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Effects of the mobile serious game (Herbarian) with location-based learning on students' retention of botanical terms and their experiences

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ABSTRACT

Background: A serious game was developed from the use of learning through drill and practice principle to enhance the knowledge memorizing together with the principle of game-based learning in education application. The aim of this study was to investigate the effectiveness of using game-based and location-based learning concepts on the student knowledge score and knowledge retention score. **Methods:** A mobile application game named "Herbarian" was developed and used in the pharmaceutical botany course as a part of the undergraduate pharmacy curriculum. The content in the game was botanical jargon linked to plant morphology. Twenty-one and 51 undergraduate students voluntarily used and did not use the game, respectively. Cumulative grade point average (GPA) was used to adjust mean knowledge and knowledge retention score by multiple regression analysis. **Results:** The results showed that the mean knowledge and knowledge retention scores between groups were not statistically significant differences after adjustment. Yet, the knowledge and knowledge retention scores of the game group were higher than the control group. Multiple regression analysis showed the statistically significant relationship between the cumulative GPA and the knowledge score. **Conclusions:** These results suggested that the game is likely to be useful to the students.

Keywords: Botanical terms, game-based learning, knowledge retention and game experience, location-based learning, mobile serious game

INTRODUCTION

Herbal medicines are widely accepted in the health-care system of Thailand and many other countries. Pharmacists play an important role in dispensing and consulting the use of herbal medicines to patients, especially in community drug stores.[1] Therefore, herbal studies in terms of identification and utilization have been included in all Thai pharmacy curriculums.[2] All pharmacy students are expected to be capable of providing correct herbal information and exploitation for patients and people. To differentiate and identify the herbs, the knowledge of basic botanical terms is a must and it will be referred to when the student's further studies on the chemical composition of herbs and clinical uses.[3] Botanical terms are a kind of jargon that requires knowledge retention. In the traditional teaching method, students have to self-study using organoleptic skills to identify the prepared herbs in the class. However, the students expressed their opinions through online course evaluation that this traditional teaching style focuses on intense memorizing that is not to their interests. Furthermore, some students do not pay attention in studying but worry whether they would

fail the test. Thus, the traditional teaching style is not the approach to help learners understand the importance and detail of the content.

Various active learning techniques including team-based learning, case-based learning, and problem-based learning help stimulate learning.[4,5] However, these learning methods are mostly intensively academic and limited in fun and challenge.[6] Consequently, students with young ages in our class tend to get uninterested in these boring and non-challenge teaching styles. Recently, there were researchers reported that game-based learning in the form of serious games would be another way to help students learn along with enjoyment.[7] This approach has become popular increasingly in medical education. Knowledge retention is a key to success in this content. It has been highlighted in the former reviews that serious games contain mixed effectiveness if compared with the conventional interventions (e.g., classroom learning) on the aspect of the improvement of engagement among health-care professionals' and students' as well as the educational performance.[8,9]

The designs of serious games are aimed at active learning and entertaining environments where they can be available on any digital platform. Typically, learning takes place from learners engaging in gameplay with the adapting of challenges from the in-game skills. The researchers define challenges as the subjective experiences that solicit the skills for learners, for example, challenges would force the learner to make an experiment, explore, or cooperate with other learners.[10-12] The complexity of serious games development is resulted from its 2-fold objectives on both to educate and motivate. The role of design elements is crucial as it influences the engaging antecedents, for instance, the ability of a learner in task concentration, the sense of control, acquired feedback, and the deep but unforced involvement. It is supported from the evidence that higher engagement would result in the deep involvement of the learner and their repeated challenges taking as offered for the improvement of the in-game performance and, subsequently the educational performance. Nine characteristics that should contain in a serious game are postulated by Bedwell as follows: An action language (some communication approaches between the person and the game as provided from a game); assessment (tracking the number of correct answers); conflict or challenge; control, or the players' capacity in altering the game; game fiction or story; environment; human interaction among the players; games immersion and the goals; and rules for a player as provided by the game.[13]

There is no game on a mobile application in cooperated with the location-based learning that is being used as the knowledge retention tool of botanical terms. Therefore, the serious game is developed with the combination of self-practicing and location-based learning where the assigned location and questions related to herbs in that area will be given to students in the game application. Students must observe the correct herb surrounding them according to the question and make an answer in the game. To enhance motivation, a leaderboard is added to show and compare student scores with a peer.

"Herbarian" is a serious game developed from the use of learning through drill and practice principle to enhance the knowledge memorizing together with the principle of game-based learning in education application.[14] Game-based learning enhances the levels of attention by learning through frequent failures and consequently helps in incremental learning. The amalgamation of game mechanics and dynamics in non-gaming applications is a theme of interest in various fields such as education, handling sophisticated equipment, health care, and armed forces.[15] This is to form the motivation and satisfaction in learning by considering the qualification of the learner from Generation Z. It should be noted that the process of game-based learning education and educational games are so diverse in their concepts.[16] Game-based learning is a comprehensive original framework that would give higher effective education since it is indicated in some studies on the positive effects of educational games. As a subsidiary component of educational games, the entire process in this game has been converted into a "Herbarian." Thus, the study aimed to evaluate the impacts of the newly developed mobile serious game, called "Herbarian," with location-based learning on students' knowledge and knowledge retention of botanical terms and to investigate their experiences in using the game. The results of this study can be used to provide a piece of evidence that class lectures combined with game-based learning enhanced student performance and potentially applied to various subjects with a similar concept.

MATERIALS AND METHODS

Development of the Mobile Serious Game (Herbarian)

Herbarian was developed as a mobile phone game-based application on the Android platform with features to dispense the questions related to the herb in a user selected location. This has been brought to use in the teaching and learning for the whole 14-week class. The game contains morphology and taxonomy knowledge while providing learning motivation by competition. The learning objectives of the course are that students can (1) understand and explain botanical terms and (2) identify plant families and some species of medicinal plants. The knowledge is used to choose the right herbs for particular treatments. Therefore, basic knowledge of plant morphology is required.

The game was constructed in three difficulty levels with an increment of the score [Figure 1]. The simplest level was an off-location mode in which students can play anywhere. The second level was an on-location mode in which students acquired the question on-site where alive herbs were presented. The last level was the complicated question that students must link the basic knowledge of botanical terms to find the plant that would be the correct answer located on-site by scanning the QR code. Modes 2 and 3 were designed using a location-based learning concept. The students must go to the location where the plant is so that they can learn the plant characteristic before answering the questions. The number of questions in the game is around 1000 questions. Students can play the game for the whole 14-week course to improve their knowledge of morphology and taxonomy. The questions in the game are not the same but are associated with the questions in the examination.

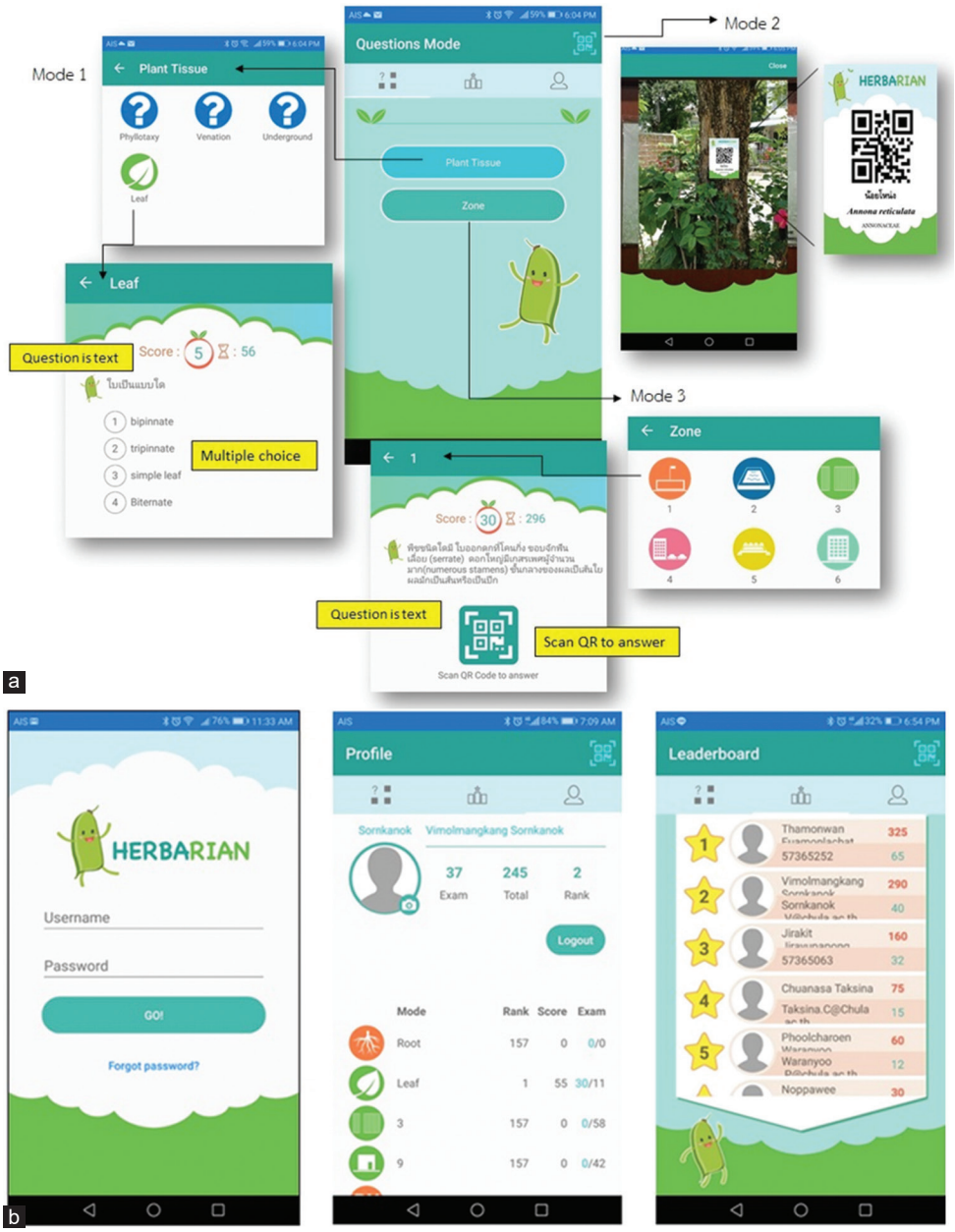

Figure 1: Game structure and screenshots of Herbarian game. (a) Three question modes. The player could select any mode to start; (b) Screenshot of login, player profile, and leaderboard

The researchers designed the system using the herb database to develop additional details related to the learning content. The teachers can create a set of questions based on the learning objectives by linking information from the herb database into answers. Students will use the game application to access questions and answer questions or perform specified activities (such as searching for herbs listed in the herb garden). When students correctly answered the questions or completed the activity, they would get the points. This is individual and self-paced learning, so the students were able to track their own and others' progress on the leaderboard. The game was also designed to inspect the access frequency of students. The surveys about motivation and user experience were applied to inquire only the game playing group by self-evaluation. The game is merely available on the Android platform which allows the download onto communication devices such as tablets and mobile phones for self-study learning.

Evaluation of the Game

Study design

The Herbarian game was used to enhance students' learning performance by supplementing with regular learning. To evaluate the effectiveness of the game, quasi-experimental research with convenient sampling had been designed to use the quantitative research methodology. The experimental group used game-based learning in addition to the regular lecture, and the control group used only the regular lecture. Figure 2 shows the study design for comparing the game-based learning and the conventional learning approach. Students had the freedom to

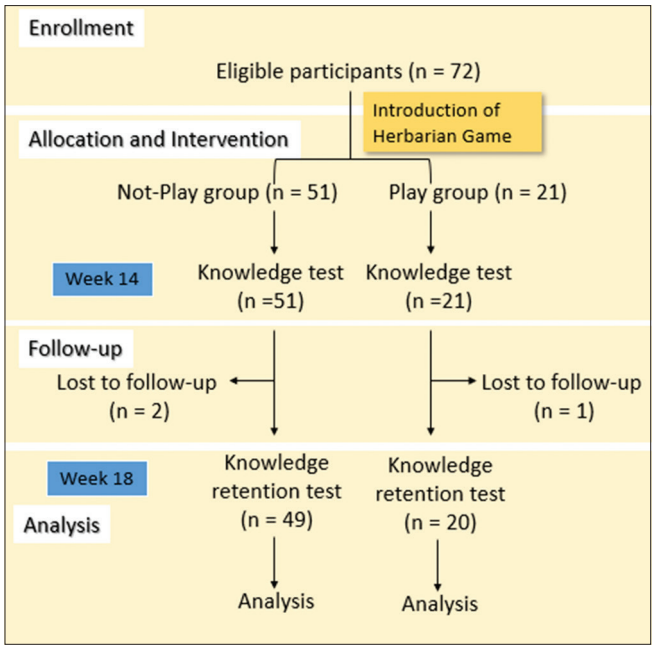

Figure 2: Diagram of study design

play or not play the game with no string attached to the academic grade. The instruction of the game was explained in the class and distributed to all students as a form of the user manual. In the manual, botanical terms were listed and illustrated as well. As usual, the knowledge score and knowledge retention score that were the primary outcomes were tested by the end of the course and 4 weeks later. Course content, practice, and exercises for these two groups were the same as they were learning together. The study protocol was approved by the Institutional Review Board (IRB) at Chulalongkorn University. This research is no more than minimal risk since the IRB approved a request to waive off all the informed consents. This study was conducted following the principles of the Declaration of Helsinki.

Participants

The 4th year pharmacy students enrolled in Pharmacognosy and Pharmacognosy Laboratory courses at the Faculty of Pharmaceutical Sciences, Chulalongkorn University. During the 14 weeks of teaching principles and methods lesson, this study was conducted where the conventional teaching course was set for 6 h/week for both pharmacognosy (three lecture credits) and pharmacognosy laboratory courses (one laboratory credit). The entire students of the class (n = 72) were informed on the 1st week that the game was used in addition to the regular lecture and participation in this game was voluntary. Since the game participation was not required, the students could withdraw from the experiment at any time and their activities and scores would not affect their grades. In addition, all personal information was protected.

Data collection and analysis

The subject area concerning knowledge was assessed in the examination at the end of the procedure. The test development principles were scientifically followed. The addressing of objectives was the very first step in the achievement test development together with the constitution of an item pool for these objectives' evaluation. According to the purpose of the study, the questions used in the test came from this specific course lecturer. The questions in this test were approved by three experts in the department of pharmacognosy. The assessment by experts had indicated the content validity of this test. Forty-two and 40 questions of lecture and laboratory examinations on the topic of morphology and taxonomy were used to evaluate student knowledge at 14 weeks. Knowledge retention scores were tested by the same examination after knowledge score 4 weeks later. Data of cumulative grade point average (GPA) were collected to adjust the knowledge score. A GPA is a number representing the average value of the accumulated final grades earned in courses over time. It is based on a 0–4.0 scale, with a 4.0 representing the best GPA. Outcomes of the study were knowledge score and knowledge retention score. Cumulative GPA was used to adjust for potential confounding by multiple regression analysis. The analysis was done by software STATA, version 13. To compare student knowledge scores between the groups for descriptive analysis, an independent *t*-test was performed for all variables. The scores after adjusting were analyzed the difference between groups at a 5% significance level. Multiple regression analysis was conducted to evaluate the relationship between the cumulative GPA, scores, and the decision to involve the game. Students who had been lost to follow-up were also excluded from the analysis.

RESULTS

Effects of the Mobile Serious Game (Herbarian) on Students' Knowledge Retention

In this part, the effects of game-based learning on the achievement of students are examined. Of the collected 72 students, 51 students did not participate in the game (70.83%) and 21 students did participate in the game (29.17%). One student and two students were lost in follow-up in the knowledge retention test in the game group and control group, respectively [Figure 2]. The relevant baseline characteristics of the enrolled students are shown in Table 1. The mean cumulative GPA was a statistically significant difference between groups (GPA 3.28 vs. GPA 3.06 in the game group and the control group, $P < 0.05$).

The result of the knowledge and knowledge retention score is shown in Table 2. All the mean scores of the game group were higher than the control group. A statistically significant difference in the mean between groups was found in the mean lecture score and mean retention score ($P < 0.05$).

After adjusted mean by multiple regression analysis, it revealed the decrease in the differences between groups' cumulative GPA. There was no statistically significant difference in mean cumulative GPA between groups. The adjusted scores of students in the game group were greater than those of students in the control group, but this difference was not statistically significant. The mean lecture scores were 80.90% and 73.73%, for the game group and the control group, respectively. Similar to the mean lecture score, the mean laboratory score was slightly different between the two groups [Table 2]. The analysis of the mean retention score revealed

that the scores decreased in both groups. However, the mean score of the control group was lower than that of the game group. The cumulative GPA also was positively correlated with all of the scores. It indicated that higher GPA students are more likely to gain an examination score [Table 3].

DISCUSSION

"Herbarian" is an educational game that is in the form of a mobile application. It was created to improve student learning outcomes in the pharmaceutical botany course. Previously, the course was taught traditionally using lecture-based learning and observation of selected plants shown in the laboratory session. The course had received negative feedback comments from the students enrolled in this course for many academic years. They felt that the contents were too much to remember and unnecessary for the pharmacy profession. Therefore, they lack interest in the subject matter. Moreover, the knowledge they gained from the course did not stay in long-term memory as we could observe the students' performance when they were passed to the next semester course. Herein, we have chosen a game-based learning strategy to solve the problem. Game-based learning has been proven that it could increase students' interest and learning motivation.[15,17-19] Moreover, location-based learning is our method of choice to encourage the student to perform learning in the real environment which is the herb garden in this subject. It is expected to increase long-term memory by exploiting experiences gained from the learner's senses. Combining location-based and game-based learning results in the mobile game Herbarian can lead students to learn in the real environment. For this course, we aimed to promote academic proficiency including long-term memory while stimulating students' interest. Therefore, game-based learning was applied together with location-based learning in the course.

The game was used as a tool in addition to the conventional pedagogy. It was added to the existing core course to increase the motivation and knowledge retention of students. The game was then evaluated by its effectiveness by observing the learning outcome (academic score) and student behaviors. In this study, we used multiple regression analysis to adjust the mean scores between groups. After adjusting, it was not found a statistically significant difference in the mean scores between groups. The students who played the game had a slightly higher average academic score compared to the control group.

The researchers retrieved the different results from other studies on the game that it had a positive influence on the performance of students when using the game additional with a traditional learning method.[8,18,20,21] Ideally, RCTs shall include the two control groups in the serious game's evaluation where one must have no game involvement with another involved with the game. Taking into account, the control group without intervention is essential in the serious game effectiveness demonstration where this remains ethical since the serious game as played by the intervention group has failed to achieve the higher skills/knowledge level rather than the control group. It was shown from the former study that game-based learning was even more effective compared to no game-based learning.[8,18] However, in academic settings, it is required to compare serious games with another form of education in promoting usage. Adopting the control groups, it could also be possible to assess the serious game whether it can provide a pragmatic solution.

It was presented from the result of the instructors' challenge since the non-significant result might not refer to the ineffective of the game. More suggestions were required on the additional activities for the game effectiveness evaluation. The results of multiple regression analysis suggested that cumulative GPA was a positive effect on the knowledge score. Cumulative GPA is an important variable affecting both participation and student performance.[22,23] Attending the game was an extra task and not linked to the academic score directly. This observation indicated that the high academic achievers would be willing to do extra works to gain more knowledge than the students with lower academic achievement. A study by Jabeen and Ahmad found that hope of success, Ego-ideal, perseverance, realistic attitude, internal control of fate, and total need achievement were related to high and low achievers.[24] In this case, the hope of success may be a driving force for the high achiever because the students answered the survey that they believed that using the game could help them achieve a higher grade of the course.

To the best of our knowledge, none of the studies on the serious game are dedicated to pharmacognosy teaching. The application of games attracts student learning attention, especially in the health-care subject area.[15] Successful serious game development is complex. This research provides an initial measurement of the impact of the game on the academic proficiency of the students. It would be the very first step for an ongoing assessment development on the efforts of this subject to foster the success of students through game intervention.

Table 1: Student characteristics

Variable	Game group (*n*=21)	Control group (*n*=51)	*P*-value
Gender (female) (%)	15 (71.43)	36 (70.59)	0.943
Mean cumulative GPA	3.28 (0.08)	3.06 (0.07)	0.049*

GPA: Grade point average, *statistically significant difference ($P<0.05$)

Table 2: Knowledge and knowledge retention score

Variable	Unadjusted mean (%)			Adjusted mean (%)		
	Game group (*n*=21)	Control group (*n*=51)	P-value	Game group (*n*=21)	Control group (*n*=51)	*P*-value
Mean lecture score	80.90 (2.58)	73.73 (1.99)	0.046*	77.01 (2.61)	75.34 (1.73)	0.062
Mean laboratory score	63.05 (3.41)	54.73 (2.29)	0.051	58.15 (2.60)	56.56 (2.09)	0.054
Mean retention score	68.32 (2.32)	61.28 (1.85)	0.038*	64.38 (2.26)	62.85 (1.68)	0.087

Compare mean by independent *t*-test, *statistically significant difference ($P<0.05$)

Table 3: Multiple regression analysis of knowledge score, the game participant, and GPA

Variable	Coefficient		
	Constant	Game participant	GPA
Mean lecture score	−0.27	1.66	24.21*
Mean laboratory score	−31.28	1.90	28.14*
Mean retention score	−5.39	1.38	21.90*

GPA: Grade point average, *statistically significant difference ($P<0.05$)

The Herbarian game shall improve the learning performance of students and assist them to achieve the learning objectives faster. This would require the process of competitive and joyful learning. Moreover, teaching quality value shall be recognized in the game with a reward to both learners and teachers in student participation. The teacher engagement would also empower the participation of students in the game. Our result was consistent with the study of Ameerbakhsh *et al*.[25] who concluded that the better learning result came from teacher encouragement more than freely enrolment by students. This paper also provided valuable information for any institutions that seek to start considering using game-based learning for their pharmacy student's improvement either in Thailand or internationally. The design of the game is readily adapted to match with other courses that are set to have the same pedagogy and features. Inconsistent with the study of Drummond et al., the recommendation is to seek the point that can be coverage by the players' intrinsic and extrinsic motivation.[26] Various current situations; for example, the spread of serious illnesses, possibly alter the traditional lecture-based classroom to online learning. Online learning platforms are offering increase retention of information and decreasing time spent in the classroom. It is useful to adopt the Herbarian game as an additional tool in the pharmacognosy class or other similar classes.

Apart from some limitations, this study used the small size of the sample population. The percentage of game-based learning adopted students added to the regular lecture was lesser than the control group (29.17% and 70.83%). The researchers performed the multiple regression analysis to adjust the selection bias and allow for minimization. In addition, the research considered only the scores from the test though the teaching-learning process evaluation may be complex at multilevel. The academic examination was on basic knowledge and memory testing. Thus, it was uneasy to evaluate the game effectiveness from the testing scores in learners' knowledge measurement. Moreover, our study was not allowed to perform the assessment of the student knowledge before participation because the examination should be kept confidential and the IRB at Chulalongkorn University did not allow us to do that method. Yet, we adjusted the scores by the regression analysis using GPA for minimizing bias and control for confounder in two groups.

CONCLUSIONS

The study developed a serious game namely Herbarian and test its effectiveness as a teaching tool for botany subjects. In summary, the serious game could lead to the effective enhancement of the pharmaceutical botany course for the pharmacy students. It may be applied to other topics in the same area or even other areas by modification of questions used in the game. To better understand the student performance relationship with the game designs, further research should be conducted by improving a study design and increasing the sample size for valid evaluation of the game.

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