Computers & Education 83 (2015) 10–21

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Can more interactivity improve learning achievement in an online course? Effects of college students' perception and actual use of a course-management system on their learning achievement

Huei-Chuan Wei, Hsinyi Peng, Chien Chou*

Institute of Education, National Chiao Tung University, 1001 University Road, Hsinchu, 30010 Taiwan, ROC

ARTICLE INFO

Article history:
Received 18 August 2014
Received in revised form
15 December 2014
Accepted 18 December 2014
Available online 31 December 2014

Keywords:
Computer-mediated communication
Distance education and telelearning
Interactive learning environments
Post-secondary education

ABSTRACT

This study aims to investigate how interactivity influence learners' use of interactive functions in the course-management system (CMS) and their online learning performance. A two-tier mediation framework is proposed to examine the mediating effects of different actual-use records concerning the CMS's interactive functions. Data are collected from 381 undergraduate students who enrolled in a general-education asynchronous online course from three universities in Taiwan. The results indicate that the relationships among students' self-reported use of interactive functions, students' perceptions of the usefulness of interactive functions, and students' actual-use logs have some direct influences on students' online learning performance (online-discussion scores, exam scores, and group-project scores). In addition, students' actual-use logs (the number of times of log-ins to the online course, the number of times students read learning materials, and the number of postings on the discussion board) have a mediated effect on students' self-reported frequency of logging into the CMS, students' self-reported frequency of using the learner–instructor/learner–learner interactive functions, and online learning performance. The findings and implications could constitute a useful guide for educational practitioners and designers concerned with the effective integration of interactivity into future online courses.

1. Introduction

Interactivity has been viewed as playing an essential role in the learning process among learners, instructors, and learning content. It is presumed to occur in all learning environments including formal education and informal education (Bernard et al., 2009; Ke, 2013). Learners can interact with peers and instructors to exchange and share their knowledge. Meanwhile, they can construct new knowledge and reorganize prior knowledge from this interaction process (Kang & Im, 2013). As Song and McNary (2011) concluded, students' interaction is always an indispensable and fundamental component of their knowledge acquisition and cognitive development in traditional face-to-face learning settings.

Owing to the rapid expansion of and progress in Internet technology and Internet use, online learning has become more and more popular in today's higher education (Ke & Kwak, 2013; Wei & Chou, 2014). Online learning enables learners and instructors to bypass regular daily or weekly face-to-face encounters, and most, if not all, learning materials are deliverable online. Online learning also enables learners to gain knowledge and skills through synchronous and asynchronous learning applications without time and space limitations (Allen & Seaman, 2013; Kaymak & Horzum, 2013). Therefore, interactivity has been viewed as one of the most important parts of learners' successful learning experiences in an online learning environment (Cho & Kim, 2013; Garner & Bol, 2011; Kang & Im, 2013; Richardson & Swan, 2003; Watson, 2013).

In order to facilitate interactivity in online learning, educators have usually been adopting a course-management system (CMS), such as Moodle or Blackboard, which can facilitate the delivery and management of online-course materials and activities while strengthening students' learning progress (Liaw & Huang, 2013; Malikowski, 2008; West, Waddoups, & Graham, 2007). Whether or not CMSs can provide

* Corresponding author. Tel.: +886 3 5731808.
E-mail address: cchou@mail.nctu.edu.tw (C. Chou).

http://dx.doi.org/10.1016/j.compedu.2014.12.013
0360-1315/

sufficient and effective interactive functions to facilitate students' interactions and learning has become an important research issue (Chou, Peng, & Chang, 2010) and is the focus of the present study.

2. Literature review

2.1. Definitions of interactivity in online learning

What exactly is interactivity in learning assisted by computers or networks? Evans and Sabry (2003) proposed a simple three-way model (computer-initiation, learner-response, and computer-feedback) to address the concept of interactivity in an online multimedia learning environment. This model parallels the common classroom three-step interaction pattern (teacher's initiation, students' response, and teacher's feedback; see Smith, Hardman, & Higgins, 2006). However, in a typical online course, interactivity should not be limited to learner–computer interaction. Chou (2003) and Chou et al. (2010) considered the technology affordance and extended the concept of interactivity in online learning into five interaction types: the learner–self, learner–learner, learner–instructor, learner–content, and learner–interface types. The researchers further proposed a technical framework of interactive functions (e.g., built-in email system, chat rooms, individual-learning records) for each interaction type in the context of CMSs.

From the above-mentioned literature, it became clear that, in a CMS, the five interaction types of online learning proposed by Chou (2003) and Chou et al. (2010) did cover all CMSs' functions. These functions were mainly designed to address various interactive needs for online learning. However, due to the highly overlapped CMSs' interactive functions in the learner–learner interaction and learner–instructor interaction, we merged these two interactive types into one human–human interaction.

In sum, we proposed a revised structure with four interaction types to further discuss students' interactions in an online learning environment. However, few studies have investigated the relationship between the noted interactive functions and students' use of or perceptions of interactive functions in online learning courses. Therefore, it seems warranted to incorporate log-in records, in addition to self-reported data about their use of interactive functions, to facilitate understanding of students' actual use of interactive functions, and to study the relationships among students' perceptions of, as well as actual use of, these interaction functions and the students' learning performances.

2.2. Interactivity and online learning achievement

As mentioned above, interactivity in online learning has been classified into multiple categories (Bannan-Ritland, 2002; Chou, 2003; Hillman, Willis, & Gunawardena, 1994; Moore, 1989; Soo & Bonk, 1998) which are believed to be significant for learners' learning experience and possible achievement in online learning. Previous studies have focused mainly on ways of improving the quality of interactivity in online learning environments (Kaymak & Horzum, 2013; Tremayne, 2005; Woo & Reeves, 2007) and on learners' perceptions of interactivity in online learning environments (Kiousis, 2002; Liaw & Huang, 2013; Sun & Hsu, 2013; Thorson & Rodgers, 2006). Not much past research has explored the interactivity involved in learning achievement. Among the few studies that have, Evans and Sabry (2003) documented evidence that students in a more interactive system had outperformed and required less time than those in a non-interactive system when taking problem-solving tests. Therefore, the two researchers concluded that more interactivity facilitates deep learning (understanding) by actively engaging the learner in the learning process. However, in their study, only three interactive functions (pace-control, self-assessment, and interactive simulation) were available to students. In other words, even in the interactive-system group, students had only limited, pre-set interactivity for carrying out their learning activities.

Similarly, some studies found that, in online learning, learners perceiving a high degree of interaction with instructors and peers tended to perceive higher learning outcomes than learners perceiving a low degree of interaction (Garrison & Cleveland-Innes, 2005; So & Brush, 2008). Kang and Im (2013) examined which factors in online university learners' perception of learner–instructor interaction (regarding such areas as guidance and learning assistance, social intimacy, instructional communication and Q&A, instructor presence, instructional support) could predict the learners' perception of learning outcomes and the learners' perception of satisfaction in online learning environments. Results showed that factors related to instructional interaction significantly predicted learners' perception of learning achievement and learners' perception of satisfaction. Furthermore, Kang and Im pointed out that instructor presence in learners' perception of learner–instructor interaction could be an important predictor of learners' perception of satisfaction in an online learning environment. By contrast, Eom, Wen, and Ashill (2006) found no support for a positive relationship between students' perception of interaction with instructors and peers and the students' perception of learning outcomes. Therefore, we can conclude that the relationship between interaction types and learning outcomes has not yet been consistently established, and thus merits further study.

Pascual-Miguel, Chaparro-Peláez, Hernández-García, and Iglesias-Pradas (2010) used students' logs to analyze the relationship between interaction and academic performance. The results provide at best only partial evidence and at worst no evidence at all that interaction indicators influence students' final course grades (such as total number of interactions, chats, or forums). In other words, there seems to be no relationship between students' platform-based activity and their final academic performance. The non-significant results might be rooted in the limitations of the small sample (48 students), the short duration of the course (2–9 weeks), and the mixed instructional context (a regular face-to-face class and an online distance class). Nevertheless, this study considered computer logs as one valid and useful data source with which to supplement students' self-reported data.

2.3. Lessons learned from past studies and research questions

The brief review of the above-mentioned studies provides a foundation for understanding interaction's role as an important component of and research issue in online learning. Past studies have shed light on the following themes.

(1) Scope and definition: Different studies have various definitions or classifications of interactivity in online-learning contexts. The present study has reached a conclusion that, in addition to human–human interaction (student–self, student–teacher, and student–student) in

traditional educational settings, an online learning environment should include human–computer (or interface) interaction and human–content interaction. This classification can further serve as a basis for the present study's categorization of all CMS functions that facilitate different interaction types.

(2) The focus on the connection between system functions and learning achievement: Some studies have tackled the issues of how the design of CMS functions should facilitate interactivity (e.g., Chou, 2003), or how students' perception of and evaluation of these functions can aid the students' learning (e.g., Chou et al., 2010); thus, it seems that the relationship between CMS functions and students' learning achievement is a topic worth investigating both theoretically and practically. In this study, we focus on the research theme of "Can these interactive functions substantially help learning?"

(3) A longer engagement: Despite some findings based on limited interactivity in certain multimedia and online systems in a one-shot, short-term treatment (such as Evans & Sabry, 2003; Lustria, 2007), there is a dearth of research on the interactivity in CMS environments and its possible effects on learning achievement. In order to better understand the relationship between learners' interactivity in CMS environments and online learning achievement, students should have access to all CMS functions to process their learning for sufficiently long periods of time (e.g., one semester). The present study uses data pertaining to CMS use that extends for longer periods of time (e.g., a whole semester).

(4) The holistic integration of learning outcomes: The term 'holistic integration of learning' refers to an overall approach that encompasses all the integral datasets related to learning outcomes. In an online-learning context, students' learning outcomes can be assessed on the basis of criteria other than final grades (see, e.g., He, 2013; Kang & Im, 2013). When forming integral datasets, educators should account for diverse learning-outcome criteria (e.g., grades on midterm and final exams, participation in online discussions, participation in group projects). Built-in CMS functions make it easy to document the above datasets, and in theory at least, diverse CMS functions can support diverse learning outcomes.

(5) Unobtrusive measures: In order to fully understand students' perception of or evaluation of CMS functions, some studies have suggested that researchers' use of unobtrusive measures can significantly supplement students' self-reported data. Unobtrusive measures are data-collection methods embedded in CMS applications, such as Log data of recording students' actual web-page hits, chat reports, chat views, forum-discussion posts, and forum-discussion views in the Moodle system (Pascual-Miguel et al., 2010) or the number and type of posts in the Blackboard system (Song & McNary, 2011). Obviously, different CMSs may provide researchers with a variety of log data, depending on system affordability and researchers' needs. In this study, we collected three log records consisting of students' frequency of log-ins (total number of times of log-ins to the online course), frequency of reading learning materials (the number of times students read the learning materials), and the number of postings students posted on the discussion board.

(6) The mediation framework: We proposed and validated a mediation framework to provide a more complete picture of the relationships among students' self-reported data, logs of actual use, and learning achievement. In this framework, students' actual-use logs serve as an outcome of students' self-reported CMS use and perceptions, and as a mediator of students' learning achievement (which is considered the ultimate outcome of concern). In other words, this two-tier mediation framework may facilitate further investigations into the simple correlations of each possible influencing variable (i.e., students' perceptions of CMS interactive functions, and students' actual CMS use) to students' learning achievement. Moreover, this framework depicts the direct and indirect effects that each variable has on the mediator and on the ultimate concern—depictions that, we believe, will provide a more holistic and system-wide view of students' online learning achievement.

The research questions are listed as follows:

(1) What are students' self-reported use of the CMS in general (including the frequency of each type of interactive function and students' perceptions of the usefulness of each type of interactive function) and the logs of students' actual use (including students' number of log-ins to the online course, the number of times students read the learning materials, and number of posts students posted to the discussion board)?

(2) Are students' self-reported CMS use and students' perceptions of the usefulness of interactive CMS functions related to students' actual-use logs and to students' learning achievements (including online discussions, exams, and group projects)?

3. Method

3.1. Participants

The participants consisted of 381 undergraduate students from three universities in Taiwan. They were enrolled in a general-education asynchronous online course delivered completely online through an e-Campus learning-management system III (the e3-system). Students were already informed of the course format before they took this across-campus course. Featuring digital learning materials such as videos and slides, this course required students to post questions and comments on discussion spaces every week throughout the semester and to complete a group project. There were 242 male students (63.5%) and 139 female students (36.5%). Of the participants, 28 (7.3%) were freshmen, 180 (47.3%) were sophomores, 131 (34.4%) were juniors, and 42 (11.0%) were seniors.

3.2. Instruments

To realize the purposes of this study, we used a self-development questionnaire to measure students' self-reported use of—and students' perceptions of the usefulness of—interactive functions in the e3-system. The questionnaire had three major parts.

The first section asked students to submit their own demographic information including gender, grade, and experience using the e3-system, as reported above.

The second section asked students to report the frequency with which they would use the e3-system's interactive functions. The reason for our reliance on a self-reported questionnaire instead of on actual log-in data stems from the e3-system's lack of detailed records for each

interactive function that students would have used. Moreover, we divided the interactions into four types: learner–self interaction, learner–interface interaction, learner–content interaction, and learner–instructor/learner–learner interaction. We then categorized the twelve interactive functions provided by the e3-system into these four interaction types. The questionnaire consisted of 12 corresponding items ($\alpha = .728$). Each item referred to a particular function in one interaction style provided by the e3-system. For example, the interactive function "Assignment-completion tracking" fell under the "Learner–self interaction" category, and the "Discussion board" fell under the "Learner–instructor/learner–learner interaction" category. The questionnaire used a six-point Likert rating format: 1 = never, 2 = only once, 3 = occasionally, 4 = regularly, 5 = frequently, and 6 = always. Having a higher score indicates that students self-reported a higher frequency of using a certain interactive function.

The third section of the questionnaire served to measure students' perceptions of the usefulness of the e3-system's interactive functions. This questionnaire consisted of 12 items ($\alpha = .811$) based on the e3-system's interactive functions provided, and these items were categorized according to the four interaction styles, just as in the second section. An example item in "Learner–self interaction" category is "To what extent do you agree that the Assignment-completion tracking function is useful for your online learning?" Each item was rated on a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. The higher a score, the more useful an interactive online-learning function was perceived to be by the students.

3.3. Data collection

In order to collect the questionnaire data, we distributed the questionnaires while students were taking their paper-and-pencil final exam in a classroom. These students were asked to write, on a voluntary basis, their identification numbers on the questionnaire so that afterward we could match students' questionnaire responses with such performance scores as online-discussion scores or exam scores. We gathered data including students' questionnaire responses and online learning performance scores for four consecutive semesters, from September 2010 to June 2012. A total of 541 questionnaires were distributed, and 381 responses matching the learning-outcome data were usable for further analyses.

Regarding students' online learning performance, we used three scores representing students' three types of performance: the online-discussion score, midterm-exam/final-exam score, and the group-project score. The three scores stemmed from data covering four consecutive semesters and rested on the same course requirements: the score for online discussion counted as 30% of the final score, the score for midterm and final exams counted as 50% of the final score, and the score for group project counted as 20% of the final score. The following information comprises pertinent details regarding the three types of scores:

(1) Online-discussion score: The measurement of online discussion performance was based on the number and quality of messages posted. Each student was required to post at least two postings per week including responses to the discussion threads posted by the instructors and by their peers; furthermore, each student had to post at least two messages in one semester for the purpose of extending peer discussion. Two instructors and three teaching assistants scored the quality of messages on the basis of two criteria: the clarity and the reasonableness of participating students' postings. These criteria were announced during the first week of the course.
(2) Midterm-exam/final-exam score (exam score): This score was the average of the midterm and final exams. All students needed to take these paper-and-pencil exams in a designated classroom.
(3) Group-project score: The aforementioned two instructors and three teaching assistants assessed the students' group projects on the basis of a set of criteria covering consistency, accuracy, completeness, creativity, and organization. These criteria were announced during the first week of the course.

For four consecutive semesters, all students had a composite grade point average that ranged from 31.75 to 92.35 (on a 100-point spectrum), with a mean of 73.35 and a standard deviation of 12.47.

To verify the use of the e3-system's interactive functions reported by students, and to compare those self-reported data to the students' online learning performance, we used three learning records: frequency of log-ins, frequency of reading learning materials, and the number of postings on the discussion board, as discussed below:

(1) Frequency of log-ins (Log-ins): This category refers to "the number of times that students logged into the online course." We obtained the data from the e3-system's interactive function "Login-status tracking." In order to eliminate "casual visits" (no substantial reading or interaction) from this set of data, we set a threshold on students' length of stay: ten minutes was the minimum time a student could stay logged in.
(2) Frequency of reading of learning materials (Readings): This frequency refers to "the number of times that students spent on reading learning materials." We obtained the data from the e3-system's interactive function "Materials-viewed tracking." We based these numbers on the duration of students' reading of lecture materials in the online course. For instance, if a student's reading time were to exceed three minutes, the record would be counted as one discrete period of reading.
(3) Number of postings on the discussion board (Postings): We obtained these numbers from the e3-system's interactive function "Presentation-status tracking."

3.4. Data analysis

Fig. 1 shows the framework of the present study. As shown in Fig. 1, the independent factors involved in the prediction of dependent factors (online-discussion score, midterm-exam/final-exam score, and group-project score) comprise nine independent variables, which pass through multiple mediators, including actual use logs.

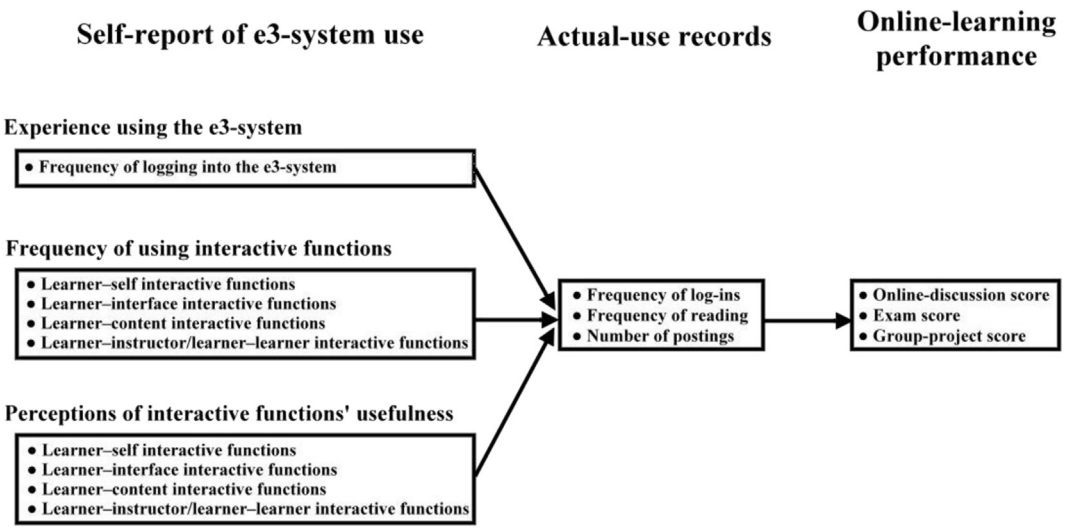

Fig. 1. The two-tier framework of this study.

We estimated the mediation analysis by using Mplus (Muthén & Muthén, 2010). We utilized the Mplus analytic routine "Model Indirect" to conduct a Sobel test (1982) so as to investigate independent variables' indirect effects on dependent variables through each potential mediator, with the delta method standard error serving to test statistical significance (Krull & MacKinnon, 2001).

4. Results

4.1. Descriptive statistics

4.1.1. Frequency of using interactive CMS functions

Table 1 provides an overview of the descriptive statistics for students' self-reported frequency of using the e3-system's interactive functions, the mean values for all interactive functions, and standard deviations separately for each interaction dimension.

Regarding interaction dimensions, questionnaire data show that the learner–interface dimension was the most frequently used (M = 4.35) interaction, followed by the learner–content dimension (M = 4.14), the learner–instructor/learner–learner dimension (M = 4.01), and last the learner–self dimension (M = 3.85).

Students' self-reports also show that, of all the listed interactive functions, the most frequently used were the assignment-handling function (M = 4.76, in the learner–instructor/learner–learner dimension), the system-announcement function (M = 4.75, in the learner–interface dimension), and the discussion-board function (M = 4.59, in the learner–instructor/learner–learner dimension).

Table 1
Students' self-reported frequency of using the e3-system interactive functions (N = 381).

Frequency of using functions	Never	Only once	Occasionally	Regularly	Frequently	Always	M[a]	SD
	N (%)							
Learner–self interaction							**3.85**	**0.89**
1. Assignment-completion tracking	12 (3.1)	6 (1.6)	35 (9.2)	95 (24.9)	182 (47.8)	51 (13.4)	4.53	1.09
2. Materials-viewed tracking	64 (16.8)	4 (1.0)	55 (14.4)	117 (30.7)	108 (28.3)	33 (8.7)	3.79	1.51
3. Grade-status tracking	44 (11.5)	13 (3.4)	85 (22.3)	112 (29.4)	104 (27.3)	23 (6.0)	3.76	1.36
4. Presentation-status tracking	45 (11.8)	16 (4.2)	83 (21.8)	113 (29.7)	104 (27.3)	20 (5.2)	3.72	1.36
5. Login-status tracking	63 (16.5)	13 (3.4)	113 (29.7)	105 (27.6)	62 (16.3)	25 (6.6)	3.43	1.43
Learner–interface interaction							**4.35**	**1.17**
1. System announcement	15 (3.9)	2 (0.5)	25 (6.6)	83 (21.8)	153 (40.2)	103 (27.0)	4.75	1.17
2. System update	63 (16.5)	5 (1.3)	36 (9.4)	110 (28.9)	115 (30.2)	52 (13.6)	3.96	1.58
Learner–content interaction							**4.14**	**1.30**
1. Multimedia presentation	33 (8.7)	4 (1.0)	52 (13.6)	115 (30.2)	142 (37.3)	35 (9.2)	4.14	1.30
Learner–instructor/learner–learner interaction							**4.01**	**0.83**
1. Assignment handling	4 (1.0)	5 (1.3)	26 (6.8)	68 (17.5)	217 (57.0)	61 (16.0)	4.76	0.92
2. Discussion board	15 (3.9)	2 (0.5)	34 (8.9)	102 (26.8)	150 (39.4)	78 (20.5)	4.59	1.16
3. Email	62 (16.3)	34 (8.9)	79 (20.7)	100 (26.2)	86 (22.6)	20 (5.2)	3.46	1.48
4. Class roster	56 (14.7)	39 (10.2)	113 (29.7)	117 (30.7)	46 (12.1)	10 (2.6)	3.23	1.29

[a] Based on a 6-point Likert scale: 1 = never, 2 = only once, 3 = occasionally, 4 = regularly, 5 = frequently, 6 = always.

Table 2
Students' perception of the usefulness of the e3-system's interactive functions (N = 381).

Usefulness of functions	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	M[a]	SD
	N (%)						
Learner–self interaction						**3.62**	**0.55**
1. Assignment-completion tracking	1 (0.3)	5 (1.3)	74 (19.4)	209 (54.9)	92 (24.1)	4.01	0.72
2. Grade-status tracking	3 (0.8)	9 (2.4)	121 (31.8)	188 (49.3)	60 (15.7)	3.77	0.77
3. Materials-viewed tracking	10 (2.6)	24 (6.3)	138 (36.2)	163 (42.8)	46 (12.1)	3.55	0.88
4. Presentation-status tracking	2 (0.5)	20 (5.2)	168 (44.1)	152 (39.9)	39 (10.2)	3.54	0.77
5. Login-status tracking	11 (2.9)	49 (12.9)	184 (48.3)	110 (28.9)	27 (7.1)	3.24	0.87
Learner–interface interaction						**3.87**	**0.68**
1. System announcement	2 (0.5)	5 (1.3)	79 (20.7)	180 (47.2)	115 (30.2)	4.05	0.78
2. System update	5 (1.3)	7 (1.8)	159 (41.7)	142 (37.3)	68 (17.8)	3.69	0.83
Learner–content interaction						**3.86**	**0.81**
1. Multimedia presentation	3 (0.8)	13 (3.4)	98 (25.7)	189 (49.6)	78 (20.5)	3.86	0.81
Learner–instructor/learner–learner interaction						**3.79**	**0.59**
1. Assignment handling	1 (0.3)	6 (1.6)	55 (14.4)	197 (51.7)	122 (32.0)	4.14	0.73
2. Discussion board	5 (1.3)	6 (1.6)	92 (24.1)	182 (47.8)	96 (25.2)	3.94	0.82
3. Email	9 (2.4)	11 (2.9)	132 (34.6)	154 (40.4)	75 (19.7)	3.72	0.89
4. Class roster	11 (2.9)	38 (10.0)	175 (45.9)	120 (31.5)	37 (9.7)	3.35	0.89

[a] Based on a 5-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

4.1.2. Perceived usefulness of interactive CMS functions

Table 2 summarizes the descriptive statistics regarding students' perceptions of the usefulness of the e3-system's interactive functions, the mean values for all interactive functions, and standard deviations separately for each interactive function in the four interaction dimensions.

Regarding interaction dimensions, the learner–interface dimension was perceived to be the most useful interaction (M = 3.87). Of all the listed interactive functions, the three functions perceived by students to be most useful for online learning were the assignment-handling function (in the learner–instructor/learner–learner dimension, M = 4.14), the system-announcement function (in the learner–interface dimension, M = 4.05), and the assignment-completion tracking function (in the learner–self dimension, M = 4.01).

4.1.3. Actual-use records of interactive CMS functions

Table 3 shows students' actual-use records concerning the e3-system's interactive functions and indicates that each student, on average in each semester, would log into the online course 25.86 times (SD = 21.98), might read learning materials 14.69 times (SD = 10.70), and might post 22.37 discussion-board messages (SD = 13.87).

4.2. Mediation analysis of the two-tier framework

For the present study, we consulted different actual-use records concerning the e3-system's interactive functions to examine the relationships among students' self-reported use of interactive functions, students' perceptions of the usefulness of interactive functions, and students' online learning performance. To facilitate this examination, we proposed a two-tier framework (see Fig. 1). Table 4 presents the statistical results of the framework's mediation analysis.

4.2.1. Independent variables' effects on online-discussion scores

As shown in Table 4, we found that the self-reported frequency with which students logged into the e3-system (B = .57, SE = .26, $p < .05$) and the self-reported frequency with which students used the learner–instructor/learner–learner interactive functions (B = 1.01, SE = .36, $p < .05$) directly affected the students' online-discussion scores. Also, the frequency of log-ins (B = .09, SE = .01, $p < .05$), the frequency of reading learning materials (B = .18, SE = .03, $p < .05$), and the number of postings on the discussion board (B = .19, SE = .02, $p < .05$) positively predicted students' online-discussion scores.

In the mediation analysis, we focused on the mediation effect. The frequency of log-ins, the frequency of reading learning materials, and the number of postings on the discussion board significantly mediated the effects that the frequency of logging into the e3-system had on online-discussion scores (respectively as follows: B = .78, SE = .15, $p < .05$; B = .53, SE = .12, $p < .05$; and B = .40, SE = .13, $p < .05$). In addition, the number of postings significantly mediated the effects that the self-reported frequency with which students used the learner–instructor/learner–learner interactive functions had on online-discussion scores (B = .48, SE = .19, $p < .05$).

4.2.2. Independent variables' effects on exam scores

As shown in Table 4, the results of our analysis show that the self-reported frequency with which students logged into the e3-system (B = .83, SE = .22, $p < .05$) directly affected their exam scores. Also, the frequency of log-ins (B = .06, SE = .01, $p < .05$), the frequency of

Table 3
Students' actual-use records of the e3-system's interactive functions (N = 381).

Actual-use records	Medium	Range	M	SD
Frequency of log-ins (total number of times of log-ins to the online course, ≥10 mins)	20	0–120	25.86	21.98
Frequency of reading learning materials (the number of times students read the learning materials, ≥3 mins)	13	0–76	14.69	10.70
Number of postings on the discussion board	24	0–99	22.37	13.87

Table 4
Mediation analysis of the two-tier framework with regression coefficients (n = 381).

Direct effect	Dependent variables					
	Discussion	Exam	Project	Log-ins	Readings	Postings
Self-report of experience using the e3-system						
Frequency of logging into the e3-system	.57 (.26)*	.83 (.22)***	.99 (.24)***	9.08 (.96)***	2.90 (.50)***	2.10 (.65)**
Self-report of frequency using interactive functions						
Learner–self interactive functions	.35 (.32)	−.33 (.28)	−.37 (.31)	1.42 (1.26)	.59 (.66)	1.61 (.86)
Learner–interface interactive functions	−.17 (.29)	−.22 (.25)	.06 (.27)	−1.42 (1.11)	−.77 (.58)	−.77 (.76)
Learner–content interactive functions	−.28 (.25)	.04 (.21)	−.11 (.23)	.81 (.95)	.95 (.50)	−.58 (.65)
Learner–instructor/learner–learner interactive functions	1.01 (.36)**	.21 (.31)	.64 (.34)	.21 (1.39)	.06 (.73)	2.48 (.95)**
Self-report of perceived usefulness of interactive functions						
Learner–self interactive functions	−.58 (.49)	−.50 (.43)	−.88 (.47)	−4.08 (1.92)	−1.06 (1.00)	−2.64 (1.31)
Learner–interface interactive functions	−.33 (.51)	.10 (.44)	−.57 (.48)	1.65 (1.98)	.65 (1.04)	.35 (1.35)
Learner–content interactive functions	.73 (.40)	.48 (.35)	.53 (.38)	−.13 (1.55)	.33 (.81)	1.62 (1.06)
Learner–instructor/learner–learner interactive functions	.62 (.48)	.44 (.41)	.20 (.45)	.53 (1.85)	−.82 (.97)	−.24 (1.26)
Actual use records						
Log-ins	.09 (.01)***	.06 (.01)***	.03 (.01)*	–	–	–
Readings	.18 (.03)***	.09 (.02)***	.10 (.02)***	–	–	–
Postings	.19 (.02)***	.06 (.02)***	.09 (.02)***	–	–	–

Indirect effect	Proposed mediator		
	Log-ins	Readings	Postings
Self-report of experience using the e3-system			
Frequency of logging into the e3-system→ discussion	.78 (.15)***	.53 (.12)***	.40 (.13)**
Frequency of logging into the e3-system → exam	.52 (.12)***	.27 (.08)***	.13 (.05)*
Frequency of logging into the e3-system → project	.25 (.12)*	.28 (.08)***	.20 (.07)**
Self-report of frequency using interactive functions			
Learner–self interactive functions → discussion	.12 (.11)	.11 (.12)	.31 (.17)
Learner–interface interactive functions → discussion	−.12 (.10)	−.14 (.11)	−.15 (.15)
Learner–content interactive functions → discussion	.07 (.08)	.17 (.09)	−.11 (.13)
Learner–instructor/learner–learner interactive functions → discussion	.02 (.12)	.01 (.13)	.48 (.19)*
Learner–self interactive functions → exam	.08 (.07)	.06 (.06)	.10 (.06)
Learner–interface interactive functions → exam	−.08 (.06)	−.07 (.06)	−.05 (.05)
Learner–content interactive functions → exam	.05 (.06)	.09 (.05)	−.04 (.04)
Learner–instructor/learner–learner interactive functions → exam	.01 (.08)	.01 (.07)	.16 (.07)*
Learner–self interactive functions → project	.04 (.04)	.06 (.06)	.15 (.09)
Learner–interface interactive functions → project	−.04 (.04)	−.07 (.06)	−.07 (.07)
Learner–content interactive functions → project	.02 (.03)	.09 (.05)	−.05 (.06)
Learner–instructor/learner–learner interactive functions → project	.01 (.04)	.01 (.07)	.23 (.10)*
Self-report of perceived usefulness of interactive functions			
Learner–self interactive functions → discussion	−.35 (.17)	−.20 (.19)	−.51 (.26)
Learner–interface interactive functions → discussion	.14 (.17)	.12 (.19)	.07 (.26)
Learner–content interactive functions → discussion	−.01 (.13)	.06 (.15)	.31 (.21)
Learner–instructor/learner–learner interactive functions → discussion	.05 (.16)	−.15 (.18)	−.05 (.24)
Learner–self interactive functions → exam	−.23 (.12)	−.10 (.10)	−.17 (.09)
Learner–interface interactive functions → exam	.09 (.11)	.06 (.10)	.02 (.09)
Learner–content interactive functions → exam	−.01 (.09)	.03 (.08)	.10 (.07)
Learner–instructor/learner–learner interactive functions → exam	.03 (.11)	−.08 (.09)	−.02 (.08)
Learner–self interactive functions → project	−.11 (.07)	−.10 (.10)	−.25 (.13)
Learner–interface interactive functions → project	.05 (.06)	.06 (.10)	.03 (.13)
Learner–content interactive functions → project	−.01 (.04)	.03 (.08)	.15 (.10)
Learner–instructor/learner–learner interactive functions → project	.02 (.05)	−.08 (.09)	−.02 (.12)

Note: Entries in all cells show the regression coefficient (B), with the standard error in parentheses.
*$p < .05$. **$p < .01$. ***$p < .001$.

reading learning materials (B = .09, SE = .02, $p < .05$), and number of discussion-board postings (B = .06, SE = .02, $p < .05$) positively predicted students' exam scores.

Our mediation analysis shows that the frequency of log-ins, the frequency of reading learning materials, and the number of discussion-board postings significantly mediated the effects that the frequency of logging into the e3-systemhad on exam scores (respectively as follows: B = .52, SE = .12, $p < .05$; B = .27, SE = .08, $p < .05$; and B = .13, SE = .05, $p < .05$). In addition, students' self-reported frequency of using the learner–instructor/learner–learner interactive functions was found to affect exam scores by way of the number of discussion-board postings (B = .16, SE = .07, $p < .05$).

4.2.3. Independent variables' effects on group-project scores

Also shown in Table 4, we found that the self-reported frequency with which students logged into the e3-system (B = .99, SE = .24, $p < .05$) directly affected their group-project scores. The frequency of log-ins (B = .03, SE = .01, $p < .05$), the frequency of reading learning materials (B = .10, SE = .02, $p < .05$), and the number of discussion-board postings (B = .09, SE = .02, $p < .05$) positively predicted students' group-project scores.

In the mediation analysis, we focused on the mediation effect. The frequency of log-ins, the frequency of reading learning materials, and number of discussion-board postings significantly mediated the frequency of logging into the e3-system's effects on group-project scores (respectively as follows: B = .25, SE = .12, $p < .05$; B = .28, SE = .08, $p < .05$; and B = .20, SE = .07, $p < .05$). Moreover, students' self-reported

frequency of using the learner–instructor/learner–learner interactive functions was found to affect group-project scores by way of the number of discussion-board postings (B = .23, SE = .10, $p < .05$).

5. Discussion

This section of the current paper addresses the dependent variables, and specifically covers our analytical results derived from the students' self-reported data, actual-use logs, and performance.

5.1. The self-reported frequency of students' use of interactive CMS functions and students' perceptions of the usefulness of interactive functions

5.1.1. Frequency of students' use of interactive CMS functions

Students reported that they "occasionally" and "frequently" used the e3-system's interactive functions (see Table 1). These findings are reasonable and support some previous findings in the online-learning contexts (Chou et al., 2010; He, 2013; Kreijns, Kirschner, & Jochems, 2003). For instance, the requirement of class participation was a great incentive to promote interaction. He's (2013) study showed that many students tended to inform the instructor of their class-participation status, noting whether they had watched a class lecture and so on. Similarly, in this study, after using the learner–self interactive functions (i.e., the presentation-status tracking function or the material-viewed tracking function), many students would email an instructor or a teaching assistant to confirm that they had been participating in the threaded discussion because online discussion participation counted toward the final course grade. Chou et al. (2010) likewise found that students' most-frequently used function was the assignment-handling function, which helped them fulfill course requirements.

In the current study, the results also indicate that students used different types of interactive functions to fulfill their learning needs or course requirements. For example, by using the assignment-handling function, students would upload their assignments to the e3-system, and by using the multimedia-presentation function, students would view learning materials. These findings support an argument proposed by Kreijns et al. (2003) that interactive functions themselves do not guarantee a minimum degree of interaction in an online course. A better online interaction can be realized only when well-designed instruction and well-established course requirements are in place to help students make use of interactive functions.

5.1.2. Perceived usefulness of interactive CMS functions

Most of the current study's students reported all interactive functions in the e3-system to be useful for their online learning (see Table 2). The top useful functions identified in the four interactive dimensions were assignment-handling tracking and the grade-status tracking (in the learner–self dimension), system announcements and system updates (in the learner–interface dimension), multimedia presentations (in the learner–content dimension), and assignment handling, discussion boards, and emails (in the learner–instructor/learner–learner dimension).

These results indicate that students' ratings derived mainly from their learning goals and needs. This finding is consistent with Chou et al. (2010), which noted that students usually regarded these interactive functions as helpful in three major areas: (1) monitoring one's own learning status (e.g., material viewed, assignment completion, grade), (2) receiving and disseminating course-related information and materials (e.g., viewing course announcements, handing in assignments), and (3) communicating with instructors and peers (e.g., using e-mail, discussion board). In this regard, students' perceptions of particular interactive functions seem to be highly related to instructors' design of learning activities. However, we should not take for granted the possibility of the fact that each of the CMS's interactive functions is useful to a diverse array of students and is useful for any given type of online learning activity. Students in general would consider certain interactive functions to be useful only if these functions could fulfill their learning needs.

5.2. A mediation framework for effective online learning

This study investigated, in an online learning environment, the structural relationships among students' perceptions of the e3-system's usefulness, actual-use records, and online learning performance.

With regard to students' online-discussion scores, the results of our mediation analysis (see Fig. 2 and Table 4) indicate that, as self-reported by students, their frequency of logging into the e3-system and their frequency of using learner–instructor/learner–learner interactive functions had direct significant effects on their online-discussion scores. Meanwhile, we found that students' actual-use records mediated the effects that both students' self-reported frequency of logging into the e3-system and students' self-reported frequency of using learner–instructor/learner–learner interactive functions had on online-discussion scores. In other words, students' actual-use records (i.e., the frequency of log-ins, the frequency of reading learning materials, the number of postings on the discussion board) mediated the relationship between students' self-reported use of the e3-system and online-discussion scores. Similarly, the number of postings on the discussion board mediated the relationship between students' frequency of learner–instructor/learner–learner interactive functions and students' online-discussion scores. The above findings are consistent with the perspective that if students often attend an online course and pay substantial attention to their learning, they will achieve satisfactory grades (Coldwell, Craig, Paterson, & Mustard, 2008; He, 2013). A potential factor supporting this perspective is that student-evaluation criteria in the context of online discussions are based largely on the number of messages posted and on the quality of postings. Students could elevate their scores by logging into their system frequently, maintaining active participation, and making meaningful discussion-board contributions that would capably synthesize content from reading materials.

With regard to students' midterm-exam/final-exam scores, the results of our mediation analysis (see Fig. 3 and Table 4) indicate that, as self-reported by students, their frequency of logging into the e3-system could directly predict their exam scores. That is, students' self-reported frequency of logging into the e3-system might have had a direct influence on their exam scores. An explanation for this association could be both that the e3-system featured uploads of all the learning materials and that the exam contents were related to the learning materials and topics listed on the discussion board. If students intended to get higher marks on exams, they had to log into the system to review learning materials as well as topics on the discussion board. Thus, the more frequently a student would log into the e3-system, the

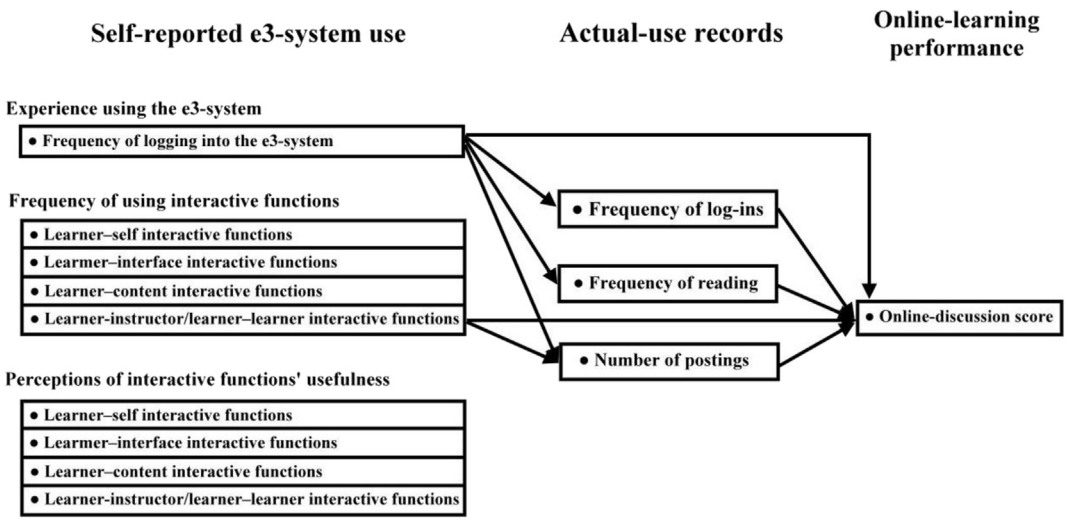

Fig. 2. The results of our mediation analysis on online-discussion scores. (The arrow means that an independent variable has a positive significant direct-effect on a dependent variable.)

likelier the student would be to his or her midterm-exam/final-exam scores. Moreover, we found that the number of discussion-board postings mediated both students' self-reported frequency of logging into the e3-system's effects and their self-reported frequency of using the learner–instructor/learner–learner interactive function's effects on exam scores. This possible causation means that students' number of discussion-board postings could mediate (in the learner–instructor/learner–learner dimension) both the effects that students' self-reported e3-system's log-in frequency had on their exam score and the effects that students' self-reported "interactive function"-use frequency had on their exam scores. From our results, it was quite obvious that the learner–instructor/learner–learner interactive functions served mainly to support students' participation in online interactions with instructors and peers for two purposes: obtaining learning materials and preparing for exams. Therefore, students' frequent use of these interactive functions influenced the students' number of discussion-board postings, which, in turn, influenced the students' exam scores.

With regard to students' group-project scores, the results of our mediation analysis (see Fig. 4 and Table 4) show that, as self-reported by students, their frequency of logging into the e3-system could directly predict their group-project scores. That is, students' self-reported e3-system's log-in frequency had a direct influence on their group-project scores. A possible explanation for this relationship is that the students were required to cooperate with peers on the group projects. Team members needed to use such interactive functions as the email function and the discussion-board function to communicate with one another, and needed to use the multimedia-presentation function to access learning materials. Students' adoption of interactive functions enabled the students' e3-system log-in frequency to influence group-project scores positively. Also according to our results, the number of discussion-board postings mediated two sets of effects: the effects that students' self-reported frequency of logging into the e3-system had on group-project scores and the effects that students' self-reported frequency of using the learner–instructor/learner–learner interactive functions had on group-project scores. The course required that the content of group projects be based on the course materials and the topics addressed in the discussion board. As a result, discussion-board content was an important resource for students seeking to reflect on and express their thoughts, to view and respond to the

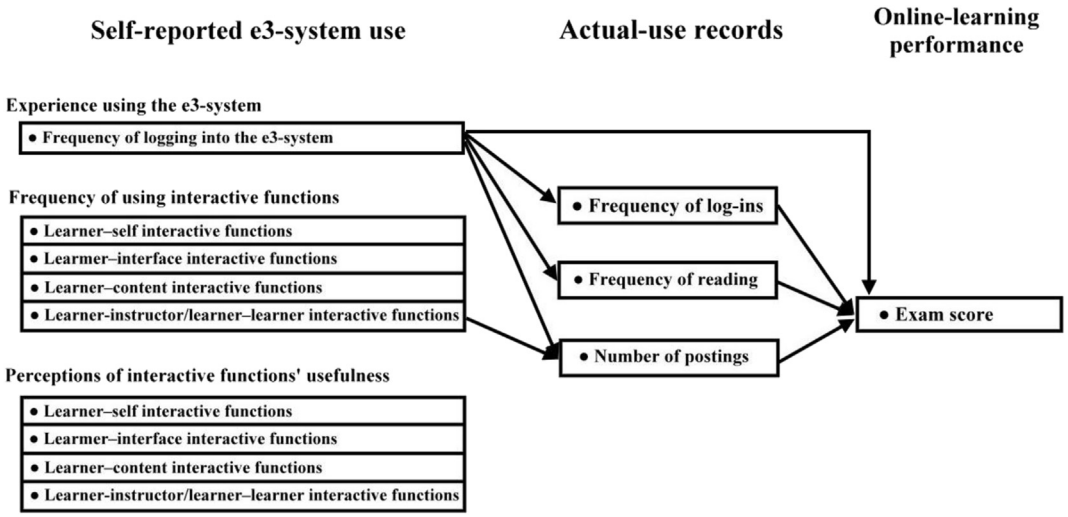

Fig. 3. The results of our mediation analysis on the exam scores. (The arrow means that an independent variable has a positive significant direct-effect on a dependent variable.)

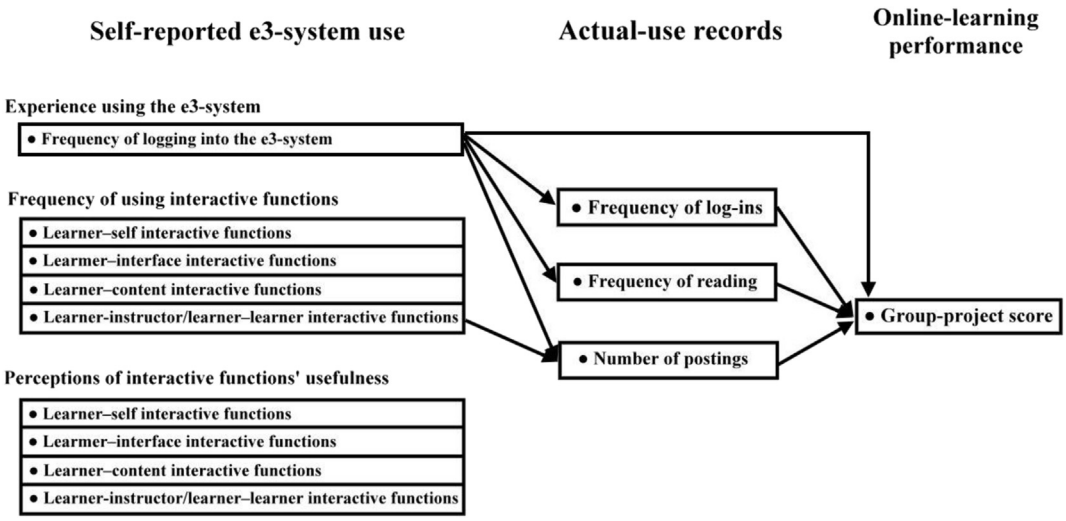

Fig. 4. The results of our mediation analysis on group-project scores. (The arrow means that an independent variable has a positive significant direct-effect on a dependent variable.)

thoughts of other students, and to gain exposure to guest experts who posted ideas on the discussion board. In order to finish group projects successfully, students should need to use the interactive functions in learner–instructor/learner–learner dimension (most notably the discussion-board function and the e-mail function). These functions permitted communication among group members, postings of questions on the discussion board, and e-mail inquiries to instructors for further assistance. This finding of the present research could support an argument proposed by He (2013): the number of questions students ask their instructors and the number of educational messages students post on discussion boards are related to students' final grades.

6. Implications and recommendations

Drawing on actual-use records, we conducted a mediation analysis to examine the effects that students' self-reported use of the e3-system had on their online learning performance. Based on these findings, our approach to the present research has several important implications for future researchers and educators.

First, students' online-discussion scores were directly influenced by students' self-reported frequency of logging into the e3-system and by students' self-reported frequency of using learner–instructor/learner–learner interactive functions; moreover, students' online-discussion scores were indirectly influenced by students' number of postings on the discussion board. The above results indicate that, in order to maximize the potential of students' online discussions, instructors and other educators can interweave substantial course-based learning materials and activities into the CMS (i.e., the e3-system in this study). In the presence of this system, students will have to log into it to complete reading assignments and to fulfill online-discussion requirements. Online-discussion forums amount to a place where some of the most important learning can occur, yet in our current study, students tended to post only as many times as was required. The instructor can engage students to participate in online discussion thoughtfully and frequently by (1) establishing explicit goals and models on the number as well as the quality of postings, (2) encouraging students to use the discussion board to share knowledge and to communicate with the instructor and peers, and (3) promptly responding to students' questions with assurance. The above facilitation strategies might successfully improve the frequency of students' system logins and the frequency of students' use of learner–instructor/learner–learner interactive functions, in turn positively influencing students' online-discussion performance.

Second, students' exam scores in the current study were a direct result of the self-reported frequency with which the students logged into the e3-system and with which the students used learner–instructor/learner–learner interactive functions; in addition, these same scores were indirectly influenced by students' number of discussion-board postings. In other words, whether through direct or indirect paths, students who want to improve their grades should consider increasing the regularity with which they perform e3-system log-ins, use learner–instructor/learner–learner interactive functions, and compose online-discussion postings. Our study's results suggest two effective ways of improving students' exam scores: (1) the CMS (i.e., the e3-system) can serve as the primary channel for delivering course content, including information about exams, and (2) educators can strengthen learner–instructor interactions by frequently initiating new discussion topics or by applying the e-mail functions or discussion boards to the task of resolving students' course-related problems.

Finally, our study's results indicate that students' group-project scores were directly influenced by students' self-reported frequency of logging into the e3-system and by students' self-reported frequency of using learner–instructor/learner–learner interactive functions. We further noted that these scores were indirectly influenced by students' number of postings on the discussion board. That is, increases in the regularity with which students log into the system, use learner–instructor/learner–learner interactive functions, and compose discussion-board postings can, directly or indirectly, enhance group-project scores. To facilitate this process, educators and particularly instructors can (1) diversify group members' demographic and educational backgrounds to increase their frequency of using these communicative functions and (2) encourage students to choose topics based on course materials, relevant resources listed in the CMS, and issues in the discussion board. Moreover, although students might not be familiar with one another in online courses, the heterogenous grouping strategy can grant them opportunities to communicate with one another through learner–instructor/learner–learner interactive functions (e.g., the e-mail function and the class-roster function), in turn promoting group-report performances.

Overall, our findings suggest that, in general, students' self-reported frequency of logging into the e3-system and of using interactive functions in the learner–instructor/learner–learner dimension may directly or indirectly influence students' online learning performance. The interactive functions provided in this study were sufficient for the participating students to fulfill specific learning activities in an online course. Therefore, we believe that, when developing and executing learning activities, educators should closely coordinate the interactive functions in the CMS (the e3-system in this study) with one another: the main benefits of such coordination would be students' completion of their learning activities and students' fulfillment of all the course requirements (Proske, Narciss, & Körndle, 2007; Sun & Hsu, 2013). Meanwhile, the students can better cultivate their online learning performance with the help of the CMS interactive functions provided.

7. Limitations and future research

One of the limitations of the study is that, rather than examine each individual interactive function of the provided CMS, we examined only the frequency with which students used four types of interactive functions. This limitation is perhaps reflective of the CMS's limited capability. For example, the e3-system could not provide the actual-use records regarding the frequency with which students logged into the discussion board or used the e-mail function, by which we could have further analyzed students' interactive behaviors in the online course. Thus, future studies can analyze detailed actual-use logs regarding the frequency of students' use of each interactive function and can, in this way, better clarify the relationships among students' perceptions of each interactive function's usefulness, the frequency of students' use of each interactive function, and students' online learning performance.

In summary, the present study has proposed and validated a two-tier mediation framework to represent the relationships between students' interactive behaviors (logs) and students' course performance in an online course. The study's large-scale sample—including undergraduate students enrolled in online courses from three universities over four semesters—further elucidates the effects of interactive functions on online learning performance, and enhances the possibility of designing effective online courses in the future.

Acknowledgements

This study was supported by the Ministry of Science and Technology in Taiwan under grant number MOST 103-2511-S-009-009-MY2. The authors would also like to thank the anonymous reviewers and the editor for their valuable comments and suggestions.

References

Allen, I. E., & Seaman, J. (2013). *Changing course: Ten years of tracking online education in the United States*. Babson Park, MA: Babson Survey Research Group.
Bannan-Ritland, B. (2002). Computer-mediated communication, elearning, and interactivity: a review of the research. *Quarterly Review of Distance Education, 3*(2), 161.
Bernard, R. M., Abrami, P. C., Borokhovski, E., Wade, C. A., Tamim, R. M., Surkes, M. A., et al. (2009). A meta-analysis of three types of interaction treatments in distance education. *Review of Educational Research, 79*(3), 1243–1289.
Cho, M. H., & Kim, B. J. (2013). Students' self-regulation for interaction with others in online learning environments. *The Internet and Higher Education, 17*, 69–75.
Chou, C. (2003). Interactivity and interactive functions in web-based learning systems: a technical framework for designers. *British Journal of Educational Technology, 34*(3), 265–279.
Chou, C., Peng, H. Y., & Chang, C. Y. (2010). The technical framework of interactive functions for course-management systems: students' perceptions, uses, and evaluations. *Computers & Education, 55*(3), 1004–1017.
Coldwell, J., Craig, A., Paterson, T., & Mustard, J. (2008). Online students: relationships between participation, demographics and academic performance. *Electronic Journal of e-Learning, 6*(1), 19–28.
Eom, S. B., Wen, H. J., & Ashill, N. (2006). The determinants of students' perceived learning outcomes and satisfaction in university online education: an empirical investigation. *Decision Sciences Journal of Innovative Education, 4*(2), 215–235.
Evans, C., & Sabry, K. (2003). Evaluation of the interactivity of web-based learning systems: principles and process. *Innovations in Education & Teaching International, 40*(1), 89.
Garner, J. K., & Bol, L. (2011, January). *The challenges of e-learning initiatives in supporting students with self-regulated learning and executive function difficulties*. Paper presented at the International Congress for School Effectiveness and Improvement (ICSEI), Limassol, Cyprus.
Garrison, D. R., & Cleveland-Innes, M. (2005). Facilitating cognitive presence in online learning: interaction is not enough. *American Journal of Distance Education, 19*(3), 133–148.
He, W. (2013). Examining students' online interaction in a live video streaming environment using data mining and text mining. *Computers in Human Behavior, 29*(1), 90–102.
Hillman, D. C. A., Willis, D. J., & Gunawardena, C. N. (1994). Learner-interface interaction in distance education: an extension of contemporary models and strategies for practitioners. *American Journal of Distance Education, 8*(2), 30–42.
Kang, M., & Im, T. (2013). Factors of learner–instructor interaction which predict perceived learning outcomes in online learning environment. *Journal of Computer Assisted Learning, 29*(3), 292–301.
Kaymak, Z. D., & Horzum, M. B. (2013). Relationship between online learning readiness and structure and interaction of online learning students. *Educational Sciences: Theory & Practice, 13*(3), 1792–1797.
Ke, F. (2013). Online interaction arrangements on quality of online interactions performed by diverse learners across disciplines. *The Internet and Higher Education, 16*, 14–22.
Ke, F., & Kwak, D. (2013). Online learning across ethnicity and age: a study on learning interaction participation, perception, and learning satisfaction. *Computers & Education, 61*, 43–51.
Kiousis, S. (2002). Interactivity: a concept explication. *New Media & Society, 4*(3), 355–383.
Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: a review of the research. *Computers in Human Behavior, 19*(3), 335–353.
Krull, J. L., & MacKinnon, D. P. (2001). Multilevel modeling of individual and group level mediated effects. *Multivariate Behavioral Research, 36*(2), 249–277.
Liaw, S. S., & Huang, H. M. (2013). Perceived satisfaction, perceived usefulness and interactive learning environments as predictors to self-regulation in e-learning environments. *Computers & Education, 60*(1), 14–24.
Lustria, M. L. A. (2007). Can interactivity make a difference? Effects of interactivity on the comprehension of and attitudes toward online health content. *Journal of the American Society for Information Science and Technology, 58*(6), 766–776.
Malikowski, S. R. (2008). Factors relted to breadth of use in course management systems. *The Internet and Higher Education, 11*(2), 81–86.
Moore, M. G. (1989). Editorial: three types of interaction. *American Journal of Distance Education, 3*(2), 1–7.
Muthén, B., & Muthén, L. (2010). *Mplus user's guide* (6th ed.). Los Angeles, CA: Muthén & Muthén.
Pascual-Miguel, F., Chaparro-Peláez, J., Hernández-García, Á., & Iglesias-Pradas, S. (2010). A comparative study on the influence between interaction and performance in postgraduate in-class and distance learning courses based on the analysis of LMS logs. In M. Lytras, P. Ordonez De Pablos, D. Avison, J. Sipior, Q. Jin, W. Leal, et al. (Eds.), *Technology enhanced learning: Quality of teaching and educational reform* (Vol. 73, pp. 308–315). Berlin, Heidelberg: Springer Berlin Heidelberg.
Proske, A., Narciss, S., & Körndle, H. (2007). Interactivity and learners' achievement in web-based learning. *Journal of Interactive Learning Research, 18*(4), 511–531.
Richardson, J. C., & Swan, K. (2003). Examing social presence in online courses in relation to students' perceived learning and satisfaction. *Journal of Asynchronous Learning Networks, 7*(1), 68–88.
Smith, F., Hardman, F., & Higgins, S. (2006). The impact of interactive whiteboards on teacher–pupil interaction in the National Literacy and Numeracy strategies. *British Educational Research Journal, 32*, 443–457.

So, H. J., & Brush, T. A. (2008). Student perceptions of collaborative learning, social presence and satisfaction in a blended learning environment: relationships and critical factors. *Computers & Education, 51*(1), 318–336.
Sobel, M. E. (1982). Asymptotic intervals for indirect effects in structural equations models. In S. Leinhart (Ed.), *Sociological methodology* (pp. 290–312). San Francisco: Jossey-Bass.
Song, L., & McNary, S. W. (2011). Understanding students' online interaction: analysis of discussion board postings. *Journal of Interactive Online Learning, 10*(1), 1–12.
Soo, K. S., & Bonk, C. J. (1998, June). *Interaction: What does it mean in online distance education?*. Paper presented at the Ed-Media and EdTelecom 98 conference, Freibourg, Germany.
Sun, J. N., & Hsu, Y. C. (2013). Effect of interactivity on learner perceptions in web-based instruction. *Computers in Human Behavior, 29*(1), 171–184.
Thorson, K. S., & Rodgers, S. (2006). Relationships between blogs as ewom and interactivity, perceived interactivity, and parasocial interaction. *Journal of Interactive Advertising, 6*(2), 5–44.
Tremayne, M. (2005). Lessons learned from experiments with interactivity on the web. *Journal of Interactive Advertising, 5*(2), 40–46.
Watson, S. (2013). Tentatively exploring the learning potentialities of postgraduate distance learners' interactions with other people in their life contexts. *Distance Education, 34*(2), 175–188.
Wei, H. C., & Chou, C. (2014, April). *The relationships among college students' online learning perception, readiness, course satisfaction, and their learning performance*. Paper presented at the 2014 American Educational Research Association (AERA) Annual Meeting, Philadelphia, PA.
West, R., Waddoups, G., & Graham, C. (2007). Understanding the experiences of instructors as they adopt a course management system. *Educational Technology Research & Development, 55*(1), 1–26.
Woo, Y., & Reeves, T. C. (2007). Meaningful interaction in web-based learning: a social constructivist interpretation. *The Internet and Higher Education, 10*(1), 15–25.