



Technology-enhanced game-based team learning for improving intake of food groups and nutritional elements



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ABSTRACT

Nutrition is a critical issue for educators, particularly given the unhealthy eating behaviors of many adolescents. While knowledge and self-reflection are important, learners must also be motivated and held accountable for their health behaviors. In order to foster healthy eating, a technology-enhanced approach, game-based team learning (GBTL), is proposed, based on social-interdependence theory. A cloud diet assessment system (CDAS) was designed for automatically providing feedback on the nutritional intake of learners through a meal analysis algorithm. Furthermore, a cloud server hosted a social competitive game which, in addition to in-class team learning activities, allowed teams to compete against each other on the basis of each group's dietary habits. A pre-test post-test quasi-experimental design evaluated the effectiveness of the GBTL group (E1) as compared to a group which received only metacognitive feedback from the CDAS (E2) and a comparison group (C). Female high school participants from three classes were randomly assigned to the three groups (C, $n = 31$; E1, $n = 20$; E2, $n = 37$). Results demonstrate significant improvement for E2 in terms of most food groups (including Dairy, Meats and Protein, Vegetables, and Fruit), as well as for macronutrients, such as calories and dietary fiber, and micronutrients, including Calcium and Vitamin C and B2. Within- and between-group comparisons confirmed the advantage of the E2 group, suggesting that technology-supported GBTL can foster healthy eating habits among adolescents, improving most nutritional elements to nearly 100% the recommended daily intake.

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1. Introduction

1.1. The importance of nutrition education to address dietary shortcomings

Healthy eating is an increasingly important consideration, particularly at elementary and secondary levels of education. Appropriate levels of nutritional intake is a serious global health problem (Lytle & Kubik, 2003) which is related to unhealthy eating. As such, there is an urgent need for nutrition education to both enhance children's understanding and beliefs regarding food and assist individuals in effectively using healthy food sources to establish appropriate dietary behaviors (American Dietetic Association, 1986). Such an emphasis on healthy nutritional intake can benefit children who are in danger of both obesity and malnutrition due to unhealthy eating habits (World Health Organization, 2010).

Studies have shown that, overall, adolescents fail to meet the recommended intake of calcium, fat, fruits, vegetables, and grains (Neumark-Sztainer, Story, Hannan, & Croll, 2002). In particular, the sufficient consumption of fruits, vegetables, and dairy is necessary for healthy development during adolescence (Diethelm, et al., 2012). Sufficient intake of fruits and vegetables is critical, since these foods provide countless health advantages and have been associated with the prevention of cancer, cardiovascular disease, and hypertension,

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although only around 3% of adults receive recommended daily levels of fruits and vegetables (Thomson & Ravia, 2011) Increased intake of dairy products is the most effective means by which the body acquires calcium and dairy has been shown to increase bone mineral density and total body bone mineral (Chan, Hoffman, & McMurry, 1995), which is critically important for adolescents, particularly for females, who seldom reach the daily recommended intake of dairy products (Mesías, Seiquer, & Navarro, 2011). Increase of dairy consumption is also proposed to help reduce the risk of developing type 2 diabetes and cardiovascular disease (Pereira et al., 2002). For female adolescents, in particular, protein, calcium and iron are critical nutritional elements that are often consumed in levels below recommended daily amounts (Stang & Story, 2005).

In order to provide guidance for individuals and institutions in terms of the types and quantities of foods which are required for a healthy lifestyle, guidelines for healthy eating are often designed and presented in the form of graphics or tables which suggest a certain number of servings from various food groups (FG). Additionally, guidelines for the intake of nutritional elements (NE), including macronutrients, such as protein and carbohydrates, as well as micronutrients, such as vitamins and minerals, are provided, based on gender, age, and BMI. In Taiwan, the Ministry of Health and Welfare provides a Diet Guide for adolescents' daily suggested servings in six food group; however, in recent reports, only 21% of the population met the minimum suggested servings for Fruits and Vegetables (Ministry of Health and Welfare, 2013) while nearly 100% of children and adolescents failed to meet the suggested servings for Dairy (Ministry of Health and Welfare, 2014). Therefore, there is an evident need to increase the consumption of Fruits, Vegetables and Dairy in Taiwan, particularly since intake of these three food groups at a younger age can lower the possibility of developing cardiovascular diseases and cancer later in life (Thomson & Ravia, 2011).

1.2. Promoting healthy eating and the future of nutrition education

To address these dietary concerns, program developers in health education have designed interventions to assist participants in changing their eating behaviors with the goal of increasing the intakes of fruits and vegetables (Parmer, Salisbury-Glennon, Shannon, & Struempfer, 2009) and dairy (Powers, Struempfer, Guarino, & Parmer, 2005). Advocating the use of a school garden as an experiential learning activity, Parmer et al. demonstrated that nutritional education alone was insufficient in increasing consumption, whereas a combination of instructional activities and gardening activities prompted significant increases in fruit and vegetable consumption. A recent approach to simultaneously promoting nutritional knowledge and consumption of legumes involved students' hands-on learning and the use of science-based activities (Atterberry, Miles, Riddle, Rueda, & Betz, 2014). However, the authors provided results from students' attitudes and knowledge outcomes, but not changes in actual consumption. Another experiential approach was adopted by Dollahite, Pijai, Scott-Pierce, Parker, and Trochim (2014), who noted improvements in self-reported nutrition habits after engaging in a dialogue-approach titled "Eating Right is Basic." Various experiential activities were included over the course of eight weeks, such as comparing actual intake and recommended consumption by food group, discussing food labels, brainstorming meal-planning guidelines, and identifying nutritional elements in different food products.

However, these interventions have seldom taken advantage of technology in order to promote healthy eating and have also neglected the social context in which healthy behaviors are learned and unhealthy habits are changed. As stated by a recent book promoting technology for health promotion, "interactive technology is perhaps the most promising medium for achieving health promotion initiatives" due to access to online information, interaction with other people, and the potential of integrating games for health management and disease prevention (Street, Gold, & Manning, 2013). Due to the relative scarcity of studies integrating mobile technology, social interaction, and game-based designs for addressing learners' dietary needs, this paper first explores the literature for relevant strategies and approaches to promote healthy eating.

2. Literature review

2.1. Cognitive, metacognitive, and social-affective elements of learning and the role of technology

In order for positive behavioral change to take place, learners must have a certain amount of knowledge and cognitive awareness. Students' eating behaviors are influenced by their knowledge of nutrition, which further influences their health (Keski-Rahkonen, Kaprio, Rissanen, Virkkunen, & Rose, 2003). Researchers (Hoelscher, Evans, Parcel, & Kelder, 2002) have developed different programs for promoting healthy eating behaviors through raising awareness, and the effectiveness of these approaches in improving students' nutrition knowledge has been shown (Bukhari, Fredericks, & Wylie-Rosett, 2011; Cheadle et al., 2012). However, while adolescents often demonstrate sufficient knowledge of healthy eating, they face maintaining healthy eating behaviors without sufficient time and awareness to follow healthy diet recommendations (Croll, Neumark-Sztainer, & Story, 2001). As such, it is challenging when conducting research in nutrition education with secondary students, and it is therefore vital to develop school-based curricula to encourage and foster adolescents' healthy eating behaviors (Lytle & Kubik, 2003), particularly during the developmentally important period of puberty (Lytle, Gerlach, & Weinstein, 2001). From these studies, it is evident that knowledge (cognition) is necessary, but often insufficient, to effectively promote healthy eating behaviors.

Metacognition, which involves an awareness of one's own thought processes and strategies, is essential for behavioral change. Self-monitoring is a metacognitive process wherein individuals recognize occurrences of their behaviors, are able to compare these behaviors to certain standards, and then exercise control over their actions and emotions (Wilde & Garvin, 2007). Researchers have demonstrated that the use of self-monitoring is an effective method for individuals to conduct observations, make recordings, and utilize metacognitive strategies for ongoing awareness of their eating behaviors (Burke et al., 2005) and weight (Burke, Wang, & Sevic, 2011), ultimately resulting in positive changes in eating behaviors. The effectiveness of self-monitoring has been established for weight loss programs in which the frequency of participants' use of self-monitoring was positively correlated to participants' weight loss (Yon, Johnson, Harvey-Berino, Gold, & Howard, 2007).

In addition to metacognitive strategies, such as self-monitoring, motivation to modify dietary behaviors is an essential factor for behavioral change (Brug, Oenema, & Campbell, 2003; Contento, Koch, Lee, Calabrese-Bartona, 2010). This involves a social and affective

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