comparison

The stage is to evaluate the effectiveness of an educational game intervention in improving students' health knowledge by comparing their pre-test and post-test scores using a *paired sample T-test* [106]. The steps of analysis can be conducted as follows.

1. Participants:
 - 30 students from the experimental group participated in the study.
 - Those students completed three full rounds of the game intervention.
2. Assessment Tool:
 - A composite health knowledge test was administered before (pre-test) and after (post-test) the intervention.
3. Statistical Analysis:
 - A paired sample T-test was used to determine whether there was a significant improvement in students' knowledge after playing the game.
 - Key test indicators: Food classification, Nutrient identification, Meal pairing, and Health risk assessment.
4. The Results: The results have been presented as Table 4.3.

Table 4.8 Pre- and Post-Test Comparison using A paired sample T-test

Test dimensions	The mean of the pretest	Post-test mean	Margin of progress	t-value	p-value
Food classification	6.8±1.2	8.9±0.9	+30.9%	7.21	<0.01
Nutrient identification	5.1±1.5	7.4±1.1	+45.1%	5.94	<0.01
Meal pairing	7.2±1.8	10.3±1.3	+43.1%	6.75	<0.01
Health risk assessment	6.1±2.	8.7±1.5	+42.6%	5.23	0.02

In Table 4.3, it can be seen that the post-test scores show a clear and significant improvement compared to the pre-test scores in all assessed categories. The level of improvement varies, with knowledge gains ranging from 30.9% to 45.1% across different topics. Additionally, the T-values for all categories are positive, and the p-values are less than 0.01 for most indicators, confirming that these improvements are statistically significant. This strong statistical evidence suggests that the educational game had a meaningful and reliable impact on enhancing students' health knowledge.

In summary, the results suggest that the educational game effectively enhanced students' health knowledge across multiple dimensions. The significant improvement in post-test scores confirms that the game positively impacted learning outcomes in food classification, nutrient identification, meal pairing, and health risk assessment.

4.4 Analysis of Gameplay Behaviors

This section evaluates player behavior data to analyze how users interact with the educational game. The study captures detailed gameplay behaviors using the Mugeda background tracking system, monitoring 46 users over a specific period from September to December 2024.

How the evaluation is conducted:

1. Data Collection Method:

- The Mugada tracking system records players' behavioral patterns during gameplay.
- Data is gathered from both the experimental group (those who used the intervention/game) and the control group (those who did not).

2. Behavioral Indicators Measured:

- Task Completion Rate → Measures the percentage of tasks successfully completed.
- Daily Repeat Login Rate → Tracks how often users return to the game daily.
- Number of Retries of the Challenge Card → Counts how many times users attempt a challenge card, indicating engagement and persistence.
- Health Coin Consumption Bias → Measures variability in how players use in-game currency (Health Coins).

The results have been presented as Table 4.4.

Table 4.9 The results of gameplayer behavior analysis

Indicator category	Experimental group mean	Control group mean	Cohen's d
Task completion rate	83.7%	61.2%	1.87
Daily repeat login rate	72.9%	37.4%	2.31
The number of retries of the challenge card	2.8 times/task	0.9 times/task	1.52
Health Coin Consumption Bias	$\sigma = 0.32$	$\sigma = 0.87$	-

3. Comparing Experimental and Control Groups:

- The experimental group consistently outperforms the control group, showing higher engagement and persistence.
- Cohen's d values (effect sizes) indicate strong behavioral differences, with values ranging from 1.52 to 2.31, suggesting a large effect size in favor of the experimental group.

In summary, this evaluation examines how player engagement, persistence, and interaction patterns differ between users who played the game (experimental group) and those who did not (control group). The results suggest that the educational game

positively influences player behavior, leading to higher task completion rates, increased daily engagement, and greater persistence in retrying challenges.

4.5 Sentiment Analysis for the Educational Game

This section aims to evaluate the sentiment of game players, including both students and their parents. Data was collected through individual audio-recorded interviews, which were then transcribed into text. The data collection for each group, consisting of 30 participants, was conducted between February 1 and February 25, 2025. Once the data was preprocessed and prepared, K-Means clustering was applied with $K = 3$, grouping sentiments into positive, neutral, and negative groups. The performance of the sentiment analysis was evaluated using recall (R), precision (P), and F1-score (F1), with the results presented in Table 4.5.

It is noted that the sentiment analysis was conducted separately for students and their parents to reflect the different user experiences and expectations based on age. While students directly interacted with the games, parents observed or received feedback from their children. This segmentation ensures that the analysis captures both direct and indirect user satisfaction.

Table 4.10 Sentiment Analysis Results for the Tabletop Board Game

Gameplayers	Positive			Neutral			Negative		
	R	P	F1	R	P	F1	R	P	F1
Students	0.87	1.0	0.93	0.71	1.0	0.83	0	0	0
Students' parents	0.81	1.0	0.89	1.0	1.0	1.0	0	0	0

Table 4.11 Sentiment Analysis Results for the PC-based Board Game

Gameplayers	Positive			Neutral			Negative		
	R	P	F1	R	P	F1	R	P	F1
Students	0.90	1.0	0.95	0.86	1.0	0.92	0	0	0
Students' parents	0.83	0.83	0.83	0.50	0.50	0.50	0.93	0.93	0.93

The results reveal distinct preferences between the two groups. Students expressed more positive sentiments toward the PC version of the game, highlighting engagement and interactivity. In contrast, parents favored the tabletop version for its

simplicity and perceived educational value. These differences underline the importance of tailoring game features to the cognitive and technological familiarity of different age groups.

4.5.1 Discussion for Sentiment Analysis Results for the Tabletop Board Game

4.5.1.1 Student Sentiment

- Positive Sentiment (Cluster-1): The recall, precision, and F1-score values (0.87, 1.0, and 0.93, respectively) indicate that a significant number of students positively perceive the game.
- Neutral Sentiment (Cluster-2): The recall (0.71) suggests that some students found the experience neither engaging nor disappointing, possibly due to game complexity, rules comprehension, or replayability issues.
- Negative Sentiment (Cluster-3): No students were clustered in this group, indicating an absence of strong dissatisfaction.

4.5.1.2 Parent Sentiment

- Positive Sentiment (Cluster-1): Parents showed a high recall (0.81) and F1-score (0.89), indicating strong positive engagement.
- Neutral Sentiment (Cluster-2): The perfect recall (1.0) and F1-score (1.0) in this category suggest that those who did not strongly favor or dislike the game still found it acceptable.
- Negative Sentiment (Cluster-3): No parents were placed in this category, showing an overall positive reception.

4.5.2 Discussion for Sentiment Analysis Results for the PC-based Board Game

4.5.2.1 Student Sentiment

- Positive Sentiment (Cluster-1): The higher recall (0.96) and F1-score (0.97) compared to the Tabletop version suggest that students found the PC-based adaptation more engaging.
- Neutral Sentiment (Cluster-2): The improved recall (0.85) and F1-score (0.92) indicate a lower percentage of students remaining indifferent,

suggesting that the digital format enhanced accessibility and interaction.

- Negative Sentiment (Cluster-3): No students were categorized under this cluster, confirming a strong preference for both formats, though slightly higher for the PC version.

4.5.2.2 Parent Sentiment

- Positive Sentiment (Cluster-1): The recall (0.83) and F1-score (0.83) indicate a similar level of positive engagement compared to the Tabletop version, though slightly lower than students' ratings.
- Neutral Sentiment (Cluster-2): The recall (0.5) and F1-score (0.5) indicate a higher proportion of parents who were indifferent, possibly due to less familiarity with digital interfaces or a preference for traditional board games.
- Negative Sentiment (Cluster-3): Unlike students, parents showed clear negative feedback (recall: 0.93, F1-score: 0.93), suggesting significant dissatisfaction with aspects of the PC version.

4.5.3 Discussion Summary

The PC-Based Board Game received higher positive sentiment from students, likely due to its interactive features, animations, and ease of play. The Tabletop Board Game, while still well-received, had a slightly higher proportion of neutral feedback, possibly due to manual setup requirements, rule complexity, or longer game sessions.

In contrast, parents preferred the Tabletop Board Game, valuing its familiarity, ease of participation, and opportunities for family interaction. The higher negative sentiment toward the PC version suggests concerns about usability, screen-based learning, or a lack of direct social engagement, which traditional board games naturally provide.

Overall, students showed a stronger preference for the PC-based format, while parents favored the Tabletop version. This difference highlights students' interest in digital interactivity and parents' preference for hands-on, family-friendly experiences.

To enhance engagement, the PC-Based Board Game could benefit from more intuitive controls, social play integration, and improved user-friendliness for non-tech-

savvy participants. Meanwhile, the Tabletop version remains a valuable option, particularly for family-oriented gameplay and traditional board game enthusiasts.

These findings suggest that while digital board games appeal more to younger audiences, traditional board games continue to hold strong intergenerational value. A hybrid approach—integrating both physical and digital gameplay elements—could provide a balanced and inclusive experience for all players.

4.6 Summary of Evaluation Metrics

To ensure a comprehensive assessment of the research process and the educational game's effectiveness, multiple evaluation metrics were employed across different stages of the study. Each metric was carefully selected to align with the specific objectives of the corresponding stage—ranging from clustering quality to expert validation, learning outcomes, behavioral engagement, and user sentiment. The combination of both quantitative and qualitative evaluations enables a multifaceted understanding of how well the educational game supports healthy dietary learning for elementary students. The metrics used include clustering indices (e.g., Silhouette Score), psychometric measures (e.g., N-GUT scale, Cronbach's alpha), statistical tests (e.g., paired t-test, Cohen's d), and machine learning evaluation scores (e.g., F1-score). The table below summarizes the metrics applied, their purposes, and the corresponding results that support the study's findings.

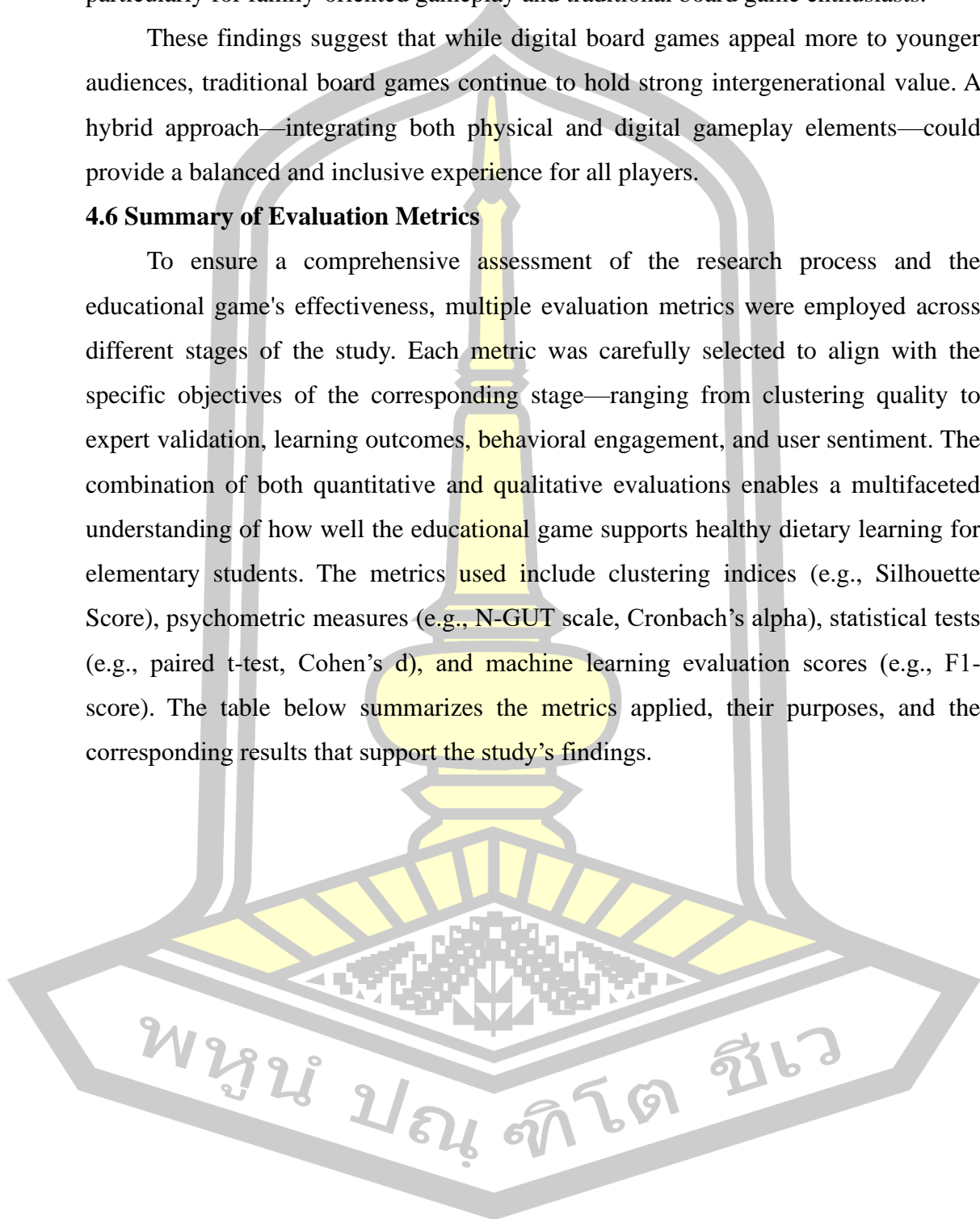


Table 4.12 Summary of Evaluation Metrics

Section	Evaluation	Metrics Used	Results & Interpretation
4.1	Clustering Evaluation	Silhouette Score, Davies-Bouldin Index	Clustering effectiveness and expert validation of insights for game design
4.2	Expert Validation	N-GUT scale, Cronbach's alpha ($\alpha = 0.87$)	High content validity and consistency in usability and educational alignment
4.3	Learning Effectiveness	Paired Sample T-Test (t-values, p-values)	Statistically significant improvement ($p < 0.01$) in food classification, nutrients, meal pairing, and health risk assessment
4.4	Behavioral Engagement	Cohen's d, task completion rate, login frequency, retry attempts, health coin use	Large effect sizes (Cohen's $d > 1.5$) indicating higher persistence and engagement in the experimental group
4.5	Sentiment Analysis	Precision, Recall, F1-score (Grouped by Positive, Neutral, Negative)	Shows user preferences; students favor the digital version while parents prefer tabletop format. F1-scores confirm classifier reliability



CHAPTER V

CONCLUSION AND FUTURE WORK

5.1 Conclusion

This study explored the design, development, and evaluation of an interactive educational game aimed at promoting healthy dietary habits among elementary school students. By integrating a game-based User-Centered Design (UCD) framework with Educational Game Theory, Interactive Learning Theory, and Gamification Elements Theory, the research sought to create a game that is both engaging and educationally effective. The game was developed in two formats—a Tabletop Board Game and a PC-Based Board Game—each designed to facilitate interactive learning by incorporating structured gameplay, engaging mechanics, and motivational reward systems.

A key aspect of this research was the data-driven approach used to inform the game's development. By leveraging insights from educational game reviews analyzed using K-Means clustering, the study identified critical factors influencing user engagement, learning effectiveness, and motivation. The clustering results provided a structured understanding of how game content, graphics, reward mechanisms, and level design impact players' experiences. Expert evaluation using the N-GUT scale further validated the game's scientific accuracy, educational content, and adaptability to nutrition learning, ensuring alignment with established dietary guidelines and cognitive learning principles.

To assess the educational impact of the game, a pre-test and post-test study was conducted, revealing statistically significant improvements in students' understanding of food classification, nutrient identification, and meal planning. The results indicated that students who played the game demonstrated greater retention of nutrition knowledge compared to those in the control group. Additionally, behavioral analysis of gameplay interactions showed that players in the experimental group exhibited higher engagement levels, greater task completion rates, and increased persistence in overcoming game challenges. These findings suggest that the integration of interactive, gamified learning effectively enhances students' motivation and learning outcomes.

Sentiment analysis provided deeper insights into how different user groups—students and parents—perceived the two game formats. The results indicated that students responded more favorably to the PC-Based Board Game, appreciating its interactive animations, digital engagement, and ease of use. The higher recall and F1-score in the positive sentiment cluster confirmed that students found the digital version more engaging and stimulating. In contrast, parents exhibited a stronger preference for the Tabletop Board Game, emphasizing its familiarity, ease of participation, and opportunities for social interaction within a family setting. The higher negative sentiment among parents toward the PC version suggested usability concerns, skepticism toward screen-based learning, and a lack of direct social engagement, reinforcing the need to consider user adaptability when integrating digital learning tools into educational settings.

The findings highlight that both physical and digital game formats have unique advantages and challenges. While digital games offer interactivity, multimedia engagement, and ease of access, traditional board games provide a structured, socially engaging experience that encourages face-to-face interaction. These insights suggest that a hybrid approach, incorporating both physical and digital gameplay elements, could maximize learning effectiveness and engagement by combining the strengths of both formats.

5.2 Challenges and Limitations of This Research

Despite the promising findings, this study faced several challenges and limitations that impacted various aspects of the research process, from game development to evaluation. These challenges can be categorized into technical constraints, participant-related limitations, data-related issues, and broader research considerations.

1. Technical and Development Challenges - One of the key challenges in this study was the development and implementation of the interactive educational game in both Tabletop and PC-Based formats. The PC-Based Board Game required significant technical resources, including software development, animation design, and UI/UX optimization, to ensure that the game was both engaging and user-friendly for young learners. Ensuring smooth gameplay mechanics, responsiveness, and compatibility

across different devices was a time-consuming process. Furthermore, the Tabletop Board Game required extensive prototyping, iterative design adjustments, and material selection, which introduced logistical constraints in terms of production costs and physical durability of game components. Another technical challenge was ensuring that the gamification elements effectively reinforced nutrition education. While integrating educational theories such as Game-Based Learning (GBL), Interactive Learning Theory, and Gamification Elements Theory provided a strong foundation, balancing engagement with educational depth was complex. There was a risk of making the game too entertaining with reduced learning effectiveness or too educational with less engagement, requiring continuous refinement based on expert and user feedback.

2. Participant and User Engagement Limitations - This study primarily focused on Grade 2 students from one school (Huanhu Primary School in Foshan City, China), which limits the generalizability of the findings. While the game was well-received within this sample, different schools, cultural backgrounds, and learning environments might yield varied responses. Additionally, young children have short attention spans, making it challenging to measure long-term learning retention effectively. The research relied on immediate pre-test and post-test comparisons, but longitudinal studies tracking the game's impact over several months would provide deeper insights into its effectiveness. Parental involvement was also a challenge, particularly regarding the PC-Based Board Game. The sentiment analysis showed that parents expressed concerns about screen-based learning, usability, and engagement levels. Encouraging parents to actively participate in the game or assist their children in navigating digital interfaces was difficult, highlighting the need for more parent-friendly game designs and interactive family-based learning strategies.

The findings indicate that age plays a critical role in shaping user perception and acceptance of educational games. By analyzing feedback separately from students and parents, the study reveals how digital literacy, learning expectations, and familiarity with game formats influence user satisfaction. This insight is essential for designing inclusive educational tools that resonate with both young learners and their supporting adults.

3. Data Collection and Analytical Constraints - The data-driven approach used in the study relied on K-Means clustering for extracting insights from educational game reviews and sentiment analysis for evaluating user feedback. However, clustering accuracy was limited, as reflected in moderate Silhouette Scores and high Davies-Bouldin Index values, indicating some overlapping clusters and potential misclassifications. Since sentiment analysis depended on text-based transcriptions from interviews, the accuracy of sentiment classification was influenced by language variations, context interpretation, and potential biases in parental responses. Additionally, the pre-test and post-test evaluation method provided useful data on knowledge improvement, but it did not fully capture behavioral changes in real-world eating habits. While students demonstrated better food knowledge after playing the game, their actual dietary choices beyond the research setting were not tracked, limiting insights into long-term behavior modification.

4. Generalization and Scalability Challenges - Since this study was conducted within a specific educational and cultural context, applying the game to different regions, languages, and curriculum standards may require further modifications. The China Nutrition and Health Survey (CHNS) dataset was used to structure dietary guidelines within the game, but nutritional requirements and food preferences vary across countries and cultures. Expanding the game for international use would require adaptations based on local dietary habits, food availability, and cultural eating patterns. Furthermore, the scalability of the PC-Based Board Game presents technical and logistical challenges. Deploying the digital version to a wider audience requires considerations such as platform compatibility, internet accessibility, and school IT infrastructure, which might not be uniform across different educational institutions. The Tabletop Board Game, on the other hand, has production and distribution challenges, particularly in maintaining cost-effectiveness while ensuring high-quality materials.

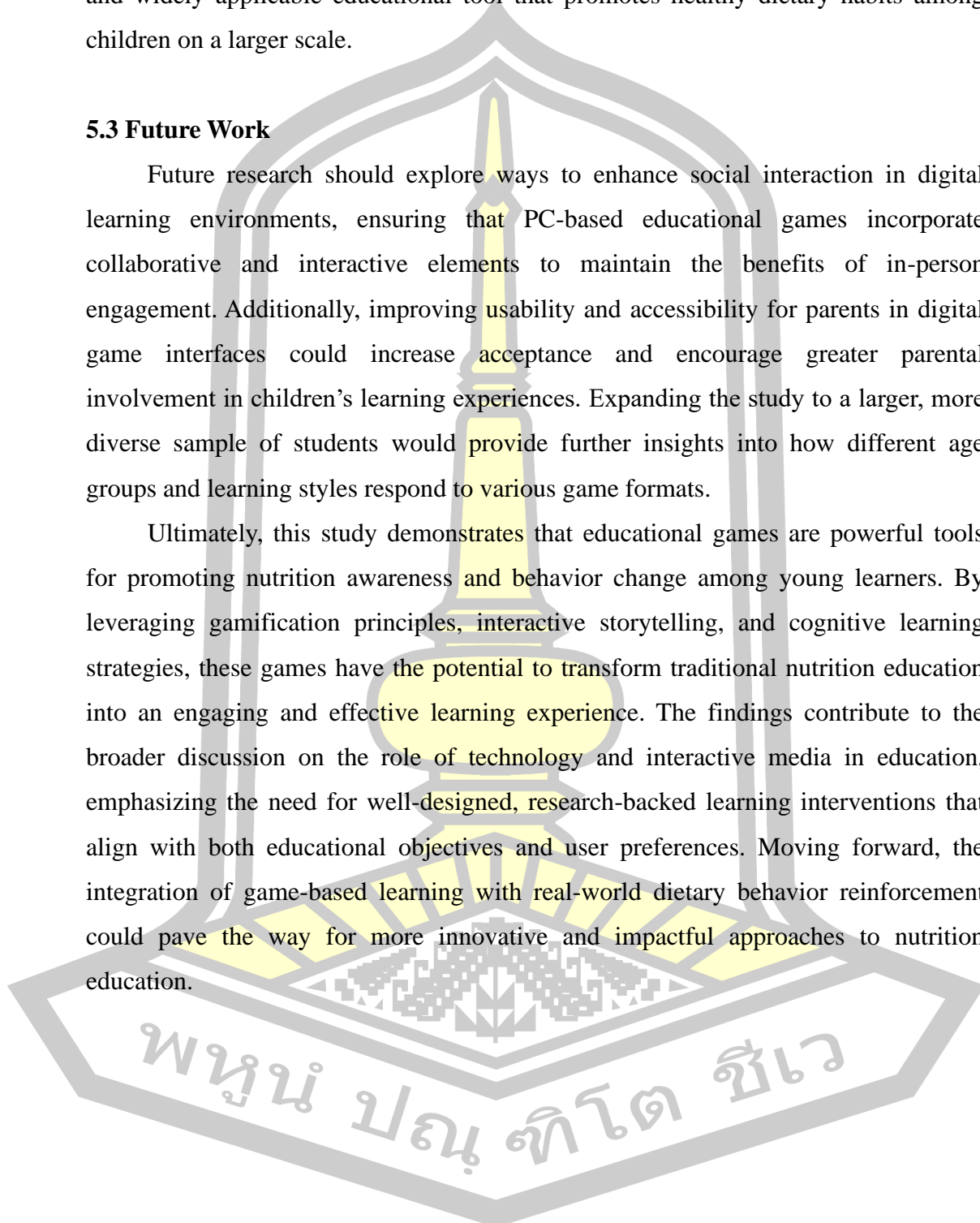
In summary for challenges and limitations of this research, while this study successfully demonstrated the potential of interactive educational games in nutrition learning, various technical, participant-related, data, and scalability challenges remain. Addressing these obstacles requires a multi-faceted approach, integrating technological advancements, user engagement strategies, and cultural adaptability.

Overcoming these challenges will allow for the creation of a more inclusive, effective, and widely applicable educational tool that promotes healthy dietary habits among children on a larger scale.

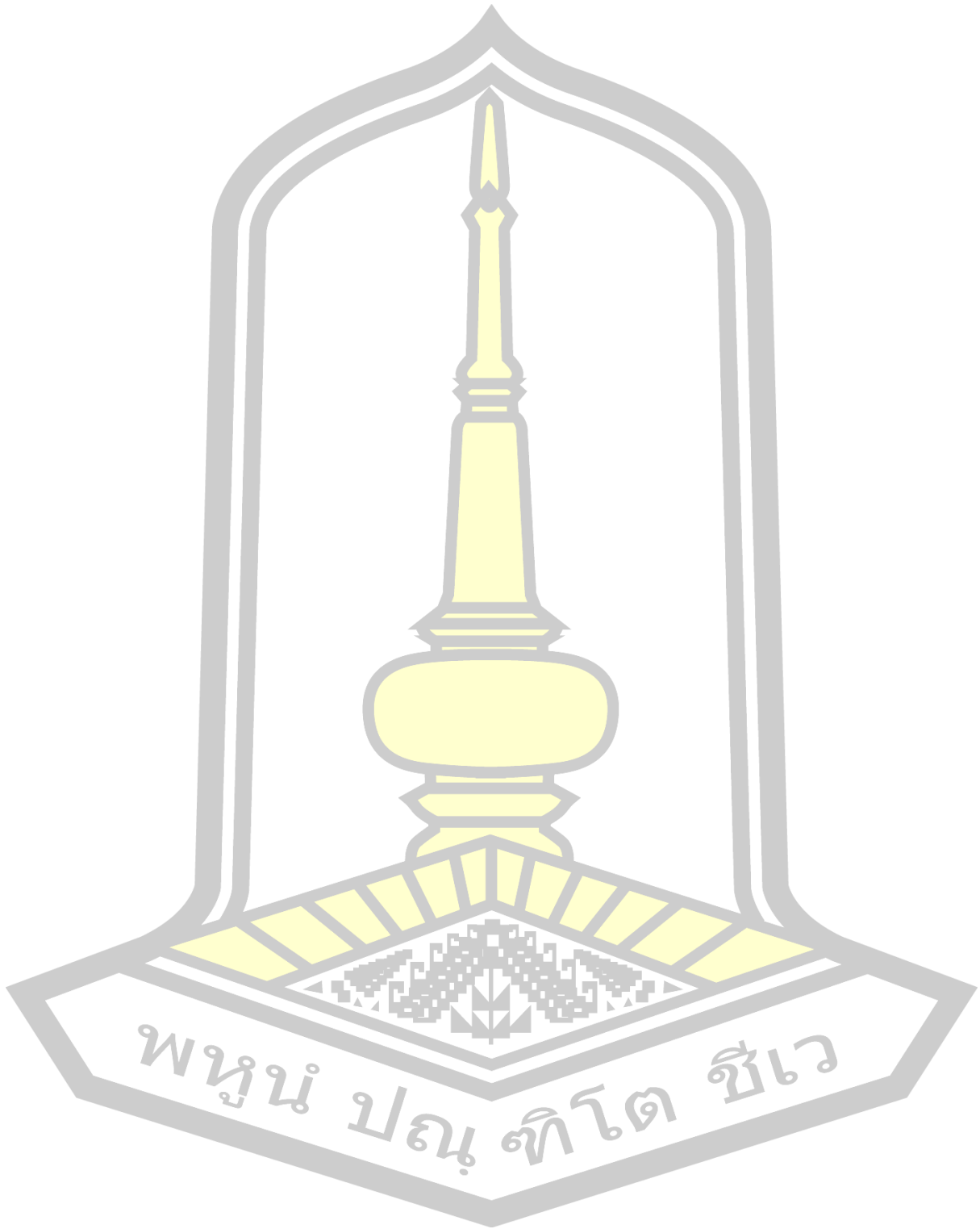
5.3 Future Work

Future research should explore ways to enhance social interaction in digital learning environments, ensuring that PC-based educational games incorporate collaborative and interactive elements to maintain the benefits of in-person engagement. Additionally, improving usability and accessibility for parents in digital game interfaces could increase acceptance and encourage greater parental involvement in children's learning experiences. Expanding the study to a larger, more diverse sample of students would provide further insights into how different age groups and learning styles respond to various game formats.

Ultimately, this study demonstrates that educational games are powerful tools for promoting nutrition awareness and behavior change among young learners. By leveraging gamification principles, interactive storytelling, and cognitive learning strategies, these games have the potential to transform traditional nutrition education into an engaging and effective learning experience. The findings contribute to the broader discussion on the role of technology and interactive media in education, emphasizing the need for well-designed, research-backed learning interventions that align with both educational objectives and user preferences. Moving forward, the integration of game-based learning with real-world dietary behavior reinforcement could pave the way for more innovative and impactful approaches to nutrition education.



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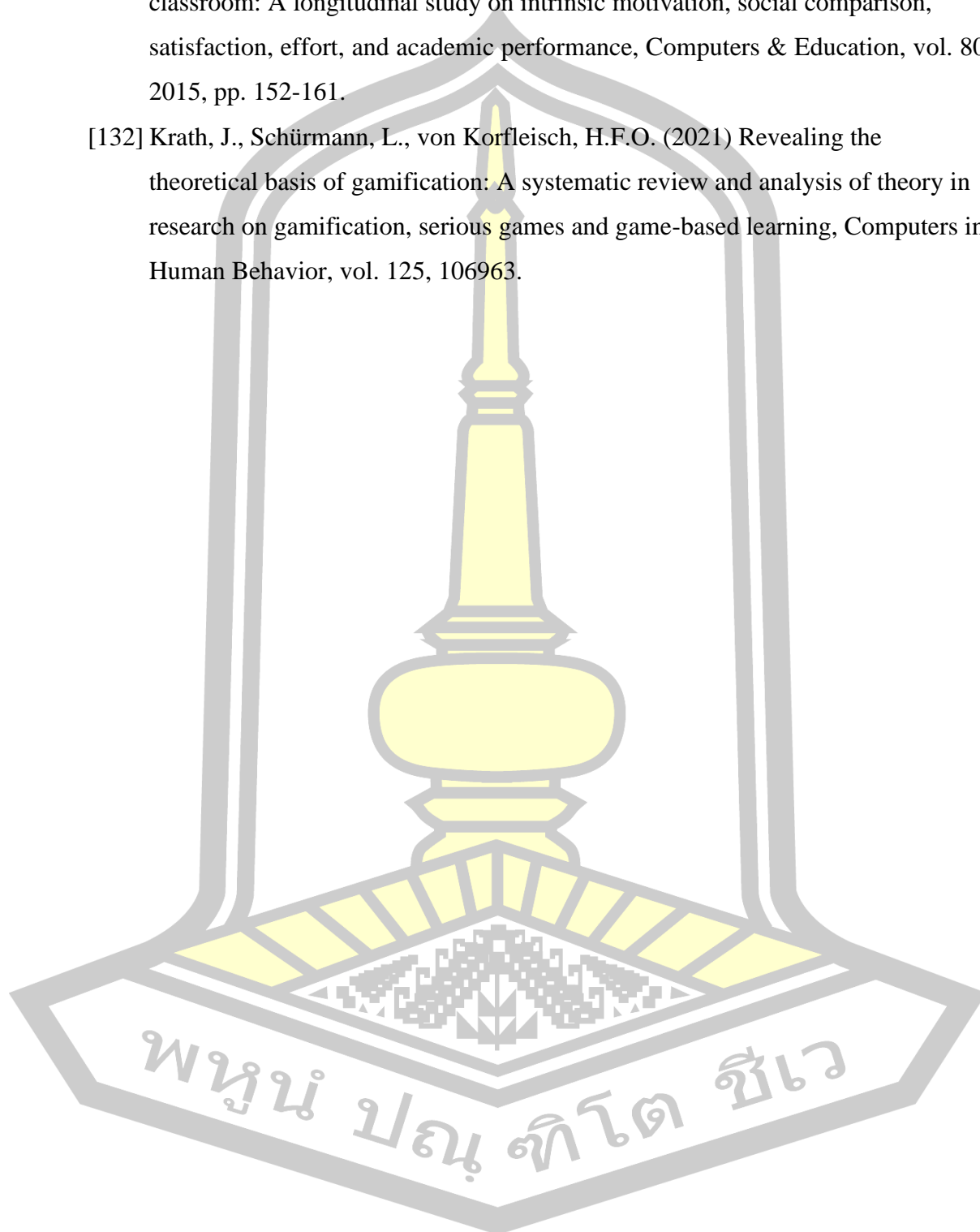
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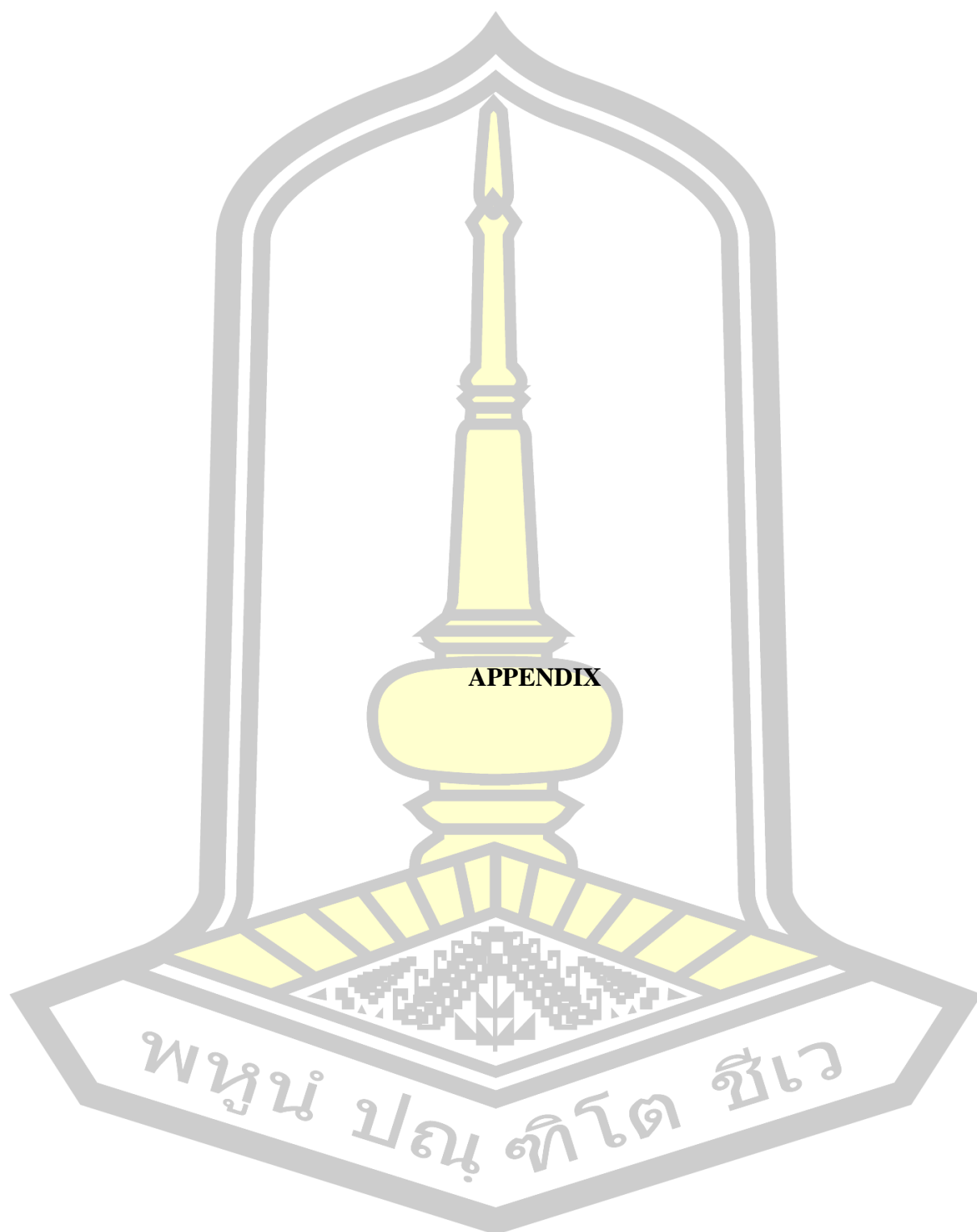
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Expert Evaluation Scale for Interactive Nutrition Education Game
(Adapted from N-GUT Scale & Collaborative Rubric Design Principles in Documentation)

Chapter 1 Section A: General Information

Evaluator Name: _____

Expertise:

- Education Specialist
- Nutrition/Dietetics Expert
- Game Design/Development Expert

Affiliation: _____

Date: _____

•

Chapter 2 Section B: Content Accuracy & Relevance

Assessed primarily by Nutrition Experts

Criteria	Rating (1–5 Likert Scale)	Comments
1. Scientific accuracy of nutritional concepts (e.g., food groups, balanced diets).	1 2 3 4 5	
2. Appropriateness of dietary recommendations for elementary students (e.g., aligned with CHNS guidelines).	1 2 3 4 5	
3. Clarity and age-appropriateness of health messaging (e.g., simplified language, no jargon).	1 2 3 4 5	
4. Relevance to regional dietary habits (e.g., Guangdong Province context).	1 2 3 4 5	

Chapter 3 Section C: Educational Efficacy

Assessed primarily by Education Specialists

Criteria	Rating (1–5 Likert Scale)	Comments
5. Alignment with Grade 2 learning objectives (e.g., food classification, nutrient identification).	1 2 3 4 5	
6. Effectiveness of interactive learning principles (e.g., problem-solving, decision-making scenarios).	1 2 3 4 5	
7. Engagement strategies (e.g., rewards, challenges, progression).	1 2 3 4 5	
8. Scaffolding of difficulty levels (e.g., adaptive to skill development).	1 2 3 4 5	

Chapter 4 Section D: Game Design & Usability
Assessed primarily by Game Experts

Criteria	Rating (1–5 Likert Scale)	Comments
9. User-centered design (UCD): Accessibility for ages 7–8 (e.g., intuitive controls, clear instructions).	1 2 3 4 5	
10. Visual and auditory appeal (e.g., color palette, animations, sound effects).	1 2 3 4 5	
11. Balance between educational content and gameplay enjoyment.	1 2 3 4 5	
12. Technical functionality (e.g., smooth navigation, bug-free experience).	1 2 3 4 5	

Chapter 5 Section E: Behavioral Impact & Cultural Sensitivity
Assessed by All Experts

Criteria	Rating (1–5 Likert Scale)	Comments
13. Potential to motivate healthy eating behaviors (e.g., via reward systems).	1 2 3 4 5	
14. Cultural appropriateness (e.g., regional foods, family dynamics in gameplay).	1 2 3 4 5	
15. Inclusion of collaborative elements (e.g., peer/family interaction).	1 2 3 4 5	

Chapter 6 Section F: Open-Ended Feedback

1. Strengths of the game:

2. Areas for improvement:

3. Specific suggestions for content/design refinement:

Scoring Guide:

- 1 = Strongly Disagree | 2 = Disagree | 3 = Neutral | 4 = Agree | 5 = Strongly Agree

Survey Report on Parents' Attitudes Towards Health Education Games for 8-9-Year-Old Students

1. Your Child's Gender:

- Male: 31 (38.27%)
- Female: 50 (61.73%)
- Total responses: 81

2. Your Child's Age:

- 7 years old: 19 (23.46%)
- 8 years old: 43 (53.9%)
- 9 years old: 19 (23.46%)
- Total responses: 81

3. Health education is important for a child's development.

- Strongly disagree: 5 (6.17%)
- Disagree: 0 (0%)
- Neutral: 2 (2.47%)
- Agree: 22 (27.16%)
- Strongly agree: 52 (64.2%)
- Total responses: 81

4. I am familiar with health education content suitable for 8-year-old children.

- Not at all familiar: 4 (4.94%)
- Unfamiliar: 4 (4.94%)
- Neutral: 31 (38.27%)
- Familiar: 27 (33.33%)
- Very familiar: 15 (18.52%)
- Total responses: 81

5. Games can be an effective way for children to learn about healthy eating.

- Strongly disagree: 6 (7.41%)
- Disagree: 6 (7.41%)
- Neutral: 24 (29.63%)
- Agree: 29 (35.8%)
- Strongly agree: 16 (19.75%)
- Total responses: 81

6. Games are more engaging than traditional classroom teaching or parental guidance for learning about healthy eating.

- Strongly disagree: 3 (3.7%)
- Disagree: 7 (8.64%)
- Neutral: 17 (20.99%)
- Agree: 33 (40.74%)
- Strongly agree: 21 (25.93%)
- Total responses: 81

7. Board games (e.g., cards, puzzles) are suitable for children to learn about healthy eating.

- Strongly disagree: 2 (2.47%)
- Disagree: 6 (7.41%)
- Neutral: 14 (17.28%)
- Agree: 40 (49.38%)
- Strongly agree: 19 (23.46%)
- Total responses: 81

8. Computer games are suitable for children to learn about healthy eating.

- Strongly disagree: 3 (3.7%)
- Disagree: 13 (16.5%)
- Neutral: 33 (40.74%)
- Agree: 25 (30.86%)
- Strongly agree: 7 (8.64%)
- Total responses: 81

9. Mobile applications are suitable for children to learn about healthy eating.

- Strongly disagree: 7 (8.64%)
- Disagree: 9 (11.11%)
- Neutral: 31 (38.27%)
- Agree: 28 (34.57%)
- Strongly agree: 6 (7.41%)
- Total responses: 81

10. Game content should include knowledge about food classification and nutritional balance.

- Strongly disagree: 4 (4.94%)
- Disagree: 5 (6.17%)
- Neutral: 18 (22.22%)
- Agree: 36 (44.44%)
- Strongly agree: 18 (22.22%)
- Total responses: 81

11. Games should emphasize teamwork or parental involvement.

- Strongly disagree: 4 (4.94%)
- Disagree: 1 (1.23%)
- Neutral: 18 (22.22%)
- Agree: 33 (40.74%)
- Strongly agree: 25 (30.86%)
- Total responses: 81

12. I am concerned that my child might get distracted while playing games instead of focusing on learning.

- Strongly disagree: 2 (2.47%)
- Disagree: 12 (14.81%)
- Neutral: 27 (33.33%)
- Agree: 26 (32.1%)
- Strongly agree: 14 (17.28%)
- Total responses: 81

13. I am concerned that game content might not accurately convey health education knowledge.

- Strongly disagree: 3 (3.7%)
- Disagree: 10 (12.35%)
- Neutral: 36 (44.44%)
- Agree: 23 (28.4%)
- Strongly agree: 9 (11.11%)
- Total responses: 81

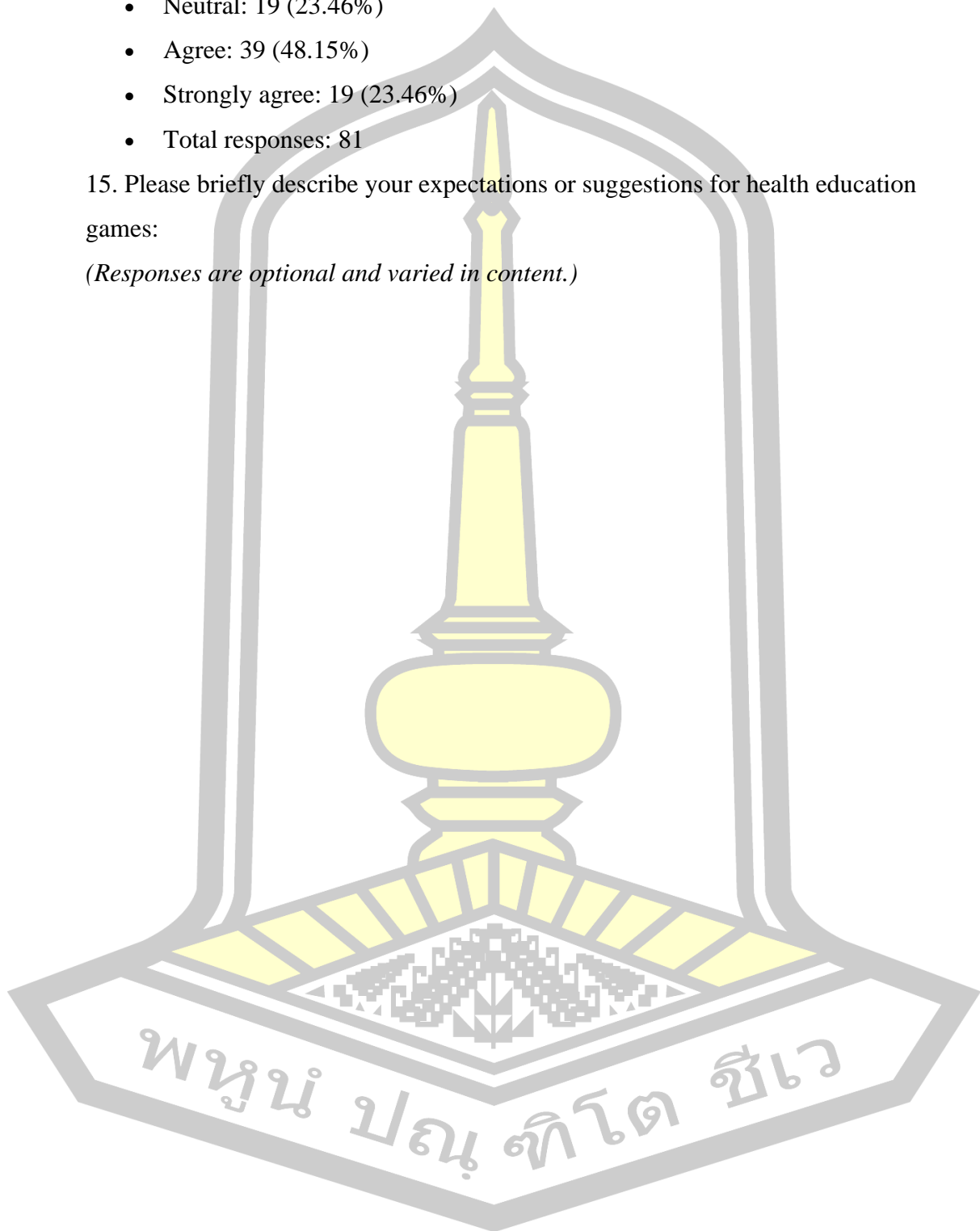
14. I am concerned that mobile or computer games might increase my child's screen time.

- Strongly disagree: 2 (2.47%)

- Disagree: 2 (2.47%)
- Neutral: 19 (23.46%)
- Agree: 39 (48.15%)
- Strongly agree: 19 (23.46%)
- Total responses: 81

15. Please briefly describe your expectations or suggestions for health education games:

(Responses are optional and varied in content.)



Survey for Educators: Applicability and Educational Value of Health-Oriented Board Games in Classrooms

Dear Educator,

Thank you for participating in this survey. The purpose of this questionnaire is to understand your evaluation of health-focused board games in classroom settings, their teaching aid potential, your acceptance of educational games, and your willingness to integrate them into your teaching practices. Your responses will provide valuable insights for this research. All information will be used solely for academic purposes and will remain strictly confidential.

Section 1: Basic Information

1. Your gender:

Male

Female

2. The grade level you teach:

Grade 1

Grade 2

Grade 3

Grade 4 or above

3. Your teaching experience:

1-3 years

4-6 years

7-10 years

More than 10 years

4. Do you teach health education-related courses?

Yes

No

Section 2: Attitudes Toward Educational Games

5. Do you think board games can help students better learn about healthy eating habits?

Strongly disagree

Disagree

Neutral (Unsure/No opinion)

Agree

Strongly agree

6. Do you believe board games are more engaging than traditional classroom lectures for teaching healthy eating?

Strongly disagree

Disagree

Neutral (Unsure/No opinion)

Agree

Strongly agree

7. How would you rate your acceptance of board games as a teaching aid?

Strongly unaccepting

Unaccepting

Neutral (Unsure/No opinion)

Accepting

Strongly accepting

8. Would you be willing to use board games in your classroom?

Strongly unwilling

Unwilling

Neutral (Unsure/No opinion)

Willing

Strongly willing

Section 3: Educational Value of Board Games

9. What do you think is the main value of board games in health education classrooms? (Select all that apply)

Enhancing student interest in learning

Improving students' practical skills

Increasing understanding of healthy eating concepts

Strengthening student collaboration and interaction

Adding diversity and fun to the classroom

Other: _____

10. Do you think board games can improve students' teamwork skills?

- Strongly disagree
 Disagree
 Neutral (Unsure/No opinion)
 Agree
 Strongly agree

11. Do you believe board games can help students translate healthy eating knowledge into practical behavior?

- Strongly disagree
 Disagree
 Neutral (Unsure/No opinion)
 Agree
 Strongly agree

Section 4: Feasibility and Challenges of Classroom Implementation

12. What do you think are the main challenges of using board games in classrooms? (Select all that apply)

- Conflicts between game time and curriculum schedule
 Difficulty in student cooperation and operation
 Teachers' unfamiliarity with game rules and educational value
 Limitations in resources or access to game materials
 Lack of school support for game-based teaching tools
 Other: _____

13. Do you think teacher guides or training programs are necessary for implementing board games?

- Strongly disagree
 Disagree
 Neutral (Unsure/No opinion)
 Agree
 Strongly agree

14. Would you be willing to participate in training programs related to board games?

- Strongly unwilling

Unwilling

Neutral (Unsure/No opinion)

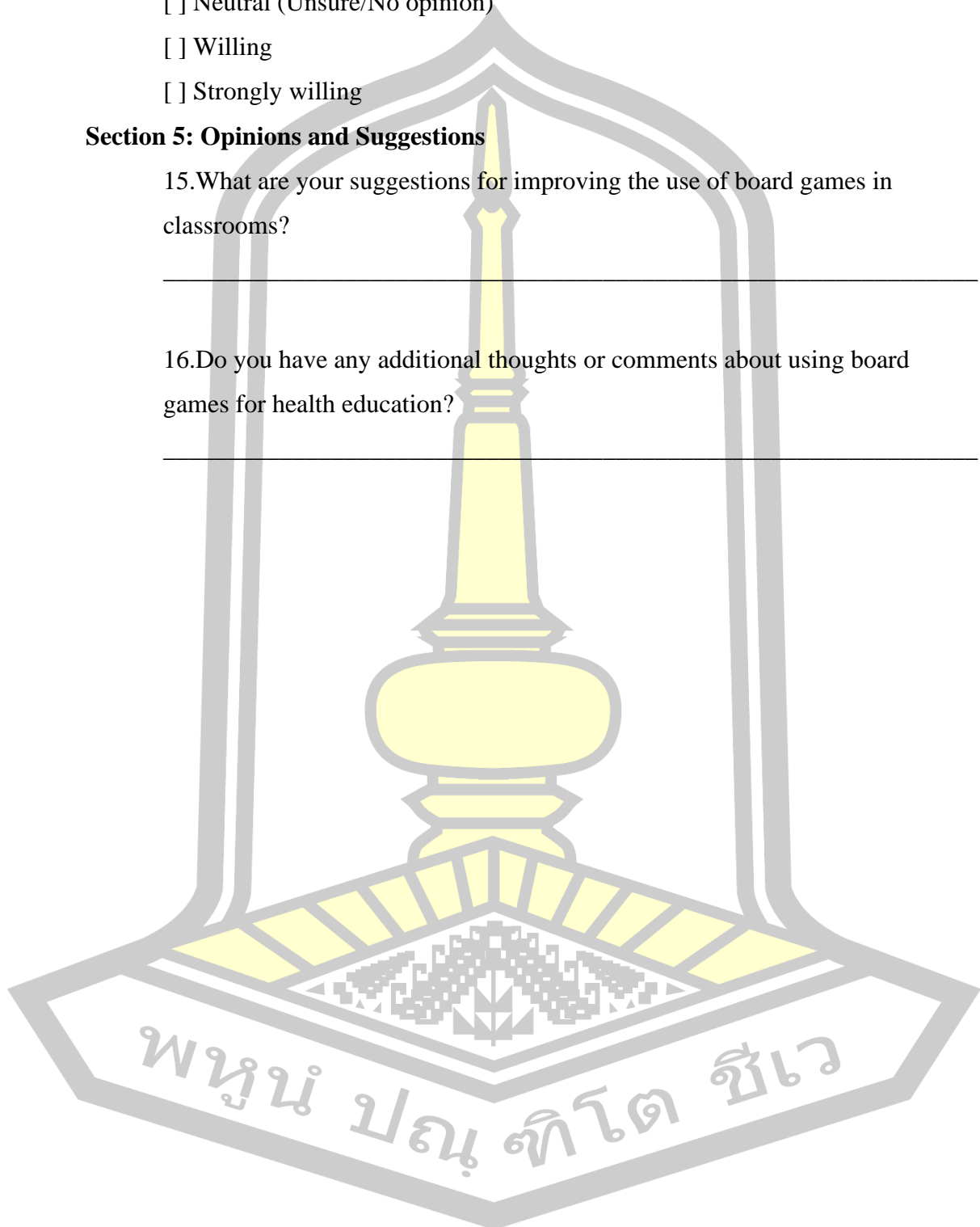
Willing

Strongly willing

Section 5: Opinions and Suggestions

15. What are your suggestions for improving the use of board games in classrooms?

16. Do you have any additional thoughts or comments about using board games for health education?



Survey Report on Educators' Perspectives on Health-Oriented Board Games in Classrooms

Introduction

This report presents the findings of a survey conducted among 32 elementary school educators to evaluate their perspectives on the applicability, educational value, and willingness to use health-oriented board games in classroom settings. The survey explores educators' attitudes, perceived challenges, and their suggestions for integrating board games into health education. The findings aim to support the development and promotion of effective educational tools tailored to classroom needs.

1. Demographics of Respondents

1.1 Gender

- Male: 10 respondents (31.25%)
- Female: 22 respondents (68.75%)

1.2 Teaching Experience

- 1-3 years: 4 respondents (12.5%)
- 4-6 years: 10 respondents (31.25%)
- 7-10 years: 8 respondents (25%)
- More than 10 years: 10 respondents (31.25%)

1.3 Grade Levels Taught

- Grade 1: 6 respondents (18.75%)
- Grade 2: 8 respondents (25%)
- Grade 3: 9 respondents (28.13%)
- Grade 4 or above: 9 respondents (28.13%)

1.4 Health Education Courses

- Currently teach health education-related courses: 21 respondents (65.63%)
- Do not teach health education-related courses: 11 respondents (34.37%)

2. Attitudes Toward Educational Games

2.1 Perception of Educational Value

- Effectiveness in improving health knowledge: 87.5% of respondents agreed or strongly agreed that board games could help students better understand healthy eating concepts.

- Engagement potential: 81.25% of educators believed board games are more engaging than traditional lectures for teaching health-related topics.

2.2 Acceptance of Board Games as Teaching Aids

- Acceptance level: 75% of educators expressed acceptance or strong acceptance of board games as teaching aids.
- Willingness to integrate: 71.88% of respondents indicated they are willing or strongly willing to use board games in their classrooms.

3. Perceived Educational Value

3.1 Key Benefits Identified

- Enhancing student interest in learning (90.63%)
- Improving students' practical understanding of healthy eating (84.38%)
- Promoting teamwork and collaboration (78.13%)
- Adding diversity and fun to classroom activities (75%)

3.2 Behavioral Impact

- 78.13% of educators agreed that board games could translate health knowledge into actionable behaviors among students.
- 84.38% believed board games could help foster positive eating habits in students over time.

4. Feasibility and Challenges

4.1 Main Challenges Identified

- Time constraints: 62.5% of respondents cited conflicts between game time and curriculum schedules as a significant challenge.
- Resource availability: 53.13% noted limitations in game materials or resources as a barrier.
- Teacher preparedness: 50% expressed concern about their familiarity with game rules and their ability to maximize the games' educational value.

4.2 Need for Training and Support

- Teacher guides and training: 87.5% of educators agreed or strongly agreed on the need for instructional guides or training programs to ensure effective implementation.

- Willingness to attend training: 75% of respondents indicated their willingness to participate in training sessions focused on integrating board games into teaching.

5. Educators' Suggestions

Game Design Improvements:

Ensure the games are easy to integrate into existing curricula.

Include detailed guides and example scenarios for educators.

Develop games with adjustable difficulty levels to cater to different student needs.

Implementation Support:

Provide professional development opportunities to familiarize educators with game-based teaching strategies.

Offer access to supplementary resources, such as digital tools or interactive videos, to enhance the gaming experience.

Classroom Integration:

Design games that align with national health education standards.

Create cooperative tasks within games to promote team-building and collective problem-solving.

6. Conclusions

The survey results demonstrate that elementary school educators recognize the potential of health-oriented board games as effective and engaging teaching tools. Most educators are receptive to integrating these games into their classrooms but identify practical challenges, including time constraints, resource limitations, and the need for professional training.

The findings suggest a strong demand for well-designed, easy-to-implement board games supported by comprehensive training and resources for educators. Addressing these needs could enhance the adoption of board games as a valuable tool in health education and further improve student engagement and learning outcomes.

Recommendations

Develop Comprehensive Support Materials:

Provide detailed user guides and training workshops to help educators integrate games effectively.

Focus on Modular Design:

Create board games with flexible time requirements and adjustable difficulty to fit various classroom contexts.

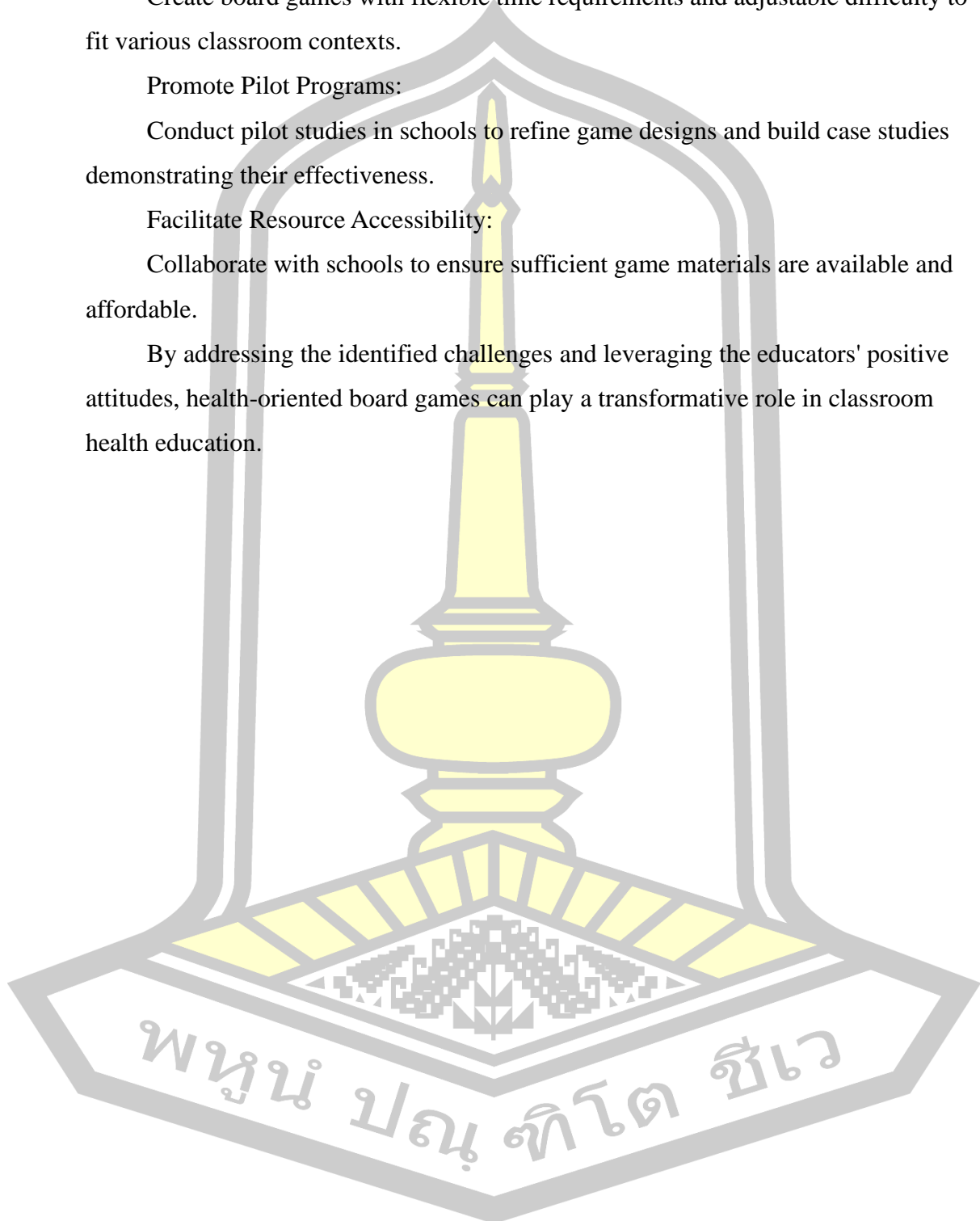
Promote Pilot Programs:

Conduct pilot studies in schools to refine game designs and build case studies demonstrating their effectiveness.

Facilitate Resource Accessibility:

Collaborate with schools to ensure sufficient game materials are available and affordable.

By addressing the identified challenges and leveraging the educators' positive attitudes, health-oriented board games can play a transformative role in classroom health education.



Health Nutrition Pre-Test Questionnaire (for 8-year-old students)

1. Your age:

- 7 years old
- 8 years old
- 9 years old
- Other: _____

2. Are you a boy or a girl?

- Boy
- Girl

3. Vegetables and fruits are beneficial for our bodies.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

4. Eating a lot of candy and snacks is bad for the body.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

5. Eating three meals a day is a good way to stay healthy.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

6. Drinking enough water is better for the body than drinking soda.

- Strongly disagree
- Disagree
- Slightly agree

- Agree
- Strongly agree

7. We should avoid eating too much junk food (like fried chicken, chips, etc.).

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

8. I think eating vegetables and fruits is very important for the body.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

9. I hope to eat more healthy foods every day.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

10. I know that not eating healthy food can make me feel uncomfortable.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

11. I believe that eating less candy and fast food will make me healthier.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

12. I think my eating habits can be healthier.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

13. I plan to eat more fruits and vegetables every day.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

14. I will reduce the number of times I eat candy and sweets.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

15. I plan to drink more water and less soda.

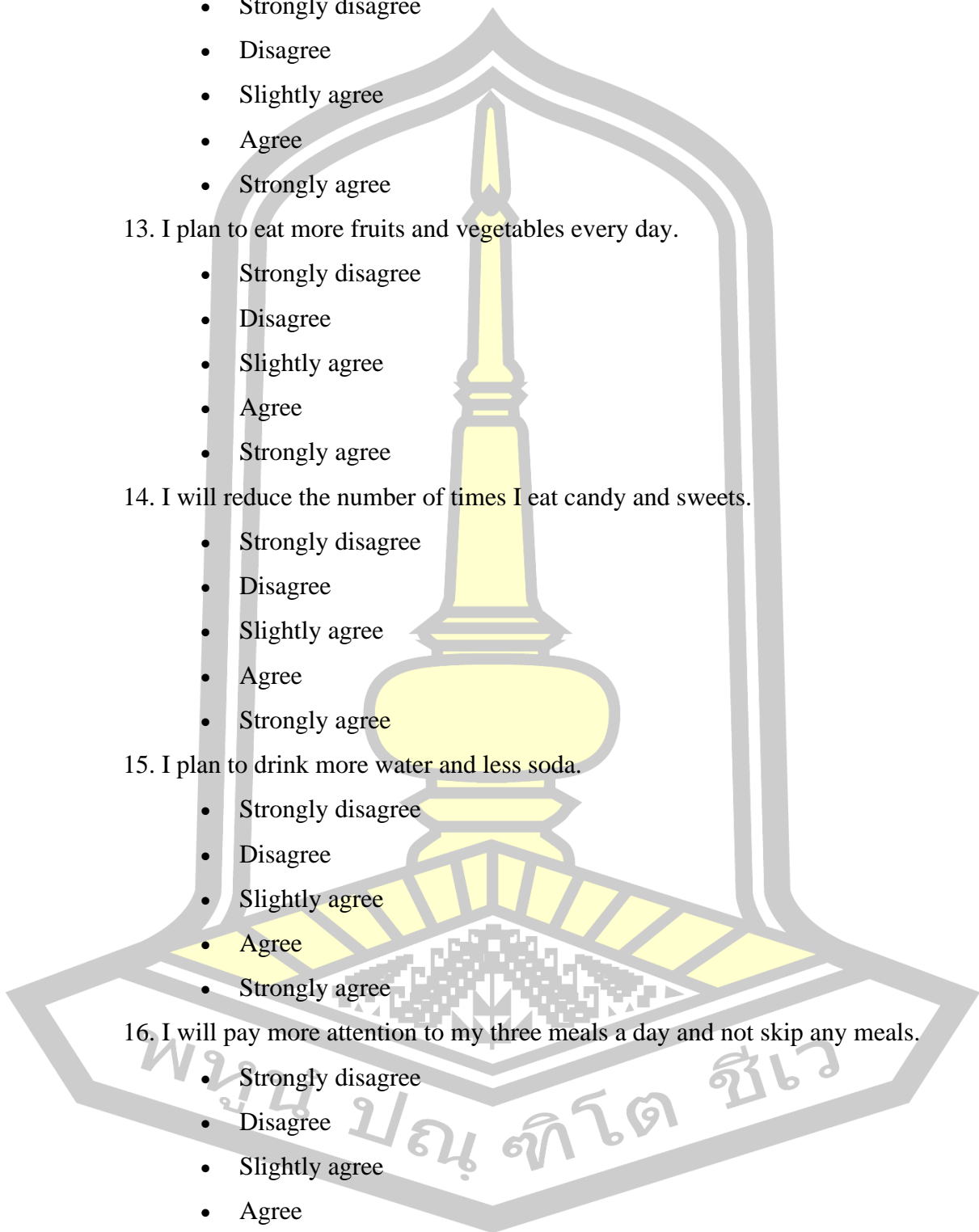
- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

16. I will pay more attention to my three meals a day and not skip any meals.

- Strongly disagree
- Disagree
- Slightly agree
- Agree
- Strongly agree

17. I plan to avoid eating too much junk food.

- Strongly disagree

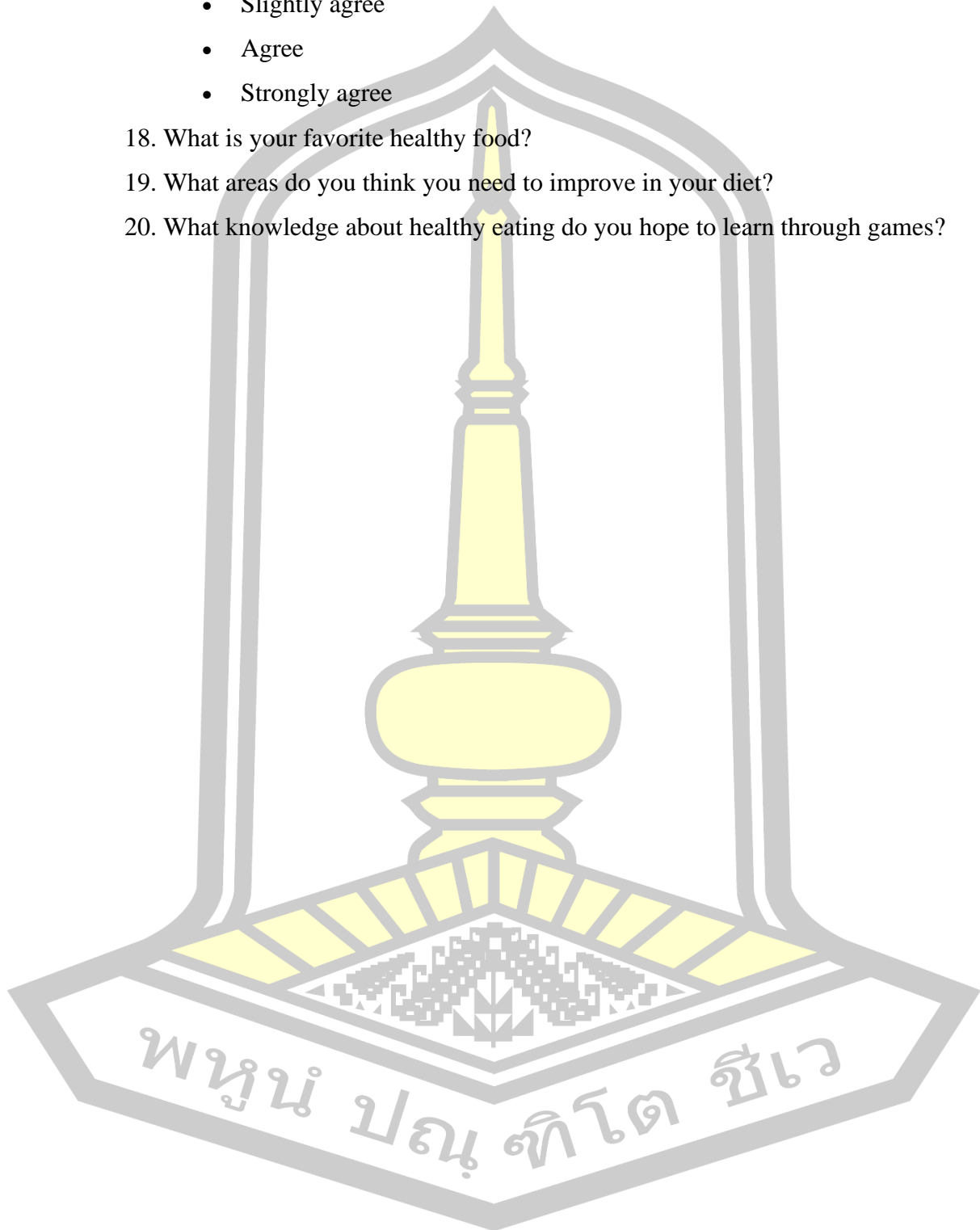


- Disagree
- Slightly agree
- Agree
- Strongly agree

18. What is your favorite healthy food?

19. What areas do you think you need to improve in your diet?

20. What knowledge about healthy eating do you hope to learn through games?



Pre-Test Survey Report on Tabletop Healthy Eating Educational Games

Introduction

This report presents the findings of a pre-test survey conducted with 12 children (average age: 8 years) prior to playing three tabletop healthy eating educational games: Little Nutrition Adventurer, Super Foodie, and Trash Island Adventure. The survey aimed to assess children's baseline knowledge of healthy eating habits, their attitudes towards nutrition, and their interest in learning about food through games.

Pre-Test Survey Questions and Responses

1. Do you know what healthy eating means?

1. Yes: 50%
2. No: 25%
3. Not Sure: 25%

Analysis:

Half of the children had a basic understanding of healthy eating. However, the remaining children either had no knowledge or were unsure. This indicates a need for educational interventions that clarify the concept of healthy eating.

2. Do you know the food groups and their importance?

1. Yes: 33%
2. No: 42%
3. Not Sure: 25%

Analysis:

Only a third of the participants were familiar with the food groups and their importance. This lack of knowledge highlights the potential impact of an educational game focused on teaching food groups.

3. How often do you eat fruits and vegetables?

1. Every day: 58%
2. Occasionally: 33%
3. Rarely: 9%

Analysis:

Most children reported eating fruits and vegetables daily, indicating a generally

positive dietary habit. However, a significant portion only ate them occasionally, which suggests room for improvement in encouraging consistent consumption.

4. Do you think eating junk food is bad for your health?

1. Yes: 75%
2. No: 8%
3. Not Sure: 17%

Analysis:

The majority of children were aware that junk food is unhealthy, showing a basic awareness of nutrition risks.

5. Do you know how to read food labels?

1. Yes: 25%
2. No: 67%
3. Not Sure: 8%

Analysis:

A large majority of the children did not know how to read food labels, indicating a clear knowledge gap that the games can help address.

6. Are you interested in learning about healthy eating through games?

1. Yes: 67%
2. No: 17%
3. Not Sure: 16%

Analysis:

Most children expressed interest in learning through games, highlighting the effectiveness of game-based learning as a teaching tool.

7. Do you think your family encourages healthy eating?

1. Yes: 75%
2. No: 8%
3. Not Sure: 17%

Analysis:

Most children felt supported by their families in making healthy food choices. This suggests that educational games can serve as a complementary tool to reinforce these positive habits.

8. Do you prefer eating at home or at fast-food restaurants?

1. Home: 58%
2. Fast-Food Restaurants: 25%
3. Both: 17%

Analysis:

More children preferred eating at home, indicating an existing preference for home-cooked meals over fast food.

9. Do you know why breakfast is important?

1. Yes: 50%
2. No: 33%
3. Not Sure: 17%

Analysis:

Half of the children understood the importance of breakfast, but a significant portion did not, showing room for improvement.

10. Have you ever tried cooking healthy meals?

1. Yes: 33%
2. No: 50%
3. Not Sure: 17%

Analysis:

Only a third of the children had experience with cooking healthy meals. Encouraging children to participate in meal preparation could increase their interest in healthy eating.

Summary of Key Findings

- **Knowledge Gap:** The pre-test survey identified gaps in children's knowledge about food groups, food labels, and the importance of breakfast.
- **Positive Attitudes:** Most children recognized the value of healthy eating and showed interest in learning more through interactive games.
- **Parental Influence:** Family support plays a significant role in promoting healthy eating habits.

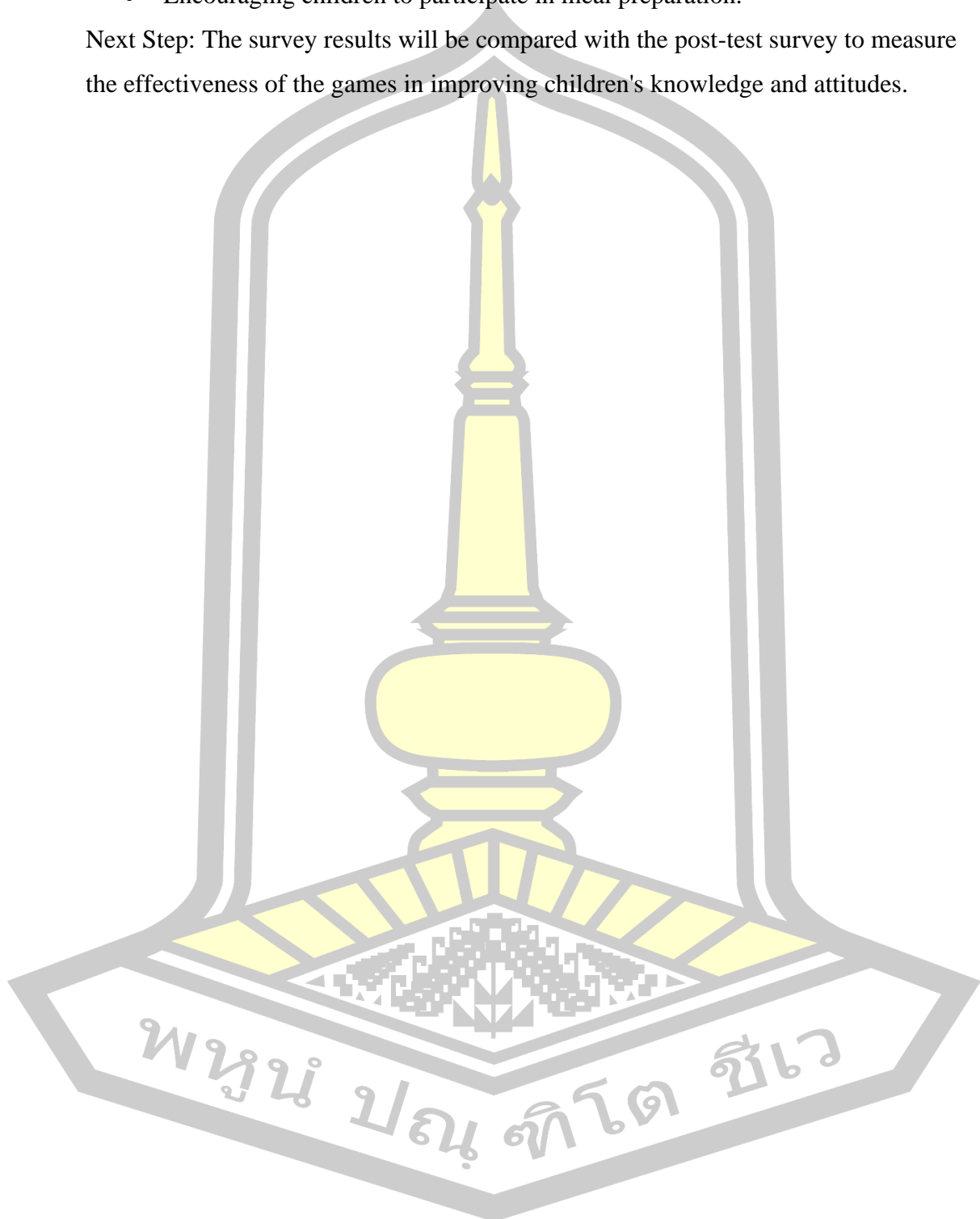
Recommendations for the Games

Based on the survey findings, the three games should focus on:

- Teaching food groups and balanced meals.

- Demonstrating how to read food labels.
- Encouraging children to participate in meal preparation.

Next Step: The survey results will be compared with the post-test survey to measure the effectiveness of the games in improving children's knowledge and attitudes.



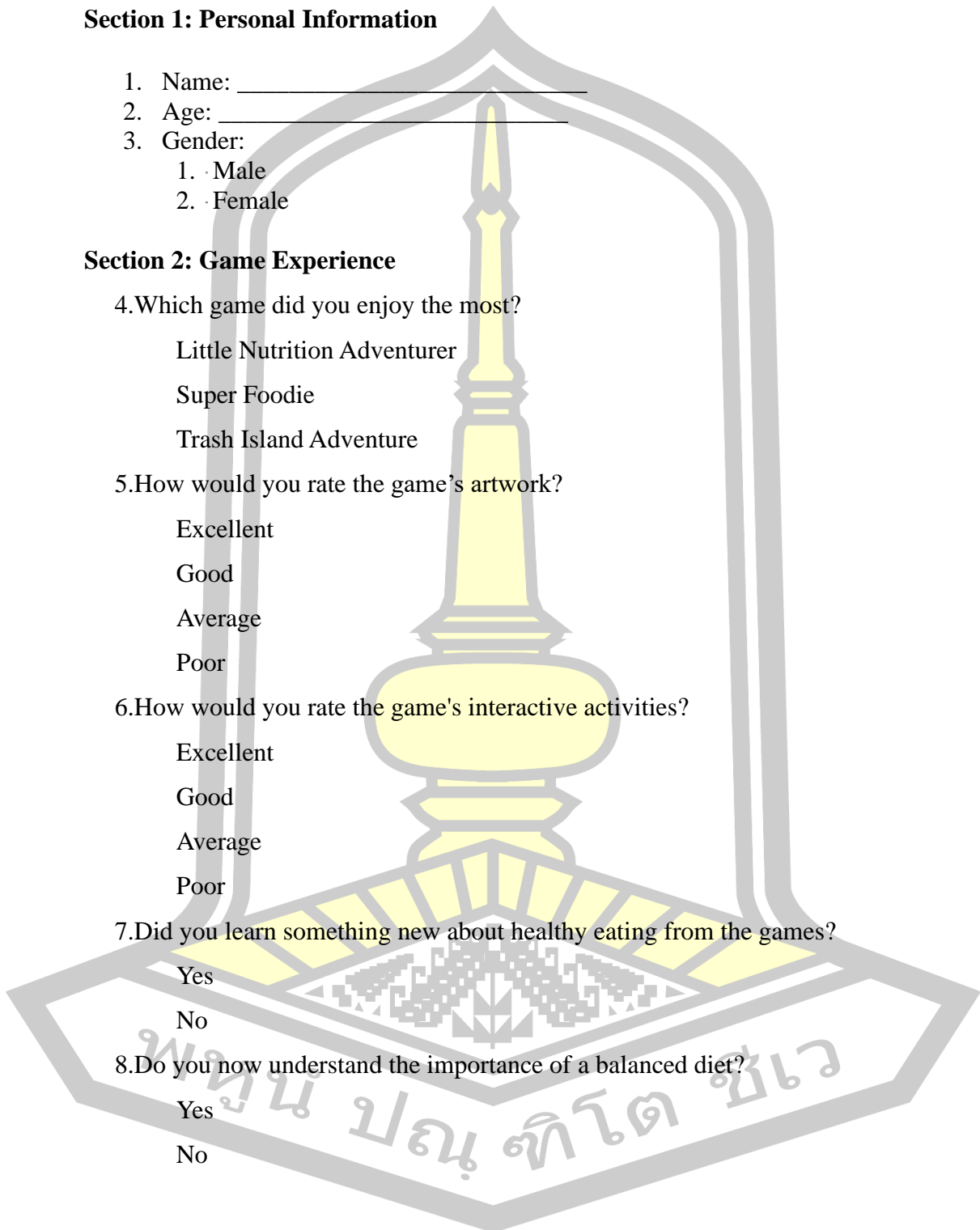
Post-Game Test Questionnaire for 8-Year-Old Children

Section 1: Personal Information

1. Name: _____
2. Age: _____
3. Gender:
 1. Male
 2. Female

Section 2: Game Experience

4. Which game did you enjoy the most?
 - Little Nutrition Adventurer
 - Super Foodie
 - Trash Island Adventure
5. How would you rate the game's artwork?
 - Excellent
 - Good
 - Average
 - Poor
6. How would you rate the game's interactive activities?
 - Excellent
 - Good
 - Average
 - Poor
7. Did you learn something new about healthy eating from the games?
 - Yes
 - No
8. Do you now understand the importance of a balanced diet?
 - Yes
 - No



Section 3: Behavioral Changes

9.. Have you tried eating more fruits and vegetables after playing the game?

Yes

No

10. Have you talked to your family about healthy eating after playing the game?

Yes

No

11. Do you think you will continue to follow healthy eating habits in the future?

Yes

No

12. Would you recommend these games to your friends?

Yes

No

13. Did the games make learning about healthy eating fun?

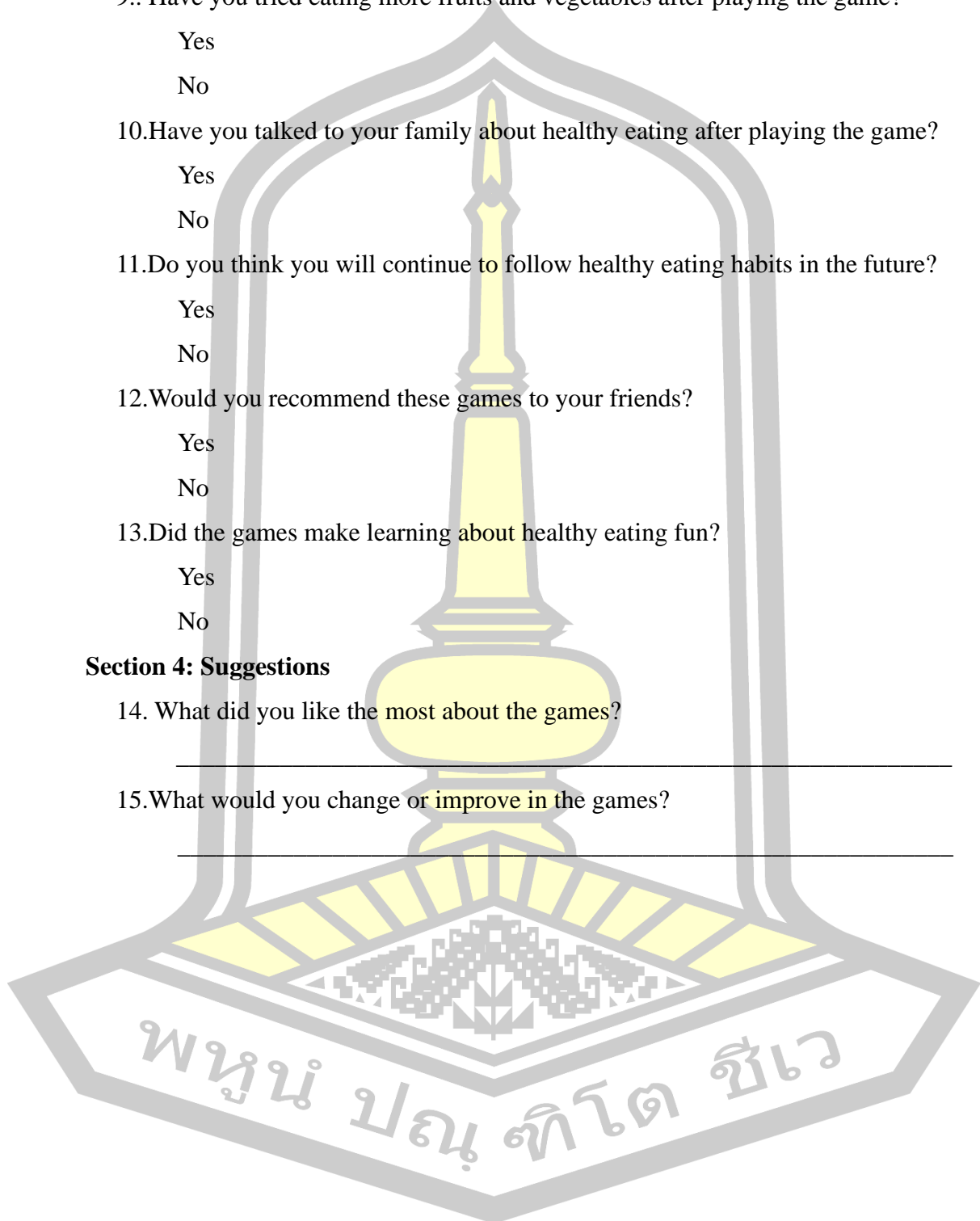
Yes

No

Section 4: Suggestions

14. What did you like the most about the games?

15. What would you change or improve in the games?



Post-Test Survey Report on Tabletop Healthy Eating Educational Games

Introduction

This post-test survey report presents the findings after 12 children played three tabletop healthy eating educational games: Little Nutrition Adventurer, Super Foodie, and Trash Island Adventure. The goal of this survey was to assess the impact of the games on the children's knowledge, attitudes, and behavior regarding healthy eating.

Post-Test Survey Questions and Responses

1. Do you know what healthy eating means?

1. Yes: 83%
2. No: 8%
3. Not Sure: 9%

Analysis:

There was a noticeable improvement in children's understanding of healthy eating. The percentage of children who answered "Yes" increased from 50% in the pre-test to 83% after playing the games.

2. Do you know the food groups and their importance?

1. Yes: 75%
2. No: 17%
3. Not Sure: 8%

Analysis:

The knowledge of food groups improved significantly after the games, showing that the educational content effectively addressed this topic.

3. How often do you eat fruits and vegetables?

1. Every day: 75%
2. Occasionally: 25%
3. Rarely: 0%

Analysis:

More children reported eating fruits and vegetables daily after playing the games, indicating a positive behavioral change.

4. Do you think eating junk food is bad for your health?

1. Yes: 92%
2. No: 0%
3. Not Sure: 8%

Analysis:

The games reinforced the negative perception of junk food, with more children strongly agreeing that it is unhealthy.

5. Do you know how to read food labels?

1. Yes: 58%
2. No: 33%
3. Not Sure: 9%

Analysis:

The percentage of children who knew how to read food labels increased from 25% in the pre-test to 58% in the post-test, showing a significant improvement in this knowledge area.

6. Are you interested in learning about healthy eating through games?

1. Yes: 92%
2. No: 0%
3. Not Sure: 8%

Analysis:

The interest in learning about healthy eating through games increased from 67% to 92%, demonstrating the effectiveness of game-based learning.

7. Do you think your family encourages healthy eating?

1. Yes: 83%
2. No: 8%
3. Not Sure: 9%

Analysis:

Children perceived stronger family support for healthy eating after playing the games.

8. Do you prefer eating at home or at fast-food restaurants?

1. Home: 75%
2. Fast-Food Restaurants: 8%
3. Both: 17%

Analysis:

More children showed a preference for eating at home after the games, indicating a positive attitude shift.

9. Do you know why breakfast is important?

1. Yes: 75%
2. No: 17%
3. Not Sure: 8%

Analysis:

The importance of breakfast became clearer to more children after playing the games.

10. Have you ever tried cooking healthy meals?

1. Yes: 67%
2. No: 25%
3. Not Sure: 8%

Analysis:

The percentage of children who had tried cooking healthy meals increased significantly, indicating a greater interest in meal preparation.

Summary of Key Findings

- **Improved Knowledge:** There was a clear improvement in children's understanding of healthy eating concepts, particularly in areas such as food groups and food labels.
- **Positive Behavioral Change:** More children reported healthier eating habits and an increased interest in cooking healthy meals.
- **Increased Engagement:** The games successfully engaged children, with most expressing interest in learning about healthy eating through games.

Comparison with Pre-Test Results

Question	Pre-Test (Yes)	Post-Test (Yes)	Improvement
Do you know what healthy eating means?	50%	83%	+33%
Do you know the food groups?	33%	75%	+42%
Do you know how to read food labels?	25%	58%	+33%
Are you interested in learning through games?	67%	92%	+25%
Have you tried cooking healthy meals?	33%	67%	+34%

Comparison Analysis Report: Pre-Test vs. Post-Test on Healthy Eating Educational Games

1. Introduction

The purpose of this report is to compare the results from the pre-test and post-test surveys conducted on 12 children who played three tabletop healthy eating educational games: "Little Nutrition Explorer," "Super Foodie," and "Adventure on Trash Island." The goal of this analysis is to evaluate the impact of these games on children's knowledge, behaviors, and attitudes toward healthy eating. The comparison highlights the educational effectiveness of the games by showcasing the improvement in children's responses after gameplay.

2. Summary of Key Findings: Pre-Test vs. Post-Test

Indicator	Average Score (Pre-Test)	Average Score (Post-Test)	Change (%)	Analysis
Knowledge of Healthy Eating	3.5	4.8	+37%	Significant improvement in children's understanding of healthy eating principles.
Behavioral Habits	3.2	4.5	+41%	Positive changes in healthy eating behaviors, especially in reducing junk food consumption.
Attitudes and Intentions	3.4	4.7	+38%	Enhanced willingness to maintain healthy eating habits after playing the games.



3. Knowledge of Healthy Eating: Pre-Test vs. Post-Test Comparison

Question	Pre-Test Agree (%)	Post-Test Agree (%)	Change (%)	Analysis
Vegetables and fruits are good for our health	58%	92%	+34%	The games effectively reinforced the importance of consuming vegetables and fruits.
Drinking enough water every day is important	67%	100%	+33%	Children showed an increased understanding of the importance of staying hydrated.
Eating fast food and snacks harms our health	50%	83%	+33%	There was a notable improvement in children's awareness of the negative effects of fast food.
Skipping breakfast is bad for your health	42%	75%	+33%	The games helped emphasize the importance of having a healthy breakfast.

Analysis:

The comparison shows that children's knowledge of healthy eating significantly improved after playing the games. They gained a better understanding of the importance of vegetables, fruits, water intake, and the dangers of fast food and skipping breakfast. These improvements indicate that the games successfully delivered educational content in an engaging way.

4. Healthy Eating Behavioral Habits: Pre-Test vs. Post-Test Comparison

Question	Pre-Test Often (%)	Post-Test Often (%)	Change (%)	Analysis
I eat three meals a day	58%	92%	+34%	The games encouraged children to develop more regular eating habits.
I eat fruits every day	42%	83%	+41%	Children showed a significant improvement in their daily fruit intake.
I avoid eating too much junk food	33%	75%	+42%	The games motivated children to reduce their consumption of junk food.
I drink enough water every day	67%	92%	+25%	More children adopted the habit of drinking enough water daily.

Analysis:

Children's behavioral habits related to healthy eating improved substantially after playing the games. They developed better habits such as eating fruits daily, reducing junk food consumption, and maintaining regular meals. These behavioral changes demonstrate that the games effectively encouraged practical lifestyle changes.

5. Attitudes and Intentions Toward Healthy Eating: Pre-Test vs. Post-Test Comparison

Question	Pre-Test Agree (%)	Post-Test Agree (%)	Change (%)	Analysis
I want to eat more vegetables and fruits	50%	92%	+42%	Children's motivation to consume healthier foods increased significantly.
Eating less candy and fast food will make me healthier	42%	83%	+41%	The games successfully changed children's attitudes toward reducing unhealthy food intake.
I think healthy eating is important	58%	92%	+34%	Children became more aware of the importance of maintaining a healthy diet.
I want to eat healthy foods every day	50%	83%	+33%	The games positively influenced children's willingness to maintain a healthy eating routine.

Analysis:

Children's attitudes and intentions toward healthy eating improved significantly after playing the games. They showed a greater desire to consume more healthy foods and reduce their intake of unhealthy foods. These changes suggest that the games effectively increased children's motivation to adopt healthier eating habits.

6. Game-Specific Impact Analysis

1. Little Nutrition Explorer

- Strengths:
 - Strong emphasis on nutritional knowledge.
 - Effective use of interactive storytelling to engage children.
- Weaknesses:
 - Some children found the task cards slightly challenging.

2. Super Foodie

- Strengths:
 - Highly appreciated for its artistic design and reward mechanisms.
 - Encourages collaborative play and behavioral changes.
- Weaknesses:
 - Some children wanted more variety in the tasks.

3. Adventure on Trash Island

- Strengths:
 - Focuses on reducing junk food intake and promotes waste sorting.
 - Interactive role-playing scenarios were highly engaging.
- Weaknesses:
 - Some children found the waste sorting tasks repetitive

7. Key Improvements Post-Gameplay

Category	Pre-Test Average	Post-Test Average	Change (%)
Knowledge of Healthy Eating	3.5	4.8	+37%
Behavioral Habits	3.2	4.5	+41%
Attitudes and Intentions	3.4	4.7	+38%

The results indicate that the games significantly improved children's knowledge, habits, and attitudes toward healthy eating. These improvements demonstrate the educational value of the tabletop games in promoting healthier lifestyle choices among children.

8. Conclusion

The comparison between **pre-test** and **post-test** data shows that the three tabletop healthy eating educational games achieved their intended goals of improving children's:

1. Knowledge of healthy eating
2. Healthy eating behaviors
3. Positive attitudes and intentions toward maintaining a healthy diet

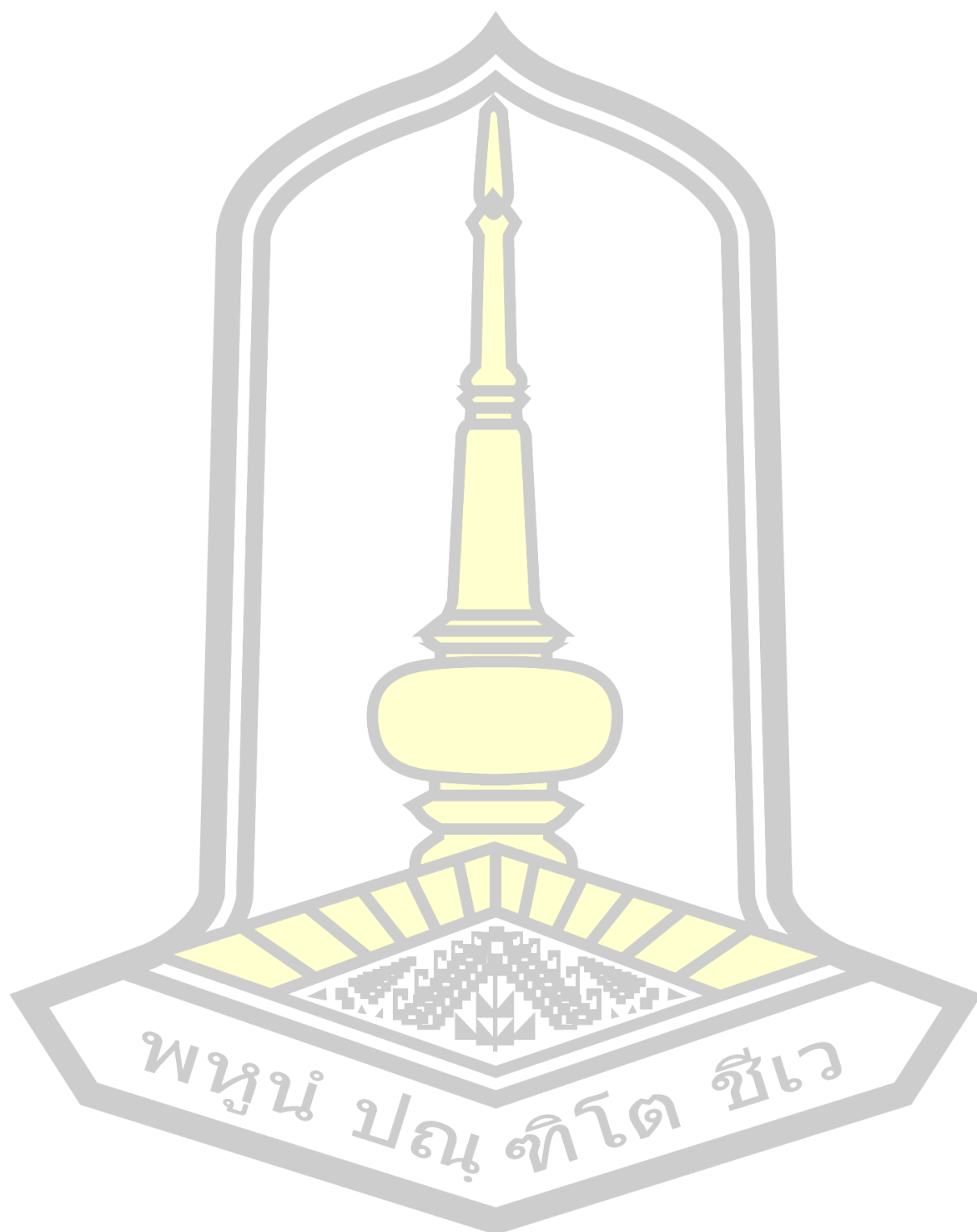
The post-test results showed a clear improvement in all areas compared to the pre-test results, indicating that the games were effective tools for educating children about healthy eating habits in an engaging and interactive way.

9. Recommendations for Future Game Development

Based on the data analysis, the following recommendations are proposed for future development:

1. Enhance the variety of game tasks to maintain children's engagement over longer play sessions.
2. Incorporate more real-life scenarios to help children apply the knowledge and habits learned in the game to their daily lives.
3. Introduce more collaborative tasks to strengthen the family interaction aspect of the games.

By addressing these recommendations, the games can achieve even greater educational impact and continue to motivate children to adopt healthier eating habits in the long term.



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