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INTRODUCTION

In traditional face-to-face teaching, all students in the class are provided verbal explanations as a group, and students passively listen and take notes (Danish & Gresalfi, 2018). However, with the rapid development of science and technology, new technologies have prompted the evolution of teaching/learning methods (Leonard & Fitzgerald, 2018). Compared with traditional face-to-face teaching, learning management systems (LMSs) combined with electronic technology can bring students together more easily, make students more excited about learning, encourage more students to participate in interpersonal interactions, encourage active learning, promote more thorough sharing, and help students develop a more open attitude towards learning (Oran, 2016). LMS learning environments can bring students more and better educational benefits (e.g., critical thinking and teamwork skills), improve learning performance (Zhang & Cui, 2018), and help students become familiar with new technologies for future use (Männistö et al., 2019).

THE REVIEW

In recent years, pioneers in educational sciences have been increasingly interested in electronic learning (e-learning) environments (Al-Samarraie & Saeed, 2018), of which the supporting theoretical framework is mainly social constructivism (Graesser et al., 2018). According to the theory of social constructivism, learning is acquiring knowledge and gaining understanding through interaction and support with peers in social groups; in addition, learning involves establishing a common understanding within a group and providing guidance to or cooperating with others. This socialization process guides individual learning and becomes the basis for improving teaching methods (Danish & Gresalfi, 2018; Loyens et al., 2007). Social constructivism emphasizes student-centred education modes that allow student autonomy and freedom through collaborative learning (Järvelä et al., 2016). This educational concept encourages students to participate in knowledge construction, which is a natural learning tendency of individuals (Nikitina, 2010). Therefore, the basic theoretical framework underpinning this study is the theory of constructivism.

Constructivists encourage students to learn through positive interactions and allow them to draw their own conclusions and outcomes independently (Khalid & Azeem, 2012). In the learning process under an e-collaborative learning environment, students create successful solutions to accomplish learning tasks, through which their personal knowledge can be enhanced (Reiter-Palmon et al., 2017; Rummel, 2018). Currently, promoting innovation and learning environments with increased cooperation are two of the most important areas in educational research (Johnson et al., 2015). The combination of innovative technologies and different forms of collaborative learning may help establish students' learning characteristics and explore their abilities more profoundly (D'Mello et al., 2017). The use of an electronic technology, for

example, a Moodle-based LMS, can create a new collaborative learning environment, allowing students to immerse themselves in an environment that has been proven to have a positive impact on learning (Salvetti & Bertagni, 2014). Not only can this collaborative learning environment enhance student development and lead to meaningful learning outcomes but it can also improve students' social and collaborative skills, learning motivation, problem-solving skills, critical thinking, and cognitive abilities through a teamwork environment. Furthermore, it can promote the development of students' negotiation and conflict resolution skills (Männistö et al., 2019). Collaborative learning through a Moodle-based LMS can further enhance learners' abilities of self-directed lifelong learning, enabling them to retain what they learn and pursue learning (Järvelä et al., 2013). For those engaged in education, using Moodle-based LMSs for teaching to improve students' collaborative learning is a relatively new idea. A large amount of related research has been conducted on e-collaborative learning in the field of education; however, relatively, nursing education lacks such research (Männistö et al., 2020).

Moodle-based LMSs open the door for new teaching methods (Hmelo-Silver & Chinn, 2015). Most studies have shown that for perceived motivation and the development of problem-solving abilities, the satisfaction reported by students who underwent e-collaborative learning is equal to or higher than that reported by those who received only traditional teaching; this finding echoes the theory of social constructivism (Hmelo-Silver & Chinn, 2015). McMullan et al. (2011) also found that web-based distance learning group members had higher satisfaction scores than those of learners who received only traditional teaching. Fernández Alemán et al. (2011) stated that compared with traditional teaching, students prefer computer-assisted learning at home. Furthermore, in a study conducted by Chiu et al. (2009), compared to a traditional teaching group, e-learning group members scored higher on 12 out of 16 items on a satisfaction scale; however, the difference was statistically significant for only one item. In summary, empirical teaching designs for e-collaborative learning have become increasingly practical. In particular, when students conduct collaborative and cognitive learning through peer interaction on a discussion platform, teachers play the roles of designer, instructor, consultant, supporter, and promoter based on the theory of social constructivism (Hmelo-Silver & Chinn, 2015). They can help students achieve learning objectives by monitoring and understanding students' knowledge acquisition and nursing skills development (Männistö et al., 2020). In addition, student satisfaction is one of the most important indicators for evaluating the quality of a learning environment (Jung, 2014). Student satisfaction with respect to meeting expectations is one of the most critical factors for evaluating the success of e-technology-based interventions (Rahman et al., 2015) and an important factor affecting learning performance (Jung, 2014).

In nursing education, most studies have indicated that in terms of developing professional knowledge and skills, electronic Moodle-based LMSs may be more effective than traditional face-to-face teaching as they lead to study achievements better than or equal to those of face-to-face teaching and are more effective in developing student abilities (Hmelo-Silver & Chinn, 2015). McCall et al. (2018) found that the effectiveness of electronic education interventions is,

at least, the same as that for traditional methods. Traditional classroom teaching based on textbooks and guidance requires students to memorize facts and figures for knowledge acquisition; however, this memorization is generally short term (Paul, 2015). The combined use of electronic Moodle-based LMSs with traditional teaching based on the social constructivism theory can promote learning through improving knowledge construction (Jeong et al., 2014), team reasoning and interaction (Baker, 2015), knowledge sharing to build a consensus, and cooperation and coordination with peers based on individual knowledge levels, all of which are conducive to learning (Männistö et al., 2020). In educational institutions, because of time efficiency requirements and flexibility, the use of Moodle-based LMSs allows students to have a more flexible and self-scheduled learning process, which promotes student independence and increases their self-teaching efficiency and study achievements (Bloomfield et al., 2010; Chan et al., 2016; Mackintosh-Franklin, 2018; Mlotshwa et al., 2020). In addition, Moodle-based LMSs provide students with various learning materials and tools, such as videos, multimedia, and e-text, that arouse their interest and help them understand complex information (Lakens, 2013). Furthermore, interactive tools such as email, posts, and virtual meeting rooms and chat rooms enhance communication between students and teachers (Smeekens et al., 2011). Finally, e-learning platforms can provide students with more information through web links and create a safe environment where students can discuss, share information, transfer new knowledge, and express their opinions in an open atmosphere (Peterson & Roseth, 2016)., Moodle-based LMSs based on social constructivism are new learning environments that can effectively promote students' active interaction among each other and facilitate individual contributions for the benefit of the group (Männistö et al., 2020).

Considering the abovementioned advantages of incorporating electronic Moodle-based LMS technology into teaching, changes should be made accordingly in nursing education methods and pedagogical structure. New technologies will inevitably change teaching and learning methodologies; therefore, it is necessary to explore the impact of Moodle-based LMSs on student learning. The purpose of this study is to evaluate whether the use of a Moodle-based LMS intervention for educational purposes significantly improves collaborative learning, perceived satisfaction, and study achievements of nursing students in a paediatric nursing course using a non-randomized pretest-posttest quasi-experimental research design. We hope that the combination of traditional classroom lectures and Moodle-based LMSs will create a new teaching model with great potential.

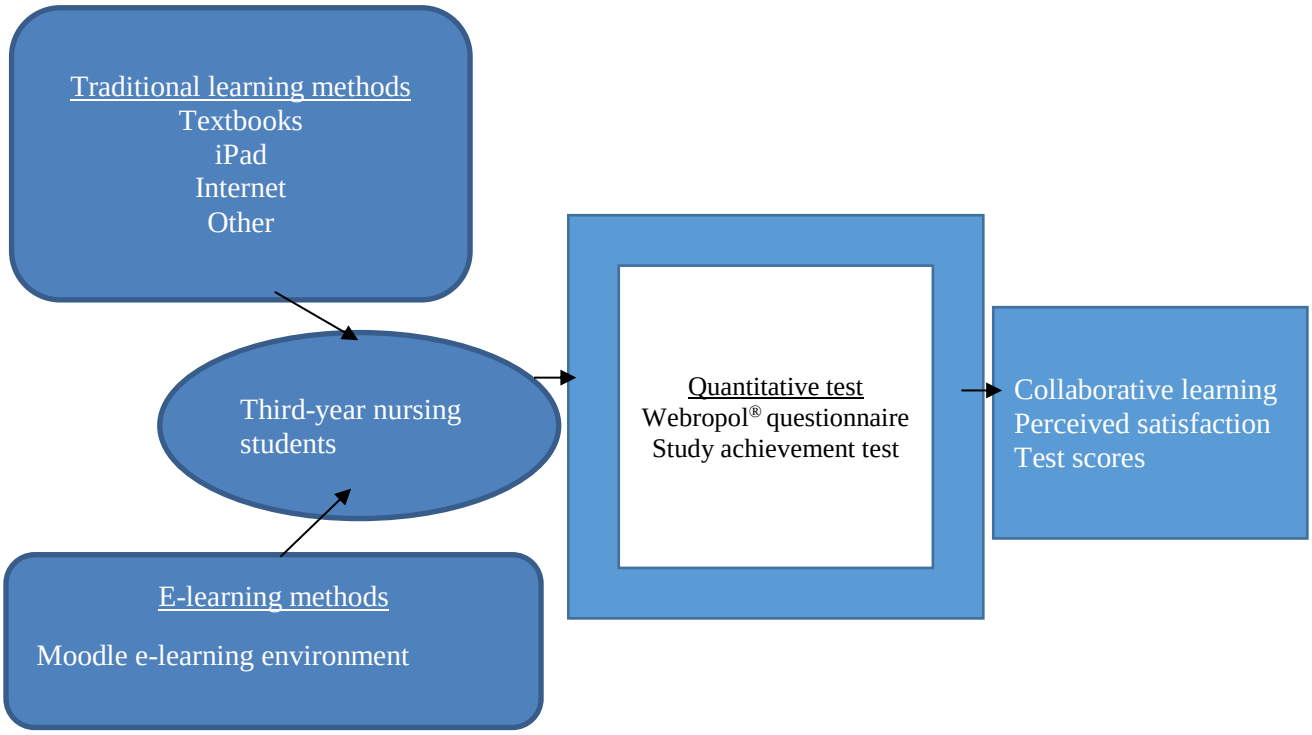
Research methods

Research design

In this study, a non-randomized pretest-posttest quasi-experimental research design was used, and students were non-randomly assigned to an experimental group (Moodle) and a nonexperimental group (non-Moodle) based on free will. The experimental group was exposed to learning methods involving a Moodle e-learning environment, textbooks, an iPad, and the Internet, among other resources. Nursing students in the Moodle group could choose any learning method at any time but use of the Moodle e-learning environment was required. Those in the non-Moodle group could use textbooks, an iPad, and the Internet, among other resources, without using the Moodle e-learning environment to complete the course. Once the study was completed, the students in the non-Moodle group were free to use the Moodle e-learning environment.

Description of the study procedures

Study framework



Study subjects

Heppner and Heppner (2004) suggested that college student recruitment should be approved by the director, dean, and experts of the institution and that participation should be voluntary. In this study, 70 third-year nursing students enrolled in a paediatric nursing course in a medical college in northern Taiwan were recruited, and they were non-randomly divided into

two groups. The Moodle group used Moodle e-learning environment technology, while the non-Moodle group completed the course in the traditional classroom environment and did not use Moodle e-learning environment technology until the completion of the study. Students completed the course following their own study plan based on their time schedule. Participating students chose to join the Moodle group or the non-Moodle group on their own. Because this course was part of nursing students' curriculum, random grouping and blind testing were impossible; hence, only volunteers could join the Moodle group and complete the course through the collaborative learning environment created by Moodle e-learning technology. To control the differences, the two groups were matched based on major (nursing students), grade (third-year students), and learning subject (paediatric nursing course), and all students took a pretest.

Environment setup

This study was conducted with a teaching environment setup that was the same as that for a general college class. The students met in the classroom on the first day of the study and received course information before beginning the study. Subsequently, all the students took the pretest in the classroom. The posttest was also held in the same classroom. Students were familiar with the environment because they often attend classes in the classroom. After the pretest, students were non-randomly assigned to the Moodle group and the non-Moodle group based on their own choice. Students in both groups received guidance in the classroom on how to use the Moodle e-learning environment for this study.

Data collection

The differences between the educational intervention measure, i.e., an e-learning environment, and traditional classroom-based face-to-face teaching were compared for paediatric nursing course. The course content and study objectives were the same for the Moodle and non-Moodle groups, and students in each group took the course during the same 18-week period. The objective of the course was to learn multidisciplinary concepts related to all aspects of paediatric nursing. Both groups were taught by the same teachers and used the same textbooks. Educational interventions were developed based on a systematic literature review (Männistö et al., 2020) and evidence from the learning theory of social constructivism (Chan & van Aalst, 2018). Study achievements were assessed via written examinations before and at the end of the course. Students in both groups were given a pretest and a posttest. The college lecturer and his teaching assistants supervised the exams and collected and graded the pretest and posttest exams.

Data were collected using an electronic Webropol® questionnaire (Figure 1), which could be accessed through a link in Moodle. There were 25 questions in the questionnaire, among which four gathered basic information and 21 were related to two survey scales. The following

basic information was collected: age, gender, educational background, and field of study. The student satisfaction scale (8 questions in total) measured student satisfaction with the course and its impact on learning. A collaborative learning scale (13 questions in total) was used to measure students' e-collaborative learning in three aspects, i.e., promoting learning, the role of teacher, and the role of student. A 5-point Likert scale (5 = completely agree, 4 = partially agree, 3 = neither agree nor disagree, 2 = partially disagree, and 1 = completely disagree) was used to measure student perception.

The student satisfaction scale included two sub-dimensions: (1) learning satisfaction (five questions) and (2) e-learning environment satisfaction (three questions). The questions related to learning satisfaction in an e-learning environment were developed and used based on previous literature (Virtanen et al., 2017). The content validity of all questions was assessed by the same expert teacher group. All questions were pretested by eight nursing students to ensure that the questions could be properly understood and interpretated. After the content validity assessment and pretest, no changes were made to the questions (Ritter & Sue, 2007). Because the student satisfaction scale combined questions for two different dimensions, the construct validity was verified (Table 1) (Männistö et al., 2019).

Exploratory factor analysis (EFA) indicated a two-factor model for the scale. The eigenvalue of the first factor (learning satisfaction) was 4.38, and the total explained variance in questions was 54.8%. The eigenvalue of the second factor (e-learning environment satisfaction) was 1.06, and the total explained variance in questions was 13.3%. These results indicated that this scale has good construct validity. Cronbach's alpha for the first and second factors was 0.84 and 0.83, respectively. The internal reliability of the instrument was evaluated using Cronbach's alpha for both factors separately and for the whole instrument. The alpha for the whole instrument was 0.944. This result indicated that this scale has good internal consistency.

In this study, the collaborative learning scale developed by Vuopala (2013) was used to evaluate collaborative learning in an e-learning environment. This scale includes three sub-dimensions: (1) promoting collaborative group work (six questions); (2) teacher's role in the collaborative learning environment (four questions); and (3) students' role in collaborative learning (three questions). The content validity of all questions was assessed by the same expert teacher group. All questions were pretested by eight nursing students to ensure proper understanding and interpretation. After the content validity assessment and pretest, no changes were made to the questions (Ritter & Sue, 2007). EFA revealed a three-factor model. The first factor (promoting group collaboration) had an eigenvalue of 5.58, and the total explained variance in questions was 43.0%. The second factor (teacher's role in the collaborative learning environment) had an eigenvalue of 2.70, and the total explained variance in questions was 20.8%. The third factor (the role of students in the collaborative learning environment) had an eigenvalue of 1.03, and the total explained variance in questions was 7.9%. Therefore, this scale has good construct validity. In addition, Cronbach's alpha for the first, second and third factors

was 0.92, 0.83, and 0.76, respectively (Männistö et al., 2019). These results indicated that the scale has good internal consistency (Table 2).

Finally, students' study achievements were assessed. At the beginning of the course, the assessment criteria for study achievements were explained to students in both groups. At the end of the 18-week course, students in both groups were assessed on the knowledge, content, methods, challenges, and learning performance in the paediatric nursing course. Study achievement was divided into six levels from 0 (failed) to 5 (excellent). Students were asked to answer the questions in a question-and-answer format. The Moodle group answered the questions online, while the non-Moodle group answered the questions in the classroom.

In this study, collaborative learning took place in a Moodle e-learning environment. To explain how students utilize collaborative learning modules, the figures below show the e-learning environment (Moodle) interfaces. The students could answer or ask questions related to the class, and data related to testing in the collaborative learning environment were collected for analysis.

Participants had access to the e-learning environment (Moodle) in the time period after the pretest and before the posttest. The operation interface was preset as a platform with different operation menus (e.g., main menu and discussion topics). After choosing the course from "My courses", students could enter the virtual classroom (Figures 2 and 3).

Experimental procedures

This study was conducted with student enrolled in a paediatric nursing course in a medical college. The person-in-charge of the research plan gave students a PowerPoint course syllabus and explained to the students the goals of the e-learning environment (Moodle) and collaborative learning in the paediatric nursing course. After answering any related questions from students, the researchers recruited student volunteers to participate in the study, and the students who volunteered to participate were required to sign a consent form. Subsequently, the participating students took a pretest. They were given a paper exam and sufficient time to complete the questions.

At the beginning of the first class, the course objectives, content, and teaching methods, as well as group learning activities and tasks, were introduced to the students. The Moodle group was divided into five small groups, of which the members remained unchanged throughout the online course. Students were allowed to form groups on their own. After the first class, students opened their Moodle account and completed their weekly assignments, online discussions, comments, self and peer reviews, material searches, reports, and various exams with others in the same group on the Moodle platform. One week before each class, five case scenarios under the study subject on the course schedule were assigned to each group. Each group used the Moodle

e-learning environment to study the case scenarios assigned. Through online discussion, comments, self and peer reviews, and material searches, each group completed a report after collaborative learning and uploaded and published it in the Moodle discussion room before the deadline for sharing and discussion. In addition, each group was asked to provide comments on and suggestions for other groups' reports. Taking the study subject of asthma as an example, the teacher assigned five asthma case scenarios to the five groups and posted the assignment on Moodle one week before the class. All groups were required to publish their report, which was created after collaborative learning, in the Moodle discussion room two days before the class. Examples of the case scenarios are as follows:

Case scenario1

Xiaoli Zeng, 10 years old. A pulmonary function test one year ago showed a FEV1pre of 56% and FEV1pre/FEV1post of 65.2%, with continuous treatment with medication. The patient had a cold five days ago and developed purulent sputum yesterday that could be cough out only with strong force. The patient was sent to the emergency room and admitted by the 5 pm-12 pm shift due to dyspnoea. The diagnosis was asthma with bronchitis. The patient was given oxygen therapy (2 L/min) through a nasal cannula and was monitored with a pulse oximeter as prescribed by the doctor. You are a day shift nurse. After shift handover, you go to the ward for respiratory system assessment and nursing care.

Case scenario2

Xiaodi Chen, 3 years old (date of birth: 104/10/02), has a history of wheezing. The patient was sent to the outpatient setting due to a runny nose, frequent cough, and significant sputum sounds that started 5 days ago, persistent fever for 3 days, dry rales in the bilateral lungs, and bilateral lung infiltration on X-ray. The patient was diagnosed with asthma with bronchitis and should be treated with steam therapy during hospitalization. Please provide relevant hygienic guidance to the family members of the patient for thoracic physiotherapy after steam inhalation in hospital.

In the course, students constructed new knowledge via research, sharing with others, and studying the given subjects. By studying in groups, students benefited from continuous social interactions, facilitating the development of problem-solving and decision-making skills. Through sharing co-constructed knowledge and continuous social interactions, students were guided to learn together. All teaching methods followed the basic pedagogical principle of collaboration and were continuously supported by teachers (Miyake & Kirschner, 2014). The collaborative tools used in the course were multimedia, videos, pictures, textbooks, writing materials, and quizzes related to theoretical knowledge (Kollar et al., 2018). The students in the

non-Moodle group received traditional face-to-face instruction that consisted of 33 hours of subject-centred teaching. Face-to-face teaching occurred in the form of lectures (PowerPoint). The Moodle group was also given additional teaching materials, while the non-Moodle group used the Moodle platform only for course material storage rather than for collaborative learning. During the course, students were asked to conduct group discussions related to different subjects presented by the teacher, without recording student responses and how they responded. The primary purpose of the discussions was to prompt students to think independently and broaden their understanding of the subject. All students in the non-Moodle and Moodle groups had 18 weeks to learn and complete the paediatric nursing course before the posttest. The posttest was given in the same manner as the pretest after 18 weeks of study, and all test results were e-mailed to the researchers by the teacher.

The study was conducted step by step following the procedures below:

1. Students entered the classroom on September 12, 2020.

2. The teacher introduced the paediatric nursing course to the students.

3. Students were given an introduction regarding the nature and importance of the study as well as the role of students as volunteer participants in the study, student autonomy, and confidentiality of the data collected. Seventy student volunteers were recruited and signed the consent form to participate in the study.

4. All student volunteers were given a pretest and divided into the Moodle and non-Moodle groups based on their own choice. Students in both groups received guidance on how to engage in the study and use the Moodle e-learning environment. They were given 18 weeks to study the course content before taking the posttest. The posttest and pretest were given in the same manner, with the only difference being the order of test questions.

5. During the 18-week study period, students could learn either individually or in groups. For the students in the Moodle group, in addition to the intervention measure (Moodle) that they volunteered to use, any learning methods were allowed pior to the posttest; however, although other learning methods were allowed, the intervention measure (Moodle) was mandatory. For both the non-Moodle and Moodle groups, other permitted learning resources included the Internet, textbooks, an iPad®, etc.

6. There was no specified requirement for the amount of time that students must spend on learning in the Moodle e-learning environment; the students were free to decide.

7. On January 2, 2021, all students in the non-Moodle and Moodle groups took a posttest.

8. The tested results were analysed.

9. Student volunteers who participated in the non-Moodle group received access to the intervention (Moodle).

10. Data collected in this study were analysed using SPSS® software.

Ethical considerations

The reliability and validity of the research were considered for every step in this study. This study was approved by the Institutional Review Board (IRB) of XX Hospital. Consent forms were voluntarily signed by all participants. All data were stored in a laptop protected by a password set by the investigator. Printed copies of the data collected were stored in a locked file cabinet that could be opened only by the investigator with a key.

Data processing and analysis

Inferential statistical analysis of quantitative data collected from the pretest and posttest was performed using the social science statistical software SPSS. First, the data were converted to frequencies, percentages, means, and standard deviations. Second, paired *t*-tests were performed to compare the mean study achievement scores for each group for the pretest and posttest as well as to test whether there was a significant difference in the pretest score between the Moodle and non-Moodle groups. Finally, one-way analysis of variance (ANOVA) was used to test the study hypothesis and compare the mean study achievement scores on the posttest after adjustment between the two groups. The following question was answered: Did the posttest score for the Moodle group increase more than that for the non-Moodle group? To identify any skewed datasets, the data were examined for the presence of interactive relationships between variables (i.e., internal consistency). Statistical analysis results may be biased when greater than 10% of data are missing (Bennett, 2001). Therefore, questionnaires with missing data that exceeded 10% of the total were discarded. Multiple imputation methods were used to handle missing data.

RESULTS

Flow of participants and sample characteristics

This study followed the flow diagram of the modified Consolidated Standards for Reporting of Trials (CONSORT) for controlled trials of non-pharmacological treatments (Boutron et al., 2008) (Figure 4). Two participants in the non-Moodle group and three in the Moodle group withdrew due to physical discomfort during the study period. Overall, 84 third-year nursing students (52 in the non-Moodle group and 32 in the Moodle group) completed the pretest and posttest. The participating students were mostly female. Their GPA (academic performance) ranged from 1.6-4.0. The most common birth order was oldest child in family, and they mostly lived in residential areas in northern Taiwan. There were no statistically significant differences in the demographic characteristics (Table 1) between the two groups. Figure 5 shows the frequency with which nursing students used the Moodle platform in this study. During the first month, the students frequently logged into Moodle. During the 4-month study period, the average frequency was highest on Mondays and Fridays, and the average monthly frequency was 97.91 engagements.

Pretest and posttest of perceived satisfaction, collaborative learning, and study achievement

In the non-Moodle group, the mean perceived satisfaction, collaborative learning, and study achievement scores were 32.54, 51.31, and 27.79 on the pretest and 33.04, 3.31, and 71.81 on the posttest, with high correlations of 35, 42, and 28, respectively, between pretest and posttest based on the paired *t*-test analysis. The paired sample tests for perceived satisfaction, collaborative learning and study achievement yielded 95% confidence intervals of 31.98 – 34.10, 51.29 – 55.33, and 70.30 – 73.32, *t* (51) values of - 0.84, -1.81, and -54.02, and *P* values of 0.405, 0.077, and <0.001, respectively. The differences in perceived satisfaction and collaborative learning did not reach a significant level; however, the difference in study achievement was significant. For the nursing students who did not use the Moodle-based LMS showed, the results indicated no significant differences between the pretest and posttest in perceived satisfaction and collaborative learning but a significant difference between pretest and posttest in study achievement.

In the Moodle group, the mean perceived satisfaction, collaborative learning, and study achievement scores were 33.34, 53.84, and 27.22 on the pretest and 35.84, 58.38, and 81.28 on the posttest, with correlations of 0.358, 0.205 and 0.307, respectively, between the pretest and posttest. The paired sample tests for perceived satisfaction, collaborative learning, and study achievement yielded 95% confidence intervals of 34.50 – 37.19, 55.80 – 60.95, and 79.36 – 83.21, *t* (31) values of -4.11, -3.96, and -63.73, and *P* values of <0.001, <0.001, and <0.001, respectively. The differences in all three aspects were significant, indicating that the nursing students who used the Moodle-based LMS had significantly different levels of perceived satisfaction, collaborative learning, and study achievement between pretest and posttest (Table 2). After the completion of the course using the Moodle-based LMS, the nursing students had

higher levels of perceived satisfaction, collaborative learning, and study achievement than before taking the course, showing certain progress in all three aspects.

Learning effects of perceived satisfaction, collaborative learning, and study achievement within and between groups

One-way ANOVA indicated that the average perceived satisfaction, collaborative learning and study achievement scores on the posttest were 33.04, 53.31, and 71.81 in the non-Moodle group and 35.84, 58.38, and 81.28 in the Moodle group, respectively. The results of Levene's test of equal variances for perceived satisfaction (Levene = 0.68, $P = 0.412 > 0.05$), collaborative learning (Levene = 0.31, $P = 0.578 > 0.05$) and study achievement (Levene = 3.34, $P = 0.071 > 0.05$) were not significant, indicating that there was no significant difference in variation between the two groups. For perceived satisfaction, the overall test results indicated a significant difference in the posttest between the two groups ($F(1,82) = 10.62$, $P = 0.002$), suggesting that perceived satisfaction could vary depending on whether classroom teaching was combined with a Moodle-based LMS. For collaborative learning, the overall test results indicated a significant difference in the posttest between the two groups ($F(1,82) = 9.48$, $P = 0.003$), suggesting that the incorporation of a Moodle-based LMS into classroom teaching could affect the level of collaborative learning. Similarly, the overall posttest result for study achievement was significantly different between the two groups ($F(1,82) = 59.30$, $P < 0.001$), suggesting that the use of a Moodle-based LMS could result in study achievement differences. In the analysis using Moodle-based LMS learning as an independent variable and perceived satisfaction, collaborative learning, and study achievement as dependent variables, the explanatory power η^2 reached 11.5%, 10.4% and 42.0%, respectively, showing high correlations between the independent variable and dependent variables (Cohen, 2013). The observed power was also high, 0.896, indicating that the data studied had high reference value (Table 3).

DISCUSSION

The aim of this study was to determine the effectiveness of combining a Moodle-based LMS with classroom teaching. This method created a new learning module wherein teaching and learning activities were not limited to a face-to-face teaching environment. Compared with those in the non-Moodle group, the students in the Moodle group had a higher level of perceived satisfaction with the paediatric nursing course. This result echoes with the ideology of constructivism and was consistent with the findings reported by Chiu et al. (2009) and Hmelo-Silver and Chinn (2015). The results confirmed that in terms of perceived motivation and problem-solving skill development, nursing students were more satisfied with the Moodle platform, a collaborative e-learning system, than traditional face-to-face teaching. By comparing their performance and expectations, the students in the Moodle group reported that that the

paediatric nursing course had met their expectations and believed that the Moodle-based LMS combined with face-to-face teaching was effective; as a result, the students had a relatively higher level of satisfaction with the course (Petruzzellis et al., 2006). In other words, the students in the Moodle group happily and satisfactorily completed the course. Although satisfaction is a psychological process that can be affected by various factors in different environments (Weerasinghe & Fernando, 2017) and has different standards, there is no doubt that student satisfaction is one of the most important indicators for evaluating teaching effectiveness and learning environment quality (Jung, 2014). Hence, student satisfaction regarding meeting expectations is one of the most critical factors in evaluating teaching success (Rahman et al., 2015) and a pivotal factor affecting learning performance (Jung, 2014).

The level of collaborative learning significantly improved in the Moodle group compared to the non-Moodle group through the use of the Moodle-based LMS. Consistent with the findings reported by Männistö et al. (2019), collaborative learning through Moodle-based LMSs enhance student development and lead to meaningful learning effects. These effects might be attributed to the new collaborative learning environment created by the Moodle platform. Submerging themselves in this environment, which has been proven to have a positive impact on learning (Salvetti & Bertagni, 2014), the nursing students began to collaborate with each other to accomplish the learning tasks assigned by the teacher and successfully developed problem-solving plans. They discussed the study topics in groups and enjoyed the equal opportunities to provide and receive assistance from group members, prompting collaborative learning (Miller & Hadwin, 2015). The Moodle platform can provide students with more opportunities to interact and enhance their collaborative learning. These opportunities eventually improve students' social and collaborative skills, learning motivation, problem-solving abilities, critical thinking, and cognitive abilities (Reiter-Palmon et al., 2017; Rummel, 2018), as well as negotiation and conflict-resolution skills. Another possible reason for improvements might be the extensive use of interactive tools such as email, posts, online meetings, and online chats. Students can discuss, share information, spread new knowledge, and express opinions in an open atmosphere using these tools, all of which promote communication among peers and facilitate new knowledge construction via social interaction (Peterson & Roseth, 2016; Smeekens et al., 2011). This is in line with the views of socio-constructivists who emphasize the important role of social interaction in individual learning and knowledge construction (Scardamalia & Bereiter, 2014). In this study, the nursing students in the Moodle group recorded a monthly average of 97.91 engagements in the learning activities on the Moodle platform during the entire course. Despite a decrease in the third month, the access frequency increased in the last month, potentially because the students were preparing for the upcoming final exam through collaborative learning with peers on the Moodle platform. By watching videos and participating in real-time chats on the platform, the students could revise activities to complete their learning tasks through team collaboration. The Moodle-based LMS provided the students with a more enjoyable and meaningful learning experience, prompting them to share their novel experience with others. The positive response of the students in the Moodle group indicated that the Moodle platform

combined with traditional classroom face-to-face teaching improved the effectiveness of teaching knowledge, skills, and abilities related to paediatric nursing and increased student learning.

The F value for study achievement, which was derived from the posttest after the Moodle group completed interactions on the Moodle platform, was 59.30, below the threshold value of 75.32. This result suggested that compared with the non-Moodle group, the Moodle group had a higher level of professional knowledge but that the two groups had similar prior knowledge in the domain of paediatric nursing. That finding indicates that the nursing students gained significant benefits from the Moodle-based LMS. The combined use of traditional face-to-face teaching and the Moodle-based LMS enabled the students to make remarkable progress, based on their study achievements, in professional knowledge after completing the paediatric nursing course. In addition to the content obtained via classroom instruction, the course constructed using the Moodle-based LMS had a significant positive impact on students with respect to obtaining paediatric nursing knowledge. This finding is inconsistent with a previous opinion from some educators that new electronic technologies are not effective learning tools and that their use in teaching does not have positive effects on students' study achievement (Ghuloum, 2010). However, our results support the opinion by Kotzer and Elran (2012) that the proper integration of novel Moodle-based E-learning environments into pedagogical frameworks is conducive to teaching and learning. They also support the findings of Mlotshwa et al. (2020), i.e., Moodle-embedded teaching activities prompt students to construct knowledge under the theoretical framework of social constructivism. The positive effect of Moodle-based LMS combined with face-to-face teaching on study achievements of students in the paediatric nursing course is generated in part because the Moodle-based LMS can help nursing students use various study materials and tools after class, for example, videos, multimedia, and email, as well as learning tasks and activity revisions. This method provides students with more diverse information and piques their interest, thus improving their understanding of complicated topics taught in class (Lakens, 2013). In addition, this new teaching method prompts students to actively construct knowledge based on immediate feedback. Expectedly, the nursing students in the non-Moodle group also significantly improved their learning in the paediatric nursing course after four months even though they received only face-to-face teaching without the Moodle-based LMS intervention. This implies that Moodle-based LMSs are not replacements for traditional face-to-face teaching but, instead, an effective complementary tool for teaching, discussing, and learning in a classroom environment (Mlotshwa et al., 2020).

Currently, a number of studies have been conducted that evaluate the use of Moodle-based LMSs for educational purposes in higher education and their effects on student learning performance (Männistö et al., 2019; Novo-Corti et al., 2013). Overall, the majority of these studies derived consistent results. Most previous studies on the use of Moodle-based LMSs indicated that this system is more satisfactory, motivating, and effective than face-to-face teaching. In this study, students were satisfied with the online LMS experience, and their

expectations regarding learning paediatric nursing were met. Further, collaborative learning via LMSs eases student interactions (Weinberger et al., 2010), promotes knowledge construction (Buder & Bodemer, 2008), and creates learning activities with new social communication and cognition functions (Phielix et al., 2011). Consequently, students are more motivated to continue their studies and thus more likely overcome challenges and master the knowledge necessary for a course, as evidenced by the improved average study achievement score on the written exam in the present study. As explained throughout the entire discussion section above, most nursing students acknowledged the effectiveness of the Moodle-based LMS as a learning tool. The encouraging findings of this study provide solid empirical evidence supporting the introduction of Moodle-based LMSs into teaching.

Limitations

Despite our considerable efforts, there are still problems related to the research design of this study. First, our results indicate that Moodle-based LMSs generate a certain level of positive satisfaction. However, the satisfaction level derived from empirical evidence analysis might not always remain the same. Because no follow-up data were collected in the present study, the question whether satisfaction remains the same over time has yet to be answered. Second, no consensus has been reached related to the methods used for evaluating technological satisfaction with Moodle-based LMSs (García-Murillo et al., 2020). The existing studies used different indicators and standards for evaluation, leading to discrepancies in the effectiveness assessment results and thus limiting the generalization of the research findings. To solve this still open issue, we suggest that the future research focus on developing new assessment tools that can provide effective alternatives.

This study clearly proved the effectiveness of a Moodle-based LMS as a complementary tool in teaching and learning. The findings from this study can further promote the use and positive contribution of this system in the field of teaching plan design and teaching techniques. In addition to providing insight into future research, our findings promote the use of Moodle-based LMSs as important elements of pedagogy in higher medical education and thus bring significant improvements to nursing education.

CONCLUSION

The main finding of this study is that the use of a Moodle-based LMS can significantly improve nursing students' perceived satisfaction, collaborative learning, and study achievement in a paediatric nursing course. The students reported that the setup and use of the Moodle-based LMS on campus was very effective. Our study not only provides teachers with empirical evidence to help them make effective teaching decisions but also promotes a positive and

optimistic attitude towards the use of online LMSs. Based on the findings from this study, Moodle-based LMSs can be adjusted for different types of nursing students in college and can affect the self-learning and learning performance of students. More importantly, during the COVID-19 pandemic, the use of Moodle-based LMSs can reduce the risk of infection and therefore should be used to develop proper and safe complementary teaching modules.

DATA ACCESSIBILITY

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TABLES

Table 1. Exploratory factor analysis of the student satisfaction scale

Item	First factor	Second factor
The first factor: learning satisfaction		
1. I feel that the course met my expectations.	.914	
2. I achieved the study objectives of the course.	.754	
3. I gained new knowledge in class.	.625	
4. I actively made an effort to achieve the objectives of the course.	.623	
5. I think that the difficulty level of the course content was appropriate.	.553	
The second factor: e-learning environment satisfaction		
6. The e-learning environment motivated me to learn the course content.		.907
7. I found that the e-learning environment was very useful.		.750
8. I think it is important to use an e-learning environment in teaching.		.671
Eigenvalue	4.382	1.064
Percentage of variance	54.8%	13.3%
Total percentage of the factor model		68.1%
Cronbach's alpha	.847	.830

Table 2. Exploratory factor analysis of the collaborative learning scale

Item	First factor	Second factor	Third factor
First factor: promoting group collaboration			
1. All group members actively participated in class activities.	.946		
2. All group members were in a positive learning atmosphere.	.938		
3. All group members had fluent interactions and profound discussions.	.846		
4. The group members prompted each other to study.	.749		
5. The group members had enough background knowledge on the subject of the course.	.654		
6. All group members can clearly explain the learning objectives.	.643		
Second factor: teacher's role in the collaborative learning environment			
7. The teacher's feedback prompted me to study.		.954	
8. Teachers actively improved opportunities for cooperation.		.891	
9. Teaching materials prompted diverse group discussions.		.688	
10. The e-learning environment made learning activities more flexible for all groups.		.360	
Third factor: the role of students in the collaborative learning environment			
11. My learning skills are a prerequisite for successful collaborative learning.			.878
12. My own learning motivation is a prerequisite for successful collaborative learning.			.810
13. Successful completion of learning tasks requires collaborative learning.			.356
Eigenvalue	5.584	2.700	1.032
Percentage of variance	43.0%	20.8%	7.9%
Total percentage of the factor model		68.1%	71.7%
Cronbach's alpha	.921	.835	.764

FIGURES

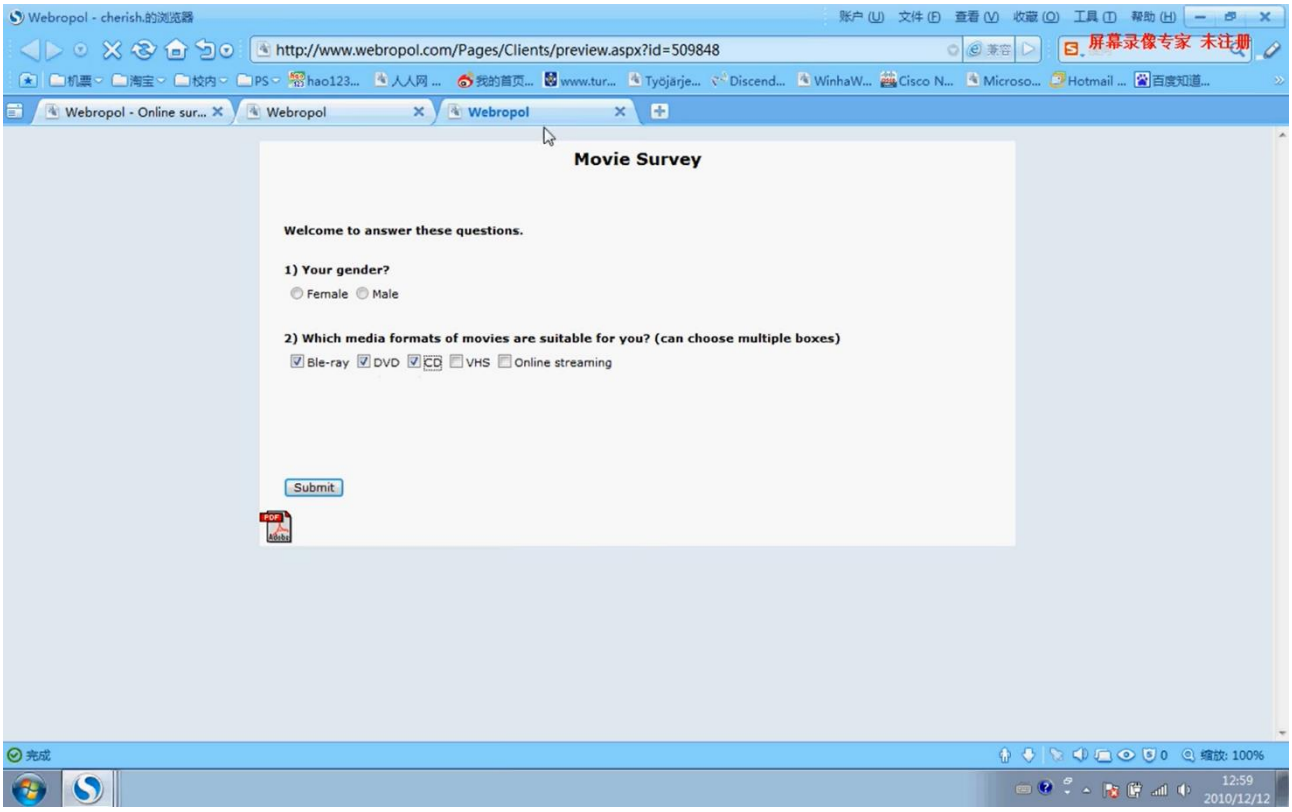

Figure 1. An example of a Webropol® questionnaire.

Figure 2. Home page of the interface platform, showing the main menu, discussion topics, and calendar.

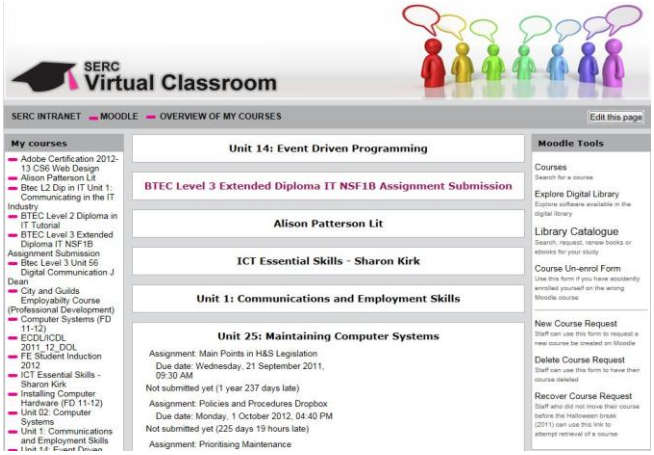

Figure 3. An example page showing how a student could access "My courses" from the main menu and enter the virtual classroom for the course.