Integrating Technology-Supported Multi-representational Scaffolding Into Board Game for Learning Muscular System Physiology

Chia-Hui Huang, Graduate Institute of Applied Science and Technology – National Taiwan University of Science and Technology, Taiwan
Yu-Chi Chen, Graduate Institute of Applied Science and Technology – National Taiwan University of Science and Technology, Taiwan
Huei-Tse Hou, Graduate Institute of Applied Science and Technology – National Taiwan University of Science and Technology, Taiwan

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Abstract
In the teaching of muscular system of physiology, it is difficult for students to memorize a large amount of knowledge such as muscle names and movements generated by muscle contraction from the traditional classroom lecture, which in turn affects the motivation and learning outcome. A board game integrating technology-supported multi-representational scaffolding was designed to promote learning motivation and achievement by the board game mechanism and scanning the game cards to provide muscular 3D animation and videos. Participants were 20 nursing students from northern Taiwan. The study was conducted to investigate the learning achievements and assessment of the game through pre-test and post-test, learning motivation, flow, game acceptance, and scaffolding usefulness questionnaire. The results showed that there was a significant improvement in the academic performance of the learners after the board game learning activity, which means that it helped the learners to construct relevant academic knowledge. In addition, the high motivation, flow and game acceptability ratings indicate helped to enhance the learners' motivation and enjoy the activities of the game. Moreover, the multi-representational scaffolding in the board game is beneficial to learners, understand the abstract concepts of the muscular system better, and reduce the confusion during the game. The data proved that the use of integrated technology-assisted learning and multi-representational scaffolding board games in the curriculum of muscular system of the anatomy and physiology can help learners construct three-dimensional concepts of muscles, understand complex theoretical knowledge, and discuss to solve the problems in the game, which can significantly enhance the learning achievement of the learners.

Keywords: Board Game, Multi-representational Scaffolding, Muscular System Anatomy and Physiology

Introduction

Anatomy and physiology are essential knowledge for all healthcare students. There is a global trend in teaching identification of specific skeletal muscles within each body region and this is accompanied by teaching actions of said muscles (Reynolds et al., 2022). DeHoff et al. (2011) considered muscle actions to be required learning, in addition to muscle identification and innervation. In the teaching of muscular system of physiology, students need to memorize a large amount of knowledge such as muscle names and movements generated by muscle contraction, and it's difficult to encouraging learning motivation to learn by using the traditional lecture method, thus affecting the effectiveness of learning (McCarroll et al., 2009). Therefore, it is important to enhance the learning outcome of muscular system physiology. In recent years, game-based learning has been increasingly emphasized, and relevant studies have shown that game-based learning can provide learners with an interesting learning environment, which in turn enhances learning motivation and learning effectiveness (McLaren et al., 2017). Studies have found that teaching activities based on board games not only promote interpersonal interaction, but also have a positive effect on learning (Hou & Keng, 2020; Hou et al., 2021; Li et al., 2018). When learners engage in board games, their cognitive comprehension improves (Mostowfi et al., 2016). Medical research has shown that in anatomy and physiology courses, the use of an educational board games in teaching the muscular system is significantly improved learning compared with the use of guided study (Luchi et al., 2019). With the advancement of technology, all kinds of interactive 3C products are everywhere in students' lives. The presentation of multimedia materials that help to understand anatomy and physiology is also advancing, and the visualization in anatomy has turned from the use of images into the use of animations, which allows students to observe anatomical structures in depth from different points of view (Küçük et al., 2016). For students, the combination of digital visualization and video effects will help them to understand the complexity of the 3D structure of the muscles and the movements generated by their contraction. Therefore, this study integrates technology-assisted learning and multi-representational scaffolding into board games to stimulate students' learning motivation through board games and technology-assisted learning. Through the design of multi-representational scaffolding, including text prompts, muscle 3D animation and demonstration video, to help students understand the 3D structure of muscles and their physiological functions, in order to reduce the confusion of students in the process of learning activities, and thus enhance the learning outcome.

Method

The teaching unit of this study was anatomy and physiology of the muscular system, and the participants were 20 nursing students from northern Taiwan. The students were divided into groups of four or five individuals to play the board game in the classroom. There are circles located on anatomical structures, where players are required to place tokens on. The game also consists of two types of cards (anatomical cards and physiology cards for the anatomical structure and physiological functions of 20 muscles) which are used to matching (Figure 1). Learners are required to use multi-representational scaffolding (Table 1) to match anatomical and physiological cards in the game. Then, according to the matching result, place the token in the correct muscle position on the main boards (Figure 2). One-group pre- and post-test research design was used for this study. The pre- and post-test scores in order to evaluate the learning effectiveness after the completion of the game. Based on the game, the questionnaires included flow status, game acceptance, learning motivation, and perceived

usefulness of the scaffold. Quizzes and questionnaires were administered before and after the game activity for 10 minutes.

Table 1. Multi-representational scaffolding

Scaffolding	Description
Text and Image	1. Cards：Text description of old and new knowledge. 2. Anatomical map：Construct knowledge about anatomical locations
3D animation	Showing the anatomy of the beginning and end of the muscle.
video	Demonstrate the movement generated by the contraction and contraction of the muscle.

Figure 1. Learners use Google Forms to complete tasks in the Gather Town conference room.

Figure 2. (A) Students to scan the QR code and to match cards.
(B) Place the token in the correct muscle position.

Results and Discussions

The Wilcoxon Signed-Rank Test was used to analyze the pre- and post-tests scores, which shows that there was a significant difference between the pre- and post-tests ($Z=3.153$, $p=0.002<0.01$). The findings demonstrated a statistically significant increase in the knowledge assessment scores after the game. The data from the flow, game acceptance, learning motivation, and scaffold usefulness questionnaires show that all sub-dimensions of flow are significantly higher than the median of 3, which indicates that students have a certain degree of high flow engagement and immersion under the learning activities of board games. Game acceptance and learning motivation are also significantly higher than the median of 3, which means that learners have high acceptance of board games and can be motivated to learn. Finally, learners were able to visibly perceive the multiple representations of the scaffolding and use the prompt during the process, which means that the design of the scaffolding can reduce students' confusion during board game learning activities and help to enhance the learning effectiveness of anatomical and physiological knowledge of the muscular system.

Conclusions

The results indicating that the learning activity of board games can arouse the interest of learners, promote peer interaction and discussion. In this study, both the results of mind flow, game acceptance and perceived usefulness of the scaffold were above the median score of 3, which means that the learners were able to immerse themselves in the games. They also felt that the board games designed in this study was easy to understand, the rules and mechanisms were well-designed, and the games were entertaining and challenging. Overall, the board games were accepted by the learners and were effective in enhancing learning outcomes. The limitation of this study is the small sample size ($n=20$), which needs to be further increased in the future, and the results of the experimental group and the control group should be compared. The study only explored learners' learning effectiveness, mental flow, game acceptance, and scaffolding usability, and it is suggested that in the future, learners' learning anxiety and cognitive load could be increased, as these are key aspects that may affect the course of learning activities when students are studying anatomy and physiology.

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Contact emails: D11122311@mail.ntust.edu.tw
hthou@mail.ntust.edu.tw