THE EFFECTIVENESS OF STEM-ARNutri APPROACH IN IMPROVING SECONDARY SCHOOL STUDENTS' KNOWLEDGE, ATTITUDES AND BEHAVIOUR TOWARDS NUTRITION

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LIST OF ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
ADIH	Associations Between Diet and Ill-Health
AFHC	Adolescent Food Habits Checklist
ANOVA	Univariate Analysis of Variance
AR	Augmented Reality
CAD	Computer-Aided Design
CTML	Cognitive Theory of Multimedia Learning
CVD	Cardiovascular Diseases
CVI	Content Validity Index
DR	Dietary Recommendation
DSKP	Curriculum and Assessment Standards Document
FCQ	Food Choice Questionnaire
GNKQ	General Nutrition Knowledge Questionnaire
IPH	Institute for Public Health
IR	Industrial Revolution
KAP	Knowledge, Attitude, Practice
KBSM	Integrated Curriculum for Secondary School
KHFCD	Knowledge of Healthy Food Choices and Diet
KR-20	Kuder-Richardson Formula 20
KSSM	Standard Curriculum for Secondary School
MANOVA	Multivariate Analysis of Variance
MAR	Mobile Augmented Reality
MMR	Mixed-Method Research

MOE	Ministry of Education
MOH	Ministry of Health
MOSTI	Ministry of Science, Technology, and Innovation
NCD	Non-Communicable Diseases
NHMS	National Health Morbidity Survey
Nutri	Nutrition
PPT	Power Point Presentation
PPPM	National Education Blueprint
QR	Quick Response
SEANUTS	Southeast Asia Nutrition Survey
SNFG	Sources of Nutrient in Food Group
SPSS	Statistical Packages for Social Science
STEM	Science, Technology, Engineering, and Mathematics
STEM-ARNutri	STEM-integrated AR Nutrition teaching and learning approach
VR	Virtual Reality
WHO	World Health Organization

LIST OF APPENDICES

KEBERKESANAN PENDEKATAN STEM-ARNutri DALAM MENINGKATKAN PENGETAHUAN, SIKAP DAN TINGKAH LAKU PELAJAR SEKOLAH MENENGAH TERHADAP NUTRISI

ABSTRAK

Nutrisi merupakan perkara yang penting dalam kesihatan dan pembangunan serta memegang peranan yang penting dalam agenda pendidikan di Malaysia. Pedagogi berkaitan tajuk nutrisi yang distruktur dengan baik dapat membantu pelajar memahami pengetahuan tentang nutrisi, menggambarkan konsep abstrak serta menggalakkan kesihatan dan kesejahteraan yang baik yang boleh mencegah penyakit tidak berjangkit dalam jangka masa panjang. Rekabentuk intervensi menggunakan kaedah gabungan ini bertujuan membangunkan pedagogi bertajuk nutrisi yang berkesan berdasarkan amalan semasa. Tahap pertama kajian meneroka amalan semasa dalam pengajaran dan pembelajaran bagi topik nutrisi dalam kalangan guru dan pelajar. Sampel bagi Tahap 1 terdiri daripada enam orang guru sains menengah rendah yang berpengalaman dan tujuh orang pelajar yang telah mempelajari topik nutrisi. Pencerapan kualitatif yang dikumpul menjadi asas pembentukan pedagogi bertajuk nutrisi dalam tahap kedua. Integrasi STEM (Sains, Teknologi, Kejuruteraan, dan Matematik) dan aplikasi realiti terimbuh (AR) membuka laluan kepada pendekatan pengajaran dan pembelajaran STEM-ARNutri. Dalam tahap ketiga, pengukuran dibuat bagi mengkaji keberkesanan pengajaran dan pembelajaran STEM-ARNutri dalam meningkatkan pengetahuan, sikap dan tingkah laku pelajar tingkatan dua terhadap nutrisi. Reka bentuk penyelidikan kuasi, kumpulan kawalan sebelum dan selepas tak setara dilaksanakan. Sampel berjumlah 121 pelajar Tingkatan Dua dari dua sekolah menengah di Daerah Baling dikelaskan secara rawak

sebagai kumpulan kawalan dan eksperimen. Temubual dijalankan ke atas pelajar dalam kumpulan eksperimen sebelum dan selepas pelaksanaan pengajaran dan pembelajaran STEM-ARNutri bagi menyokong penemuan data kuantitatif. Dapatan menunjukkan terdapat perbezaan dari segi pengetahuan, sikap dan tingkah laku terhadap nutrisi dalam kalangan pelajar sebelum dan selepas pelaksanaan pengajaran dan pembelajaran STEM-ARNutri. Dengan menggunakan soal selidik Tahap Pengetahuan Am Nutrisi (GNKQ), bagi mengukur pengetahuan pelajar terhadap nutrisi, MANOVA menunjukkan perbezaan yang signifikan secara berstatistik antara kumpulan eksperimen dan kawalan bagi gabungan konstruk pengetahuan, $F(4,116) = 57.802$, $p<0.05$; Wilk's $\Lambda = 0.334$; separa $\eta 2 = 0.666$. Sikap pelajar diukur menggunakan soal selidik Faktor Pemilihan Makanan (FCQ) dengan MANOVA menunjukkan perbezaan signifikan secara berstatistik antara kumpulan eksperimen dan kawalan bagi gabungan dimensi sikap, $F(4,116) = 50.426$, p 0.05; Wilk's = 0.365; separa $\eta 2 = 0.635$. Tingkah laku pelajar terhadap nutrisi diukur menggunakan soal selidik Senarai Semak Tabiat Makanan Remaja (AFHC), dengan ujian-t sampel bebas menunjukkan perbezaan signifikan secara berstatistik antara kumpulan eksperimen dan kawalan dari segi tingkah laku terhadap nutrisi, $t(119) = 13.20$, $p=0.000$. Dalam kajian ini, analisis temu bual kualitatif telah digabungkan dengan analisis statistik kuantitatif untuk menunjukkan faedah pendekatan pengajaran dan pembelajaran STEM-ARNutri dalam kalangan pelajar dalam kumpulan intervensi berbanding dengan kumpulan kawalan. Selain itu, pendekatan ini menangani masalah dunia sebenar dengan menawarkan penyelesaian untuk meningkatkan kesedaran dan mengurangkan kesan penyakit tidak berjangkit (NCD) dalam kalangan pelajar, sekali gus menggalakkan gaya hidup yang lebih sihat. Kesimpulannya, dapatan kajian ini menggambarkan pendekatan pengajaran dan pembelajaran STEM-

ARNutri mampu meningkatkan pengetahuan, sikap dan tingkah laku pelajar terhadap nutrisi.

THE EFFECTIVENESS OF STEM-ARNutri APPROACH IN IMPROVING SECONDARY SCHOOL STUDENTS' KNOWLEDGE, ATTITUDES AND BEHAVIOUR TOWARDS NUTRITION

ABSTRACT

Nutrition is a critical part of both health and development and holds a prominent place in the educational agenda in Malaysia. Proficient and well-structured nutrition education has the potential to enhance students' ability to grasp the knowledge towards nutrition, visualize the abstract concept, and promote good health and wellbeing, which can prevent Non-Communicable Diseases (NCD's) in the long run. This mixed-methods intervention study aimed to create a more effective nutrition education approach based on current practices. The first level of the study investigated the existing teaching and learning practices concerning nutrition topics among secondary school students and teachers. The sample for Level 1 comprises six experienced lower secondary science teachers and seven students who have studied the topic of nutrition. Qualitative insights gathered during this level served as the foundation for developing nutrition instruction in level two. The integration of Science, Technology, Engineering, and Mathematics (STEM) with Augmented Reality (AR) mobile applications led to the formulation of the STEM-ARNutri teaching and learning approach. During the third level, the study evaluated how the STEM-ARNutri teaching and learning approach influenced the knowledge, attitudes, and behaviors of Form Two students in relation to nutrition. This assessment employed a quasi-experimental design, specifically a non-equivalent pre- and post-test control group design. A sample of 121 Form Two students from two secondary

schools in Baling district were randomly assigned to control and experimental groups. Interviews were conducted with the students from the experimental group before and after the execution of the STEM-ARNutri teaching and learning approach to gain insight into the quantitative findings. The results demonstrated noticeable differences in students' knowledge, attitudes, and behaviors related to nutrition before and after the introduction of STEM-ARNutri teaching and learning approach. Using the General Nutrition Knowledge Questionnaire (GNKQ) to measure students' knowledge towards nutrition, MANOVA showed a statistically significant difference between the experimental and control groups on the combined GNKQ constructs: $F(4,116) = 57.802$, $p<0.05$; Wilk's $\Lambda = 0.334$; partial eta squared $\eta 2 = 0.666$. Students' attitude towards nutrition was measured using the Food Choice Questionnaire (FCQ), and MANOVA indicated a statistically significant difference between the experimental and control groups on the combined attitude dimensions: F (4,116) = 50.426, p 0.05; Wilk's = 0.365; partial eta squared $\eta 2 = 0.635$. Students' perceptions of nutrition's behavior were measured using the Adolescent Food Habits Checklist (AFHC) Questionnaire, where an independent sample t-test revealed a statistically significant difference for the post-test between the experimental and control groups for perceptions of nutrition's behavior: $t(119) = 13.20$, $p=0.000$. In this study, qualitative interview analysis was merged with quantitative statistical analysis to demonstrate the benefits of STEM-ARNutri teaching and learning approach among the students in the intervention group as compared to the control group. Moreover, this approach addressed real-world problems by offering a solution to heighten awareness and mitigate the impact of non-communicable diseases (NCDs) among students, thereby promoting a healthier lifestyle. In conclusion, the findings of this

study reflected that the STEM-ARNutri teaching and learning approach was able to enhance students' knowledge, attitude, and behavior towards nutrition.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The development of nutrition science has consistently demonstrated a connection between health and nutrition ever since the discovery in the 20th century of the consequences of malnutrition (Ruth et al., 2020). Beyond the adverse impact malnutrition has on socioeconomic progress, the insufficient availability of quality foods undermines the overall health and well-being of population of all ages (Sweerts et al., 2016). The phenomenon known as the nutrition transition, characterized by a shift towards consuming fast and convenient foods rich in sugar and fat, has been on the rise. The consumption of these foods, combined with sedentary lifestyles, has been linked to conditions such as overweight, obesity, and Non-Communicable Diseases (NCDs) like diabetes, cancer, and cardiovascular diseases (Popkin, 2015). While these conditions were once primarily associated with developed nations, they are now increasingly prevalent in developing and less affluent countries as well (WHO, 2018). Like many other countries in transition, Malaysia is a nation amid transition, and the prevalence of obesity and associated NCDs has continued to increase among Malaysians, surpassing the global average (NHMS, 2022).

In a world where lifestyle changes are rapidly accelerating, timely nutritional education is the cornerstone for achieving robust health and well-being in childhood and later stages of life. Profound nutrition education at the elementary level can provide students with insights on how to reverse this dietary transition by offering a thorough analysis of what they consume, along with the eating patterns associated

with modernization (Quaidoo et al., 2018). The transition from adolescence to adulthood presents a greater risk for young people to adopt inadequate dietary habits, which may lead to the development of serious diseases like osteoporosis, obesity, diabetes, and cancer later in life. Therefore, adolescence is widely acknowledged as a crucial period during which nutrition education can play a pivotal role in establishing lifelong healthy eating habits (Sprake et al., 2018). The Diet and Nutrition Survey underscores the importance of nutrition education in elementary schools for students aged between 4 to 18 years old (IPH, 2020). Such education at the school level is vital to improving children's nutritional status, particularly in addressing the problem of malnutrition among youth (Chong et al., 2016). The relationship between knowledge, attitude, and behavior is closely intertwined with the teaching and learning of nutrition, leading to significant changes in students' food choices and, ultimately, their health and performance (Husain et al., 2021).

Specifically, the education on nutrition that students receive in school should equip them with practical knowledge about nutrition in their daily lives, foster the development of positive attitudes, and promote changes in their behaviour toward healthy eating. Nutrition knowledge in this study implies basic knowledge on dietary recommendation, food group, healthy food choice, diet, disease, and weight management among young children and adolescents (Kliemann et al., 2016), while attitude analyses about health, mood, convenience, sensory appeal, natural content, price, weight control, familiarity, and ethical concern (Andrew Steptoe et al., 1995) On the other hand, behavior addresses areas in which adolescents may be able to affect how closely their diets conform to guidelines on healthy eating, with reference to the avoidance of specific energy-dense foods, the selection of low-fat alternatives, the consumption of fruit and vegetables, and snacking behavior (Johnson et al., 2002).

Consequently, the nutritional knowledge that students acquire in school leads to positive changes in their food choices, which, in turn, influence their attitudes and behaviors related to food (Gao et al., 2021).

To effectively engage students in behavioural change, cultivate positive attitudes, and provide them with sufficient knowledge, it is considered essential to adopt a cross-disciplinary approach to teaching and learning (Tavolacci et al., 2015). Nutritional knowledge, encompassing topics like food categories, dietary habits, obesity, malnutrition, eating patterns, and snacking behaviour, is inherently interdisciplinary (National Health Morbidity Survey (NHMS), 2019). For students to grasp the implications of fast food and an unhealthy lifestyle, they should be presented with a real-life problem that reflects societal issues, such as the problem of obesity. While dissecting this problem, students are encouraged to make informed decisions and propose solutions that are rooted in real-world concepts. Given the interdisciplinary nature of these real-world issues, there is a need for the integration of cross-disciplinary teaching and learning in the field of nutrition (English, 2017).

One way of presenting cross-disciplinary teaching and learning of nutrition is through integrated Science, Technology, engineering, and Mathematics (STEM) education, as integrated STEM education enables people to achieve educational goals by preparing them for daily life and work life (Pimthong & Williams, 2018). STEM education is viewed as interdisciplinary since all four disciplines of science, technology, engineering, and mathematics promote disciplinary crossing by bridging real-world problems (English, 2017). Some studies have proposed Augmented Reality (AR) as a platform to stage a real-life context by acting as a powerful processor to either composite virtual and real objects or display a three-dimensional (3D) simulated environment in real time (Azuma et al., 2011). Augmented Reality is

a technology that superimposes computer-generated images, sounds, or other sensory inputs on a real-world environment in real-time, enhancing the user's perception of reality (Sahin & Yilmaz, 2020). Augmented Reality is a technology platform that can be utilized for nutrition education, allowing learners to interact with digital nutrition content and enhancing their comprehension of the nutritional aspects of food and its impact on health (McGuirt et al., 2020).

A study from Journal of Nutrition Education and Behaviour on nutrition education have revealed that interactive teaching methods, which encourage active involvement, can effectively enhance students' understanding of nutrition and encourage them to make healthier food choices. A systematic review discovered that students who participated in nutrition education programs integrating Science, Technology, Engineering, and Mathematics (STEM) alongside augmented reality technology exhibited positive attitudes, behaviors, and knowledge regarding healthy eating (Kalimuthu et al., 2023). Therefore, the amalgamation of STEM, which is interdisciplinary in nature, and AR, which enables 3D views, would be an appropriate strategy to teach and learn about nutrition (Nutri). Hence, in this study, a STEM-ARNutri teaching and learning approach has been developed to measure the effectiveness of the approach in improving secondary school students' knowledge, attitude, and behavior towards nutrition**.**

1.2 Background of the Study

Good nutrition is essential for growth, development, and the maintenance of health throughout life (WHO, 2018). However, the globalization of the human diet, as well as the progress of global economic development, is affecting human health and nutritional intake. As the global economy grows, the differences in diet patterns

between nations with varying income levels are becoming less distinct. According to the WHO's (2017) report, diets that were previously high in complex carbohydrates and fiber are now making way for more varied diets with a higher proportion of fats, saturated fats, and sugars. These changes in diet are leading to changes in disease patterns, with a shift from infectious and nutrient-deficiency diseases to higher rates of coronary heart disease, diabetes, cancer, and obesity. Currently, obesity is a significant global epidemic that affects more than half of the population, especially in rapidly industrializing and industrialized countries (Yusop et al., 2018).

According to the Southeast Asia Nutrition Survey of Malaysian Children (SEANUTS Malaysia), the prevalence of overnutrition among children aged 7–12 years was 21.6 percent in 2013, which was greater than the prevalence of undernutrition (13.8 percent). According to the 2019 National Health Morbidity Survey (NHMS), the prevalence of overnutrition has climbed to 29.8%, while the incidence of undernutrition has increased to 22.7 percent among children aged 5–17 years. This significant issue of malnutrition problems in Malaysia may impact children's growth and development later in life. Obese children have been shown to have a higher risk of high blood pressure, high cholesterol, and impaired glucose tolerance in adulthood, whereas undernourished children may have a higher risk of poor cognitive development and physical impairment (NHMS, 2019).

Unlike most adults, children often find it challenging to make wise choices between consuming nutritious or unhealthy foods (WHO, 2017). Education plays a crucial role as it empowers individuals to make informed decisions about their health and enhances their "health literacy," enabling them to actively contribute to improving the environments that impact their well-being (Kupolati et al., 2015). School-based nutrition education remains one of the most effective settings for

children to acquire knowledge and skills related to nutrition. Therefore, it is essential to implement a comprehensive nutrition education program in elementary schools to teach students the significance of healthy eating and an active lifestyle in achieving optimal nutritional status (Ministry of Education Malaysia, 2018). Nutrition education equips children with knowledge about nutrition, which in turn helps shape positive attitudes and encourages healthy behaviors (Heiman & Olenik-Shemesh, 2019). Providing children with knowledge and practice in healthy eating during their formative years is particularly beneficial, as dietary habits established in childhood tend to persist into adolescence and can be challenging to change later in life (WHO, 2017). Therefore, it is imperative to educate children about nutrition and healthy eating to prevent the development of overweight or obesity in the future (Asakura et al., 2017).

In a similar vein, the science curriculum for lower secondary schools in Malaysia incorporates various nutritional knowledge components. Specifically, the subject of nutrition is covered in Form Two as part of the broader theme of "Maintenance and Continuity of Life" within the science curriculum (MOE, 2016). This nutrition-focused segment primarily addresses health-related topics and delves into aspects of health maintenance. To organize the curriculum effectively, the lessons on nutrition have been further categorized into Learning Area 3.0, specifically focusing on nutrition, in accordance with curriculum standards (MOE, 2016). In essence, within the nutrition topic, students receive instruction on several key areas, including food classifications, the significance of a balanced diet, the functioning of the human digestive system, the processes involved in absorbing and transporting digested food, as well as the elimination of waste through defecation. Moreover, students are also taught how to lead a healthy lifestyle. Additionally,

discussions encompass aspects such as the effects of nutritional deficiencies, dietary patterns, and the issue of obesity. These compulsory curricula include many learning goals and knowledge standards connected to acquiring skills and familiarizing students with new nutrition knowledge (MOE, 2016).

Numerous teaching methods have been employed to impart nutrition lessons at the elementary and secondary school levels. These approaches encompass diverse techniques such as classroom discussions, worksheets, taste-testing, and creative activities like role-playing or drama, among others (Niswah et al., 2021). Conversely, engaging students in hands-on activities like school gardening, developing culinary skills, organizing exhibitions, and conducting workshops has also presented challenges (Heiman & Olenik-Shemesh, 2019). The advent of new technologies, such as the Internet, World Wide Web, and computer-tailored learning, has also opened opportunities for effective learning experiences (Reilly et al., 2018).

In the Malaysian context specifically, nutrition intervention has been widely employed to disseminate information on healthy diets and nutrition to various population groups. However, this type of intervention is still uncommonly implemented for secondary school students (Sharifah et al., 2016). Hence, this study opted for lower secondary students as participants. Previous studies have demonstrated that while there are various modes of nutrition interventions, their impact on eating habits remains uncertain (Sharif Ishak et al., 2020). Consequently, numerous endeavours have been made to enhance the teaching and learning of nutrition.

As our understanding of nutrition extends beyond individual well-being to encompass global considerations, a fresh perspective on nutrition intervention

becomes necessary (Ruth et al., 2020). Previous research indicates that incorporating interactive technology into nutrition instruction can enhance student learning and engagement in the subject. An interactive digital platform that offers three-dimensional visualizations and enables students to interact with the virtual environment has been identified as a promising and effective method for delivering nutrition knowledge (Chin et al., 2020). Therefore, it is essential to overhaul the nutrition curriculum and adopt a well-structured teaching and learning approach to ensure a comprehensive understanding of nutrition concepts and the development of essential nutritional knowledge and skills. Taking a cross-disciplinary approach that bridges real-world problems has the potential to stimulate the creation of new standards, curricular materials, teaching methods, professional development, assessments, and international dialogue, particularly in the context of K–12 education (Brooks & Begley, 2014). This approach aids students in comprehending and interpreting interdisciplinary nutritional knowledge while integrating nutrition-related concepts into daily life applications. Consequently, it fosters positive attitudes and behaviours toward nutrition (Ruth et al., 2020).

STEM education has garnered significant attention in the transformation of formal school education, providing students with exceptional learning experiences (Zendler et al., 2018). It is an interdisciplinary field that bridges science, technology, engineering, and mathematics (Bybee, 2020). Integrated STEM education is clearly defined as an interdisciplinary approach that combines academic concepts with real-world lessons, allowing learners to apply science, technology, engineering, and mathematics, thereby promoting scientific literacy through community interaction (Kelley & Knowles, 2016). Over time, STEM education has evolved into a multidisciplinary and integrated effort that emphasizes creativity and the practical

process of solving complex contextual problems using modern tools and technology. This interdisciplinary nature of STEM disciplines enhances students' progress and performance in learning when applied to real-world problems faced by society (Kim et al., 2015). Therefore, effectively engaging students in high-quality STEM education necessitates a comprehensive restructuring of the curriculum, instruction, and assessment processes. This involves integrating technology and engineering elements into the core science curriculum, as well as fostering scientific inquiry and developing skills related to the engineering design process in science education (Kennedy & Odell, 2014). Kularbphettong et al. (2019) further emphasizes that technology and engineering are crucial components of integrated STEM education, facilitating a meaningful understanding of fundamental scientific concepts.

Nutrition, which is interdisciplinary in nature, promotes successful teaching and learning when integrated with the four disciplines of STEM education. STEM education is one of the areas where AR can be used effectively (Pimthong & Williams, 2018). Cross-disciplinary teaching and learning is accomplished by integrating the four STEM disciplines with nutrition and presenting the combination of nutrition and STEM disciplines on an AR platform. Having an AR-integrated technological tool as a platform to stage the health literacy connected to nutrition in the aggregation of STEM-ARNutri teaching and learning approach allows a deeper understanding of the global health challenges of the modern world concerning health and lifestyle. AR is an emerging technology that has dominated educational research over the past decade and allows overlaying layers of virtual information on real scenes with the aim of increasing the user's perception of reality (Ablyaev et al., 2019). Bridging the virtual and real worlds, augmented reality (AR) creates a reality that is enhanced and augmented (Liou et al., 2017). AR implementation is defined by

the integration of real-world and virtual components that are interactive in real-time and presented in a three-dimensional view (Roy et al., 2017).

Given the exciting advancements and obvious usefulness of AR as an enhanced user interface technology, researchers think that AR has enormous potential ramifications and many advantages for the augmentation of teaching and learning settings (Arici et al., 2019). AR has the potential to engage, stimulate, and motivate students to explore class materials from various perspectives, assist in teaching subjects where students could not feasibly gain real-world first-hand experience, improve collaboration between students and instructors, encourage student creativity and imagination, assist students in taking charge of their learning at their own speed and on their own route, and provide an authentic learning environment suited for different learning styles (Nielsen et al., 2017).

Moreover, augmented reality (AR) can be advanced through the combination and integration of various cutting-edge technologies, such as mobile devices, wearable computers, and immersion technologies. Notably, the rise and rapid adoption of mobile phones have made Mobile Augmented Reality (MAR) a viable option (Yang, Mei & Yue, 2018). Numerous studies have highlighted the significant role of mobile devices in education today and recognized their potential for enhancing teaching and learning approaches (Craig, 2013). In addition, research has shown that the combination of AR technology with mobile applications can facilitate users' comprehension of visually presented information. The utilization of a 3D perspective through AR further enhances the quality of learning, while interactivity increases students' attention, engagement, and sense of presence during the learning process (Yang et al., 2018).

The integration of STEM disciplines that are interdisciplinary in nature, as well as AR as technology tools, to stage learning subject knowledge in 3D representations of real-world problems such as health literacy and obesity in a highly interactive manner is the most appropriate cross-disciplinary teaching and learning tool to teach nutrition to Form Two students. STEM-ARNutri, as a teaching and learning approach in this study, allows students to address real-world issues by bridging barriers across all STEM dimensions.

A systematic review has established that nutrition interventions and health education programs enhanced by technology are effective in enhancing the nutrition knowledge, attitudes, and behaviours of adolescents (Marques et al., 2018). The integration of adequate nutrition knowledge into daily dietary habits is recognized as a fundamental method for promoting a healthy lifestyle (Vidgen, 2016). Nutrition knowledge, in this context, is defined as a scientific concept developed by nutrition educators to encompass the cognitive processes individuals use to understand information related to food and nutrition (Nor Baizura, 2018). In this study, nutrition knowledge encompasses knowledge on the source of nutrients in food, dietary recommendations, food groups, healthy food choices, weight management, and knowledge on health problems or diseases associated with diet. There is mounting evidence that young children in developing and developed countries are increasingly choosing harmful dietary choices owing to a lack of knowledge and a poor understanding of nutritious foods (Jones et al., 2017). This is primarily because, as represented in the media, the idea of 'food' has shifted from a source of nutrition to a marker of lifestyle and a source of pleasure (Lucas et al., 2017). According to a nationwide survey, the nutrition knowledge acquired during adolescence is considered one of the most influential factors that can have a lasting effect on

individuals' healthy lifestyles (Ashari et al., 2022). In Malaysia, several studies have been conducted to evaluate the nutritional knowledge of adolescents, specifically overweight and obese children. This research aims to emphasize the importance of good nutrition as it serves as the cornerstone for the development of healthy, flourishing, and productive communities and nations (Lim et al., 2018).

Apart from knowledge, nutrition intervention is also thought to be essential to instilling a positive attitude toward healthy eating early in childhood and adolescence. (Partida et al., 2018). In psychology, attitude is described as a psychological construct, a mental and emotional entity that is embedded in an individual (Eagly & Chaiken, 1998). Specifically, attitude towards nutrition is defined as a psychological factor influencing food choice and consumption (Cox & Anderson, 2004). Consequently, research conducted in Malaysia reveals that there has been a noticeable shift in attitudes towards unhealthy eating patterns in recent years. This change has led to an increase in the prevalence of conditions such as overweight, obesity, cancer, diabetes, and cardiovascular-related illnesses. There is now a pressing need to improve dietary attitudes to promote the maintenance of a healthy physical and mental state (Rahayuwati et al., 2019). Basically, the eating patterns most often linked to unhealthy diets are low fruit and vegetable consumption, skipping breakfast, high fat and energy content, low fiber content, and high soft drink consumption (Lipsky et al., 2017). Other factors that influence individuals' eating patterns include biologically determined preferences such as sensory factors (e.g., sweet, salt, and hunger), experience or familiarity with food, cultural norms, and individual beliefs (e.g., green is healthy), environmental factors (e.g., availability and price), and social structure (Kobayashi et al., 2015). Therefore, the attitude in this study implies health, mood, convenience, sensory appeal, natural content, price,

weight control, familiarity, and ethical concern, which are interconnected in nature (Andrew Steptoe et al., 1995).

Changes in dietary behaviour also play an important role in promoting healthy eating among teenagers (Chong et al., 2016). Generally, eating behaviour refers to the dietary choices and other food and nutrition-related behaviours that individuals do to attain a desired result of their own choosing (El Harake et al., 2018). Specifically in nutrition, dietary behaviour encompasses the contents of the dietary lifestyle of an individual rather than simply comprehending meals in terms of nutrients or calories (Ritchie et al., 2015). Eating behaviour, like any other behaviour, develops early in life in response to a variety of psychological, social, economic, and environmental variables. Once established, eating habits are very difficult to alter (Herath et al., 2017). Research conducted in Malaysia highlights the importance of examining the development of eating behaviour and habits among young individuals due to the significant influence of dietary patterns on health and the occurrence of disease outbreaks (Min et al., 2018). Ishak et al. (2020) propose that cultivating a comprehensive understanding of healthy eating and promoting sustainable dietary patterns should commence at a young age, starting with primary education in Malaysia. It has been observed that dietary habits formed during childhood tend to persist throughout life. Evidence indicates that Malaysian children who adopt poor eating habits face an elevated risk of malnutrition and the development of noncommunicable diseases (NCDs) later in life, including hypertension, coronary heart disease, diabetes, and obesity (Don et al., 2015).

Hence, in order to address the growing concern of childhood obesity and the associated health risks, it is crucial to empower schoolchildren with the ability to make informed food choices and instill in them a positive attitude towards healthy eating behaviours (Sweerts et al., 2016). Research also suggests that one of the most effective ways to impart multidisciplinary nutrition knowledge to students is through educational initiatives within schools, particularly through the integration of nutrition concepts into science education (Bundy et al., 2017). STEM-ARNutri teaching and learning approach could be a suitable teaching and learning approach for obtaining complete nutrition knowledge to solve complex real-world problems facing society. This is because this approach facilitates a 3D view of food classes and diseases associated with nutrition imbalance that may overcome a lack of knowledge and a poor understanding of nutritious foods. STEM-ARNutri, as a comprehensive cross-disciplinary teaching and learning approach, educates students on improving nutrition knowledge, attitudes, and behaviours towards practicing healthy eating and active living to achieve good nutritional status and a healthy lifestyle.

1.3 Statement of the Problem

The rapid progress of science and technology, coupled with the increasingly fast-paced nature of human life, has led to the emergence of civilization-related diseases. One contributing factor to this phenomenon is the shift towards processed foods that lack essential nutrients like vitamins, minerals, and fiber while containing high levels of fat and carbohydrates, which pose significant health risks to individuals (WHO, 2019). Additionally, an imbalanced nutritional status during childhood can have severe long-term consequences, including reduced quality of life,

diminished self-esteem during adolescence, and an increased likelihood of developing health problems in the future (Ruth et al., 2020).

According to previous literature, Malaysia has seen a steady increase in adolescent obesity rates (NHMS, 2019), mirroring the global trend (Tanno, Ege & Yanai, 2018). The Ministry of Health conducted the third National Health and Morbidity Survey (NHMS) in Malaysia, which indicated that childhood obesity (in individuals under the age of 18) had reached a prevalence of 11.9 percent (NHMS, 2017). Additionally, studies have demonstrated that adolescents frequently fail to consume the recommended amounts of fruits and vegetables (Henchoz et al., 2019), indulge in high-fat, calorie-dense snacks (Husain et al., 2021), skip meals, and consume fast food more frequently (Hanna et al., 2017). The literature indicates that traditional nutrition lessons led by teachers, such as lectures and demonstrations, may have led to minimal knowledge, attitude and behavioral changes among students. This could be a contributing factor to the rising prevalence of non-communicable diseases (NCDs) among Malaysian adolescents (Kalimuthu et al., 2023).

According to Ruth et al. (2020), insufficient nutrition knowledge is the primary contributor to irreversible harm to human health. The study found that a significant proportion of participants had poor knowledge when it came to identifying foods containing starch and fiber, with 35% of the sample unable to correctly categorize even half of the foods presented as high or low in fiber. Belogianni et al. (2021) reported similar negative findings concerning dietary fat and coronary heart disease knowledge. Similarly, in Malaysia, the younger population tends to prefer desserts, snacks, and fried food, as highlighted by Norimah et al. (2015). The root cause of this problem is closely related to a lack of basic knowledge on dietary recommendations, food groups, healthy food choices, diet, disease, and

weight management among young children and adolescents. This finding suggests that young children do not understand the importance of healthy eating and that contemporary nutrition-related programs do not effectively provide nutrition knowledge (Teo et al., 2019).

Another significant contributor to health-related issues is negative dietary attitudes. When children have poor or negative attitudes towards their diet, they are at a higher risk of developing overweight or obesity, which are risk factors for chronic lifestyle diseases later in life (Rungsaran et al., 2022). In today's society, with the growing prevalence of the western diet and the increased exposure to food advertisements aimed at children, it is even more critical to educate children about making appropriate food choices (Wadolowska & Stasiewicz, 2020). A study conducted by the Institute for Public Health (IPH) in 2020 revealed that there is still a deficiency of efforts to instil positive attitudes towards healthy eating habits during childhood and adolescence in Malaysia.

In recent years, there has been a growing focus on the eating behaviour of young people, with claims that many adolescents have a poor diet (Kulpy & Bekaroo, 2017). A national survey carried out in 2020 showed that improper eating behaviours in young children can lead to various health issues that may manifest later in life (IPH, 2020). Such dietary behaviour can result in an increased intake of calorie-dense nutrients, leading to higher rates of overweight, obesity, and diabetes. Additionally, imbalanced diets, frequent consumption of processed foods, and eating out can result in deficiencies of essential nutrients such as calcium, vitamin A, thiamine, and riboflavin, leading to a state of nutritional imbalance characterized by over-nutrition and nutrient deficiencies simultaneously (Teo et al., 2019). Thus, promoting and maintaining healthy eating behaviours in childhood and altering

existing dietary patterns remain significant challenges for nutrition educators (Skrzypek et al., 2020).

Nutrition has been included as part of the secondary-level science curriculum (MOE, 2018). Although the curriculum covers topics like food groups, the importance of a balanced diet, the human digestive system, the process of absorbing and transporting digested food, and defecation, there is still a reported lack of knowledge, attitudes, and behaviours in this area (Marques et al., 2018). In recent times, there has been growing concern about the decreasing interest of students in nutrition, as they often perceive it as an abstract discipline that requires a deep level of understanding and visualization (Teo et al., 2019). This perception is fueled by the limitations of current technology, which does not provide effective visualization of nutritional phenomena. Consequently, the teaching and learning process fails to create opportunities for students to engage in negotiation, debate, critical examination, assessment, and synthesis of real-life problem-solving solutions (Chin et al., 2020).

Inter-disciplinary teaching and learning using integrated STEM is pertinent to students' grasping skills and knowledge, as each STEM component brings a valuable contribution to a well-rounded education that enables them to overcome emerging health problems such as malnutrition, overnutrition, and obesity. However, there is a dearth of evidence on students' knowledge and understanding of integrated STEM (Pearson, 2017). There are always many challenges to integrating STEM education since incorporating four dimensions into real-world and meaningful learning experiences for students is an enormously complex and demanding process (Hunter-Doniger & Sydow, 2016). To this extent, integrated STEM has not been implemented properly (English, 2017), particularly in secondary schools and in the context of

nutrition teaching and learning, as nutrition is expected to be a central focus of health care in the future to improve health literacy (Hu et al., 2017).

Research indicates that there's room for improvement in the way students learn about nutrition. Various technologies have been employed for this purpose, but the utilization of Augmented Reality (AR) with a three-dimensional (3D) perspective represents a more advanced approach in terms of chronological progression (Yulia et al., 2018). However, the full potential of AR has not yet been harnessed for nutrition education, primarily due to the limitations of technology both in terms of delivering nutritional information and the utilization of AR technology (Hwang et al., 2015). Consequently, there is a pressing need for the development of technology capable of providing comprehensive nutritional information. It's worth noting that educational research pertaining to the integration of the four interdisciplinary STEM disciplines with nutrition, and the cohesive presentation of this blend on an AR platform, is still in its early and rudimentary stages.

1.4 Purpose of Study

The purpose of this study is to develop the STEM-ARNutri teaching and learning approach to teach nutrition and to evaluate the effectiveness of STEM-ARNutri teaching and learning approach in improving secondary school students' knowledge, attitude and behavior towards nutrition.

1.5 Research Objectives

Specifically, this study aims to achieve the following research objectives:

1. To explore the current practices of teaching and learning of nutrition content knowledge in secondary school through science subject.

2. To propose STEM-ARNutri teaching and learning approach to teach nutrition to Form Two students.

3.1 To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' knowledge towards nutrition.

   i. To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' dietary recommendations.

   ii. To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' sources of nutrient in food groups.

   iii. To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' knowledge of healthy food choices and diet.

   iv. To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' associations between diet and ill-health.

3.2 To explore the changes in nutrition knowledge after the exposure to STEM- ARNutri.

4.1 To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' attitude towards nutrition.

i) To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' attitude in Dimension 1: Natural content, health, and weight control

ii) To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' attitude in Dimension 2: Sensory appeal and mood

iii) To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' attitude in Dimension 3: Price and convenience

iv) To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' attitude in Dimension 4: Familiarity and ethical concern

4.2 To explore the changes in attitude towards nutrition after the exposure to STEM-ARNutri teaching and learning approach.

5.1 To measure the effectiveness of STEM-ARNutri teaching and learning approach in improving Form Two students' behaviour towards nutrition.

5.2. To explore the changes in behaviour towards nutrition after the exposure to STEM-ARNutri teaching and learning approach.

1.6 Research Questions

The research questions for this study are as follows:

1. What are the current practices of teaching and learning of nutrition content knowledge in secondary school through science subject?

2. How does the finding from RQ1 inform the need for STEM-ARNutri teaching and learning approach?

3.1 Is there any significant difference between the control and experimental group's linear combination of the post-test mean score for students' knowledge towards nutrition?

i) Is there any significant difference between the control and experimental group's post-test mean scores for dietary recommendation?

ii) Is there any significant difference between the control and experimental group's post-test mean scores for sources of nutrient in food groups?

iii) Is there any significant difference between the control and experimental group's post-test mean scores for knowledge of healthy food choices and diet?

iv) Is there any significant difference between the control and experimental group's post-test mean scores for associations between diet and ill-health?

3.2 How knowledge towards nutrition changed after exposed to STEM-ARNutri teaching and learning approach?

4.1 Is there any significant difference between the control and experimental group's linear combination of the post-test mean score for students' attitude towards nutrition?

i) Is there any significant difference between the control and experimental group's post-test mean scores for Dimension 1 (natural content, health and weight control)?

ii) Is there any significant difference between the control and experimental group's post-test mean scores for Dimension 2 (sensory appeal and mood)?

iii) Is there any significant difference between the control and experimental group's post-test mean scores for Dimension 3 (price and convenience)?

iv) Is there any significant difference between the control and experimental group's post-test mean scores for Dimension 4 (familiarity and ethical concern)?

4.2 How attitude towards nutrition changed after exposed to STEM-ARNutri teaching and learning approach?

5.1 Is there any significant difference between the control and experimental group's post-test mean score for students' behaviour towards nutrition?

5.2 How behaviour towards nutrition changed after exposed to STEM-ARNutri teaching and learning approach?

1.7 Hypotheses

Hypothesis which related to the problems were developed as follows:

Knowledge towards Nutrition

H_01: There is no significant difference between control and experimental group's linear combination of the post-test for knowledge towards nutrition score.

H_01a: There is no significant difference between the control and experimental group's post-test scores for dietary recommendation (DR).

H_01b: There is no significant difference between the control and experimental group's post-test scores for sources of nutrient in food group (SNFG).

H_01c: There is no significant difference between the control and experimental group's post-test scores for knowledge of healthy food choices and diet (KHFCD).

H_01d: There is no significant difference between the control and experimental group's post-test scores for associations between diet and ill-health (ADIH).

Attitude towards Nutrition

H_02: There is no significant difference between control and experimental group's linear combination of post-test for attitude towards nutrition score.

H_02a: There is no significant difference between the control and experimental group's post-test scores for Dimension 1(natural content, health, and weight control).

$H_0$2b: There is no significant difference between the control and experimental group's post-test scores for Dimension 2(sensory appeal and mood).

$H_0$2c: There is no significant difference between the control and experimental group's post-test scores for Dimension 3(price and convenience.

$H_0$2d: There is no significant difference between the control and experimental group's post-test scores for Dimension 4(familiarity and ethical concern).

Behaviour towards Nutrition

$H_0$3: There is no significant difference between control and experimental group's post-test scores for behaviour towards nutrition.

1.8 Significance of Study

This research provides a demonstration of an intervention mixed-method design that can be utilized as a model for conducting studies on similar topics or contexts. The study consisted of three levels. The first level of the study involved conducting semi-structured interviews with teachers and students to explore their current practices related to nutrition. The qualitative data obtained at this level served as the basis for the subsequent levels of the study. In the second level, the researchers used the qualitative data findings to develop the STEM-ARNutri teaching and