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Collab-Analyzer: An environment for conducting web-based collaborative learning activities and analyzing students' information-searching behaviors

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Researchers have found that students might get lost or feel frustrated while searching for information on the Internet to deal with complex problems without real-time guidance or supports. To address this issue, a web-based collaborative learning system, Collab-Analyzer, is proposed in this paper. It is not only equipped with a collaborative mechanism for helping group members solve problems on the web, but also facilitates teachers and researchers in analyzing students' collaborative information-searching behaviors and performance by providing eighteen quantitative indices. To examine the effectiveness of the proposed learning system, a total of 224 university students and 16 teachers participated in an experiment, in which a web-based problem-solving activity for a social studies course was conducted. The experimental results show that the teachers gave positive evaluations of Collab-Analyzer in terms of promoting students' web-based problem-solving ability and information searching skills. Moreover, the students showed high agreement with both the usefulness and ease of use of the system. The research findings also show that high interactive type students have more significant learning performance than moderate and low interactive students. Finally, implications and suggestions for how to accommodate the needs of students after adopting the proposed Collab-Analyzer system are given.

Introduction

With the popularity and development of computer networks, the World Wide Web has become an important source of acquiring information (Hwang, Kuo, Chen, & Ho, 2014; Kuo, Chen, & Hwang, 2014; Tsai & Tsai, 2003). Researchers have indicated that web-based information-searching performance is highly correlated with problem-solving competences (Eisenberg & Berkowitz, 1990; Kuo, Hwang, & Lee, 2012), which has been identified as an important and challenging issue in education (Hwang & Kuo, 2011). In a traditional problem-solving task, students usually need to go through several phases to complete the learning tasks, including "identifying the problem," "interpreting the problem mentally," "proposing solution strategies," "organizing knowledge related to the problem," "allocating resources for solving the problem," "checking progress toward the objective," and "evaluating the accuracy of the proposed solution," which engage them in higher order thinking (Davidson & Sternberg, 2003). In a web-based learning environment, teachers usually conduct learning activities that engage students in comprehending and answering a series of questions related to a specific issue via seeking, selecting, abstracting, and summarizing information on the web (Chu, Hwang, & Huang, 2010; Hsu, Hwang, Chuang, & Chang, 2012). Hwang and Kuo (2011) called such online issue-inquiring activities "web-based problem solving." They pointed out that students could gain a great deal in the activities by linking what they have learned from textbooks to real-world contexts if the target issue and the corresponding questions are well designed.

In the past few years, studies have reported the benefits of engaging students in issue- inquiring activities via searching for relevant information on the web ((Hsu, Hwang, Chuang, & Chang, 2012; Hwang, Tsai, Tsai, & Tseng, 2008; Kuo, Hwang, Chen, & Chen, 2012; Kuo, Hwang, & Lee, 2012; Panjaburee, Hwang, Triampo, & Shih, 2010). For example, several studies have shown that, with proper learning supports, such activities can benefit students by improving their high-order thinking as well as their cognitive structure (Hwang, Chen, Tsai, & Tsai, 2011; Tsai, Tsai, & Hwang, 2011).

On the other hand, researchers have indicated the difficulties encountered during the web-based problem-solving process for those students who do not have enough information-seeking, selection, abstracting or summarizing skills; in particular, elementary school students (Bilal, 2002; Kuo, Hwang, & Lee, 2012). Therefore, it has been emphasized that effective learning tools and strategies are needed to assist students to gain cognitive and meta-cognitive skills in web-based learning activities (Chen, 2008; Chen, 2010; Kay, 2011; Zamani & Shoghlabad, 2010). Cognitive skills refer to the ability of efficiently finding answers for a specific issue or question, while meta-cognitive skills refer to the ability of adapting the strategies for finding the answers. A number of studies (Amershi & Morris, 2008; Moraveji, Morris, Morris, Czerwinski, & Riche, 2011; Kuo, Hwang, & Lee, 2012; Mason & Watts, 2012; Morris, 2008; Morris & Horvitz, 2007; Morris, Paepcke, & Winograd, 2006) have further indicated that integrating collaborative learning strategies, in which students are able to share opinions, knowledge, or experiences thorough online discussions might be helpful to them in making reflections on the keywords and web pages adopted in web-based problem-solving activities (Mason & Watts, 2012; Mitnik, Recabarren, Nussbaum, & Soto, 2009). For example, in the study of Mason and Watts (2012), a series of collaborative problem-solving and information-sharing experiments were conducted. From the experimental results, they found that the students who explored and solved problems collaboratively showed better learning outcomes than those who faced the same learning tasks individually, since sharing information or ideas via network communications could help the students find good solutions more efficiently.

Unfortunately, some existing learning systems, such as one called Meta-Analyzer that provides a questioning interface and a search engine to engage students in searching for information to answer a series of questions related to a specified issue (Hwang et al., 2008), were not designed for conducting collaborative web-based problem-solving activities, not to mention providing the facilities of recording and analyzing the collaborative problem-solving behaviors and performance of students, which could help educators better understand students' interactive patterns in a collaborative learning activity. Such a collaborative learning record may play a role in leading educators to grasp how much effort is exerted by individual students in a group (Amershi & Morris, 2008; Moraveji et al., 2011; Morris, 2008; Morris & Horvitz, 2007; Morris et al., 2006).

To address this issue, this study attempted to develop a web-based collaborative problem-solving system called Collab-Analyzer. The system not only enables teachers and researchers to conduct web-based collaborative problem-solving activities by providing an online information searching function, but also facilitates analysis of students' learning behaviors and learning performance by recording their web-based problem-solving behaviors. In addition, the system is able to summarize the learning logs into 18 quantitative indicators, such as the maximum number of inputted keywords in a search trial, number of trials for searching for information in answering the question, and the total time the student spends on selecting the searched pages for browsing, to help teachers or researchers further analyze the students' learning performance.

To examine the effectiveness of the proposed learning system, a total of 224 undergraduates and 16 teachers recruited from three universities in Northern Taiwan were asked to trial the system to investigate the following research questions:

(1) How can the 18 indicators be used to represent the students' web-based problem-solving performance?
(2) What are students' perceptions of Collab-Analyzer in terms of usefulness and ease of use?
(3) Do teachers perceive Collab-Analyzer as a helpful tool for conducting and analyzing Web-based learning activities?

Development of a learning environment for analyzing Web-based collaborative problem-solving behaviors

To assist teachers or researchers in analyzing the Web-based problem-solving behaviors of students, a Web-based system, Collab-Analyzer, was developed. This system is not only a learning environment for conducting Web-based problem-solving activities, but also an assessment and learning management system for helping teachers and researchers analyze students' learning behaviors.

System structure

Figure 1 depicts the system structure of Collab-Analyzer, which comprises six components, that is, Search Agent, Web Response Content Analyzer, Web Bookmark Sharing Function, Information & Discussion Platform, Student Searching Behaviors Analyzer, and System Setting Functions. For example, assume that a group of students receive the following questions related to the issue "Falling birthrate problem":

(1) Please find out the birthrate in 1979 and 2012 in Taiwan.
(2) Currently, what is contributing to the falling birthrate problem in Taiwan?
(3) What industries can be affected by the low birthrate problem?
(4) If you were the President or Premier, what policy would you advocate to promote the birthrate?

To answer the questions, students can use the Search Agent, which is a metasearch engine that accesses the Internet resources by calling existing search engines to acquire information based on the requests of the students by entering keywords for a given question, to search for information by inputting keywords, such as "birthrate 1979." Once the search engines return the web pages that match the keywords, Web Response Content Analyzer is invoked to analyze the content of the web pages and adjust their format to match the display interface of Collab-Analyzer. Students are allowed to browse appropriate web pages that could be useful for answering the questions, and to add those pages to their personal bookmark list. Moreover, the bookmarks can be shared with other group members by activating the Web Bookmark Sharing Function, which not only enables the sharing of bookmarks, but also provides the Information & Discussion Platform for students to discuss the target question in a timely manner. In the above example, the students can share the keywords they used, the answers they found, and their bookmarked web pages with group members after trying to find appropriate web content for answering the questions. Via information sharing and discussions, more appropriate keywords or better answers could be found.

All of the web-based problem-solving behaviors, including determining keywords, selecting web pages to browse, abstracting web page content, submitting answers, adding or removing bookmarks to or from the list, and web-based discussions are recorded and analyzed by the Student Searching Behaviors Analyzer. Based on the raw records and the summarized quantitative indicators, teachers can evaluate individual and group learning performance. Moreover, Collab-Analyzer is not only a cloud-based learning tool for conducting online problem solving activity, but also an assessment and learning management system for helping teachers analyze students' learning behaviors. It provides teachers with more flexible functions in pedagogical design via System Setting Functions in the systems' teacher interface. The functions allow the teacher to set up any learning theme with four questions, to maintain student profiles and to organize the number of students in a group, and so forth. Once the teacher completes all of the settings for the learning activity, each team member can start working on the learning task and finish solving the problem collaboratively via web-based interaction.

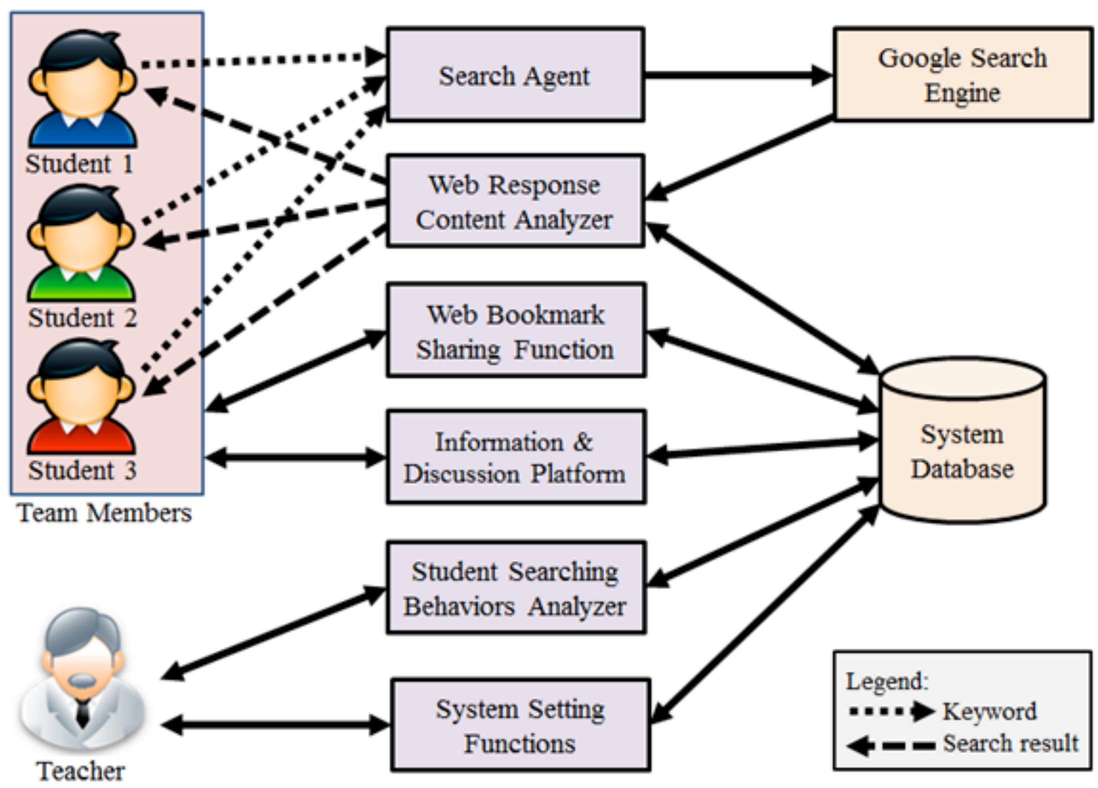

Figure 1. System structure of Collab-Analyzer.

System functions and operating procedure for students

When students log into the system, they are first required to choose a given learning topic (e.g., "Falling birthrate problem"). Figure 2 shows the student interface of Collab-Analyzer. It consists of three main functions: "Search for web information," "Bookmark," and "Logout of system." When using the "Search for web information" function, the students are required to answer a series of questions related to the learning topic via the following procedure:

(1) Read the question shown in the "Question" area (e.g., "Please find out the birthrate in 1979 and 2012 in Taiwan").
(2) Search for information by inputting proper keywords in the keyword area (e.g., "birthrate 1979").
(3) Obtain relevant web content from the searched results shown in the "Results" area. The students can browse the web pages by clicking on the corresponding links. Via browsing the web page content, they can collect information related to the given question.
(4) Discuss with group members. To facilitate group interaction and collaboration, the learning system displays the status of each group member, such as web-based or offline. Students can send messages to their team members no matter what their status is. For offline members, the messages will be displayed when they log in.
(5) Record important web pages in the bookmark list. If the students find some valuable web content for answering the questions, they can bookmark the web page in the private bookmark list and share it with their group members.
(6) Input answers to the "Answer" area and submit their answer.

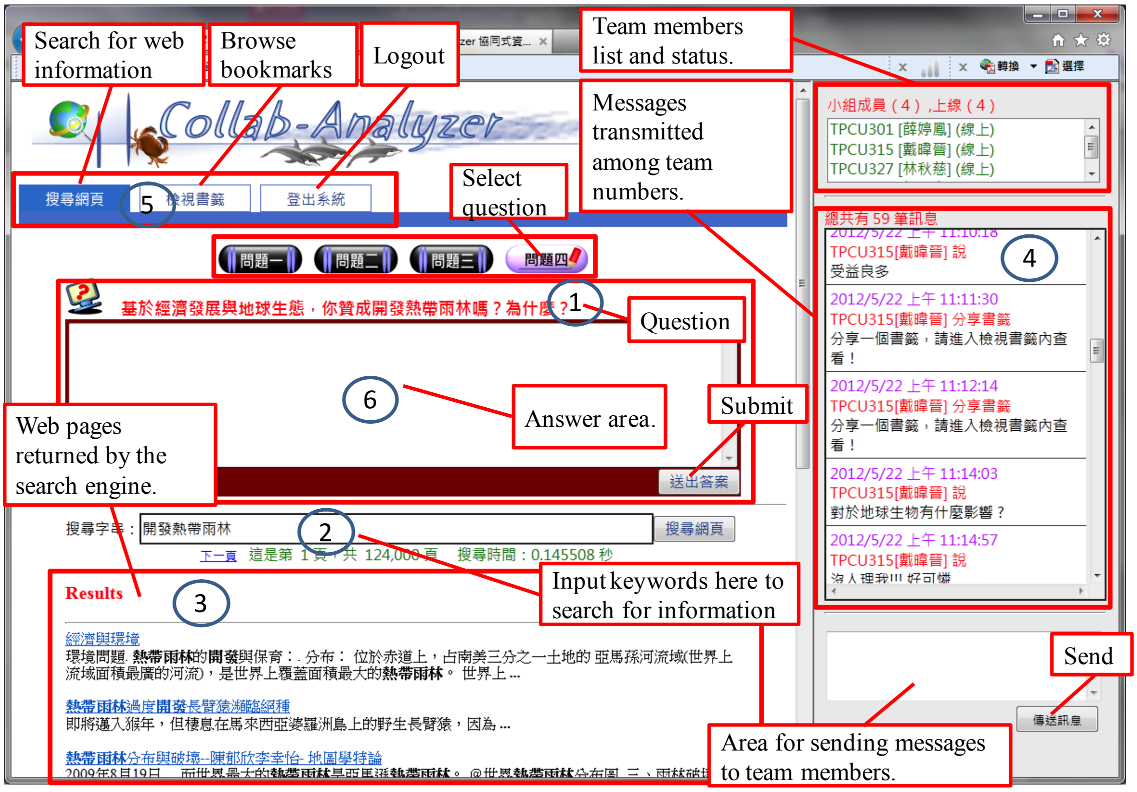

Figure 2. Student interface of Collab-Analyzer.

System functions for teachers

The teacher interface comprises six main functions: "Main page," "Student answer and portfolio for information-searching," "Topic management," "Student information manager," "Setting student team members," and "Logout of system." The "Topic management" function enables teachers to create new learning topics and the related questions for conducting web-based collaborative problem-solving activities. Moreover, teachers can create new accounts for students via the "Student information manager" and set up subgroups for collaborative learning via the "Setting student team members" function.

As shown in Figure 3, the "Student answer and portfolio for information-searching" function is useful to teachers for reviewing students' learning behaviors and answers to the questions. Teachers can evaluate the answers to each question submitted by the students. As mentioned above, Collab-Analyzer provides 18 quantitative indicators, consisting of 14 personal indicators (i.e., I_1 to I_{14}) and 4 collaborative indicators (i.e., CI_1 to CI_{14}), for analyzing the students' personal searching portfolios for answering questions:

- I_1: Maximum number of inputted keywords in a search trial.
- I_2: Number of trials for searching for information in answering the question.
- I_3: Total time (seconds) spent on selecting the searched pages for browsing.
- I_4: Number of different pages that are browsed but not adopted.
- I_5: Total time (seconds) spent on browsing the pages that are not adopted.
- I_6: Number of different pages that are adopted for answering the question.
- I_7: Total time (seconds) spent on browsing the adopted pages for the first time.
- I_8: Number of times visiting and revisiting the adopted pages.
- I_9: Total time (seconds) spent on browsing the adopted pages taking revisits into account.
- I_{10}: Number of pages that are browsed but not adopted taking revisits into account.

- I_{11}: Total time (seconds) for browsing the pages that are browsed but not adopted taking revisits into account.
- I_{12}: Number of pages that are marked and adopted for answering the question.
- I_{13}: Number of pages that are marked but not adopted for answering the question.
- I_{14}: Number of modifications made in answering the question.
- CI_1: Ratio of personal shared bookmarks, which is computed by (the number of personal shared bookmarks) / (the number of personal bookmarks), where the higher the ratio, the more personal bookmarks are shared. For example, assuming that a student has bookmarked 5 web pages and shared 3 of the web pages with his/her group members, the ratio is 0.6 (i.e., 3 divided by 5).
- CI_2: Ratio of personal shared bookmarks in the team, which is computed by (the number of personal shared bookmarks) / (the number of team members' shared bookmarks), where the higher the ratio, the more personal bookmarks are shared compared to the number of bookmarks for the whole team. Assuming that a student shares 3 web pages with his/her group members, and there are totally 15 web pages shared by the whole team during the learning activity, the ratio is 0.2 (i.e., 3 divided by 15).
- CI_3: Ratio of personal sent learning task-related messages, denoting the number of learning task-related messages sent compared with total personal messages sent by the student. The higher this ratio is, the more learning task-related messages are sent. Collab-Analyzer provides an interface to help teachers filter out the irrelevant messages before computing the value of this indicator. Assuming that a student has sent 20 messages to peers and 10 of the messages are relevant to the learning tasks (i.e., 10 learning task-related messages), the ratio is 0.5 (i.e., 10 divided by 20).
- CI_4: Ratio of personal sent learning task-related messages in the team, where the higher the ratio, the more learning task-related messages are sent compared with the number of messages sent by the whole team. Assuming that a student sent 10 learning task-related messages to the group members, and there are totally 40 learning task-related messages sent by the whole team during the learning activity, the ratio is 0.25 (i.e., 10 divided by 40).

In the teacher interface, teachers can refer to the logs to find out how individual students answered the questions, including the adopted keywords and web pages. Moreover, they can also browse the content of the adopted web pages as well as the answers submitted by the students to see how the students abstracted the web content for answering the questions. They can also refer to indicators to analyze individual students' ability to search for information, select web pages, abstract web content, and summarize the findings. For example, if the values of I_5 (e.g., Total time spent on browsing the pages that are not adopted) is greater than the average, it is reasonable to assume that the student might have had difficulty in selecting the appropriate web pages to browse.

Research design

Participants

In order to investigate the validity of the 18 quantitative indicators in Collab-Analyzer, a total of 224 undergraduates and 16 teachers were recruited from three universities of science and technology in Taiwan to participate in a collaborative web-based problem-solving activity. The students were 20 years old on average. All of the teachers had experience in using computers and networks in their classes.

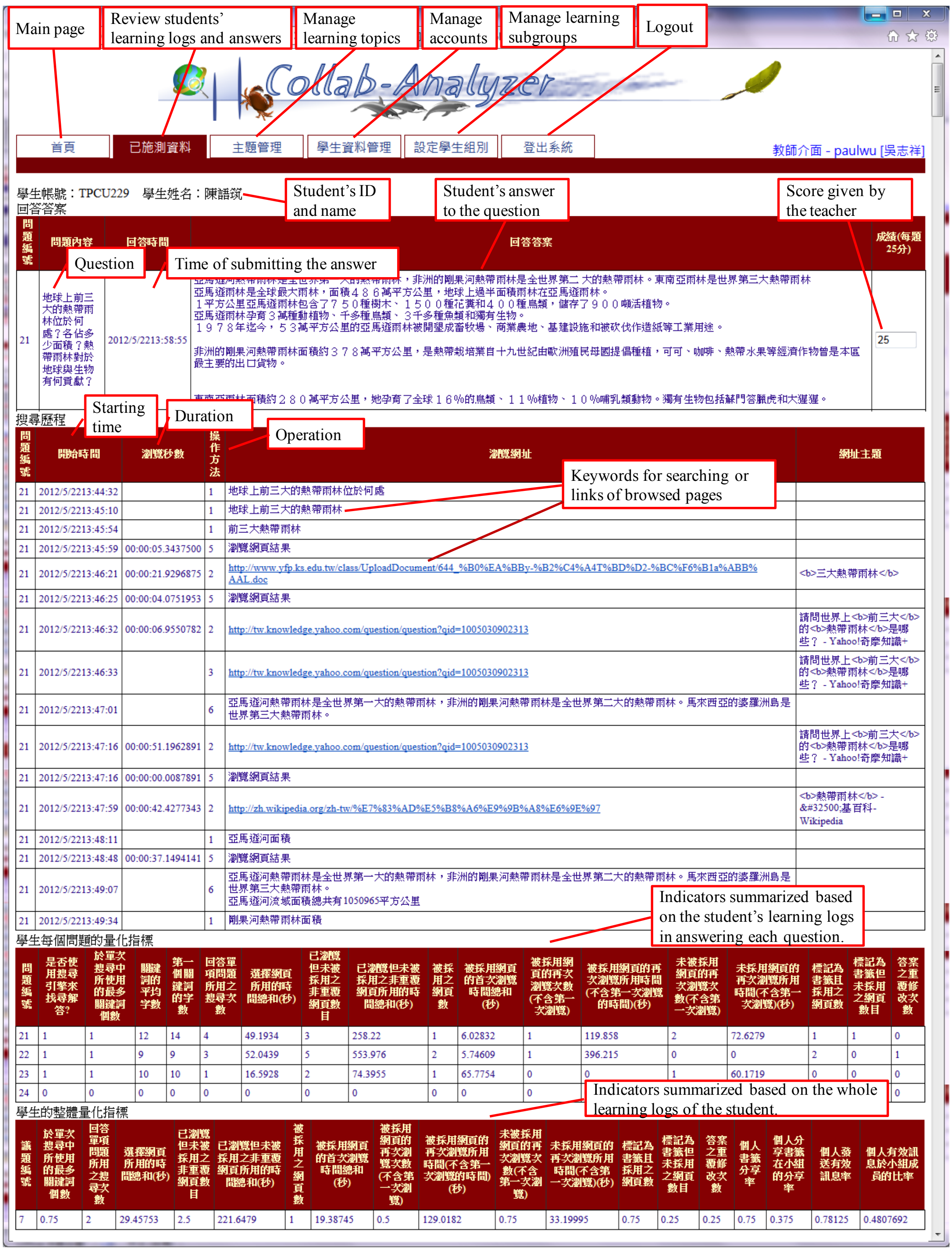

Figure 3. Teacher interface of Collab-Analyzer.

Experimental procedure

Figure 4 shows the experimental procedure for Collab-Analyzer. The students were divided into small groups consisting of 3 or 4 members based on a heterogeneous grouping method (Yiping, Philip, & John, 2000). The experiment was conducted with a one-shot case study design; that is, all of the participants were in the experimental group and were asked to fill in a questionnaire after the experiment. At the beginning, a 60-minute orientation was given and the students were allowed to practice using Collab-Analyzer. Each student was assigned to a computer in computer classrooms with network facilities. They were asked to work online together via Collab-Analyzer. All of the groups were required to find out the best answers to the following four questions related to the "Ageing problem" issue using Collab-Analyzer within 120 minutes:

(1) Find out the number of people over 70 years old in 1980 and 2010 in your country.
(2) Your country is going to be an ageing society. What factors lead to an ageing society? Why?
(3) What are the potential problems of ageing societies? Indicate the differences between an ageing society and a non-ageing one.
(4) If you were the policy makers in the government, what would you do to cope with this problem?

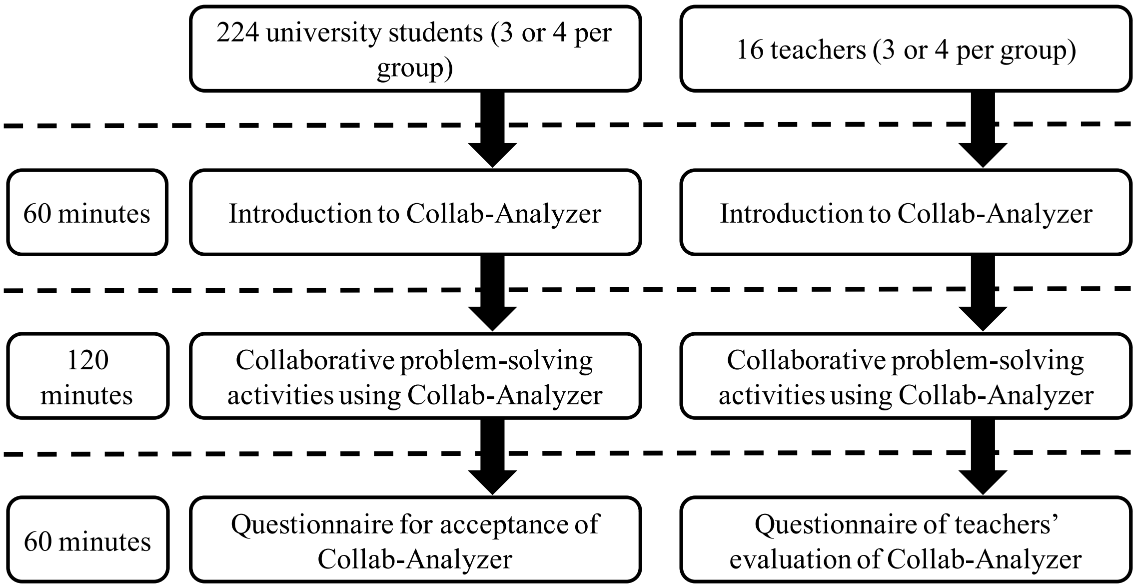

Figure 4. Experimental procedure for Collab-Analyzer.

The first three questions can be regarded as information-finding questions. The answers to these questions were assessed by teachers based on their correctness and completeness. To answer an information-finding question, students needed to search for information related to the question and submit answers by summarizing the information they searched for. Question 4 can be viewed as a divergent question. The answers to this question were evaluated by examining their clarity and originality (Kuo, Hwang, & Lee, 2012). A divergent question can be answered based on students' personal opinions as well as what they have learned from textbooks and web-based resources. During the learning process, the students were asked to discuss and share ideas for answering the questions with group members via the Information & Discussion Platform provided by Collab-Analyzer, which keeps a thorough record of both their private and collaborative learning logs.

After the participants completed the collaborative problem-solving activities, the system displayed an online questionnaire with nine items for perceived usefulness and six for perceived ease of use to collect opinions from the students. An online questionnaire with 9 items for evaluating the usefulness of Collab-Analyzer was used to collect opinions from the teachers.

Technology acceptance questionnaire

After the experiment, two questionnaires were administered to collect feedback from the participants, that is, the teachers and the students. The questionnaire for the teachers' evaluation of Collab-Analyzer was adapted from the study by Hwang et al. (2008), who have developed a web-based problem-solving system and have evaluated the system using a questionnaire for teachers. The questionnaire comprised 9 items with a 6-point Likert rating scheme ranging from 1 to 6. A higher rating represents a more positive evaluation of the system. The Cronbach's α of the scale is 0.806, indicating that the measure is reliable (Bryman & Cramer, 1997; Cohen, 1988). In this study, we did not adapt the questionnaires items beyond replacing the name of the tool.

The technology acceptance questionnaire items for students were adapted from those developed by Chu, Hwang, Tsai, and Tseng (2010). This questionnaire was constructed and validated by the researcher and two experts in test construction. It included 9 items for the *usefulness* dimension, numbered 1–9, and 6 items for the *ease of use* dimension, numbered 10–15, with a 6-point Likert rating mechanism. The Cronbach's α values of the two dimensions are 0.946 and 0.890 respectively, showing the high internal consistency and reliability of the scale (Bryman & Cramer, 1997; Cohen, 1988).

Results

Analysis of the indicators of Collab-Analyzer

Table 1 shows the means and standard deviation values of the descriptive statistics of the 18 quantitative indicators collected from the 224 university students, which facilitate teachers' deep understanding of the students' learning status and give real-time feedback to allow the teachers to adjust their teaching strategies according to individual student needs.

To investigate the relationships among these indicators as well as to examine if they conceptually represent the students' web-based problem-solving behaviors, the factor analysis method proposed by Ford, Miller, and Moss (2001, 2002) was employed. As the indicators included various types of web-based behaviors (e.g., number of browsed pages and total time spent browsing the pages), Z scores were used to standardize their values.

Table 1
Descriptive statistics of the indicators with n = 224

	Mean	SD
I_1: Maximum number of inputted keywords in a search trial.	3.17	2.54
I_2: Number of trials for searching for information in answering the question.	3.93	2.41
I_3: Total time (seconds) spent on selecting the searched pages for browsing.	142.16	187.87
I_4: Number of different pages that are browsed but not adopted.	3.31	4.18
I_5: Total time (seconds) spent on browsing the pages that are not adopted.	259.27	276.43
I_6: Number of different pages that are adopted for answering the question.	1.75	1.27
I_7: Total time (seconds) spent on browsing the adopted pages for the first time.	183.51	199.75
I_8: Number of times visiting and revisiting the adopted pages.	2.00	2.67
I_9: Total time (seconds) spent on browsing the adopted pages taking revisits into account.	179.95	239.85
I_{10}: Number of pages that are browsed but not adopted taking revisits into account.	3.18	4.10
I_{11}: Total time (seconds) for browsing the pages that are browsed but not adopted taking revisits into account.	127.73	165.37
I_{12}: Number of pages that are marked and adopted for answering the question.	2.17	2.65
I_{13}: Number of pages that are marked but not adopted for answering the question.	2.39	3.09
I_{14}: Number of modifications made in answering the answer.	0.16	0.44
CI_1: Ratio of personal shared bookmarks.	0.59	0.36
CI_2: Ratio of personal shared bookmarks in the team.	0.26	0.20
CI_3: Number of personal sent messages.	0.61	0.30
CI_4: Ratio of personal sent messages in the team.	0.26	0.20

Table 2 presents the analysis results. Four factors were obtained from the indicators, that is, "Relevant information-selecting competence," "Question-answering competence," "Relevant information-sharing ability," and "Keyword-adopting ability." The eigenvalue of each factor is larger than 1.00 with a variance of 58.88% explained. According to the literature, only those indicators with a load larger than 0.4 should be retained in a factor (Hair, Black, Babin, & Anderson, 2009); therefore, one of the indicators (I_{14}) was removed. Thus, only 17 quantitative indicators remained. The internal reliability indexes (α coefficients) of factors 1, 2, 3, and 4 were 0.840, 0.759, 0.813, and 0.615 respectively; furthermore, that of the entire item set was 0.683, suggesting that the derived factors were reliable for representing the web-based problem-solving behaviors of the students.

Table 2
Rotated factor loadings and Cronbach's α values for the four factors (subscales) of quantitative indicators with n = 224

Quantitative indicators	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1: Relevant information-selecting competence α = 0.84				
I_{10}: Number of pages that are browsed but not adopted taking revisits into account.	0.864			
I_4: Number of different pages that are browsed but not adopted.	0.823			
I_{11}: Total time (seconds) for browsing the pages that are browsed but not adopted taking revisits into account.	0.799			
I_3: Total time (seconds) spent on selecting the searched pages for browsing.	0.780			
I_5: Total time (seconds) spent on browsing the pages that are not adopted.	0.598			
I_{13}: Number of pages that are marked but not adopted for answering the question.	0.563			
Factor 2: Question-answering competence α = 0.76				
I_8: Number of times visiting and revisiting the adopted pages.		0.891		
I_6: Number of different pages that are adopted for answering the question.		0.770		
I_{12}: Number of pages that are marked and adopted for answering the question.		0.744		
I_9: Total time (seconds) spent on browsing the adopted pages taking revisits into account.		0.677		
I_7: Total time (seconds) spent on browsing the adopted pages for the first time.		0.445		
Factor 3: Relevant information-sharing ability α = 0.81				
CI_1: Ratio of personal shared bookmarks.			0.824	
CI_3: Ratio of personal sent learning task-related messages.			0.814	
CI_2: Ratio of personal shared bookmarks in the team.			0.774	
CI_4: Ratio of personal sent messages in the team.			0.764	
Factor 4: Keyword-adopting ability α = 0.62				
I_2: Number of search attempts for answering the question.				0.814
I_1: Maximum number of keywords used in a search operation.				0.722
Eigenvalue	3.650	2.737	2.596	1.616
% of variance	20.280	15.203	14.420	8.977

Overall α = 0.68, total variance explained is 58.88%.

The results of further analysis of the correlation between the four factors and the students' problem-solving task scores are shown in Table 3, indicating that the four factors related to the students' collective searching behaviors are significantly correlated ($p < 0.01$). For example, the students' question-answering performance is highly related to their relevant information-selecting performance. Meanwhile, the analysis results show that the students' problem-solving task scores are positively related to the values for the four factors ($p < 0.01$). Such findings further confirm the validity of the 17 indicators and the four factors for representing the students' Web-based collaborative problem-solving performance.

Table 3
Inter-correlation matrix of the four factors with n = 224

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1: Relevant information-selecting competence	--			
Factor 2: Question-answering competence	0.37^{**}	--		
Factor 3: Relevant information-sharing ability	0.25^{**}	0.25^{**}	--	
Factor 4: Keyword-adopting ability	0.17^{**}	0.20^{**}	0.46^{**}	--
Total score for the four questions	0.16^{*}	0.17^{**}	0.22^{**}	0.24^{**}

*p<.05; **p<.01

Analysis of acceptance of Collab-Analyzer

The questionnaire of acceptance is divided into two subscales, *usefulness* and *ease of use*. A total of 224 university students took part in the experiment and filled in the questionnaire in the post-test stage. The higher the mean score, the greater the degree of acceptance. The mean score (mean = 5.11) and standard deviation (SD = 0.94) of the overall scale shows that the students were highly accepting of Collab-Analyzer (with a high mean value) and had consistent perceptions of it (with a small SD value). The analysis of the two subscales, *usefulness* and *ease of use*, is described as follows.

The subscale of the *usefulness* of Collab-Analyzer is related to the extent to which a user believes that using the technology to complete the present work is useful, and whether the technology would be useful in future presentations. The higher the score, the greater the usefulness. As shown in Table 4, the overall mean score of usefulness reaches 5.10, suggesting that the students believe Collab-Analyzer is useful in the Sociology course, especially in terms of items 1, 6, 7, and 9.

Item 1, which refers to the relationship between the learning content and Collab-Analyzer, shows a high mean score (i.e., 5.16), indicating that the students believed that they could obtain a lot of data by searching for information on the Internet. Item 5 shows a mean score of 5.09, indicating that the students believed that Collab-Analyzer was helpful to them in promoting their information-searching and problem-solving performance. Item 9 had a mean score of 5.17, indicating that the students believed that the system could lead them to better understand the learning content. However, item 3 had a mean score of 4.93, which is less than that of the other items, suggesting that some of the students thought they would be interrupted by communicative messages sent from other members when they were trying to concentrate on the learning content.

As for the items relating to collaborative context, item 6 and item 7 had high mean scores of 5.11 and 5.20, indicating that the students were confident with Collab-Analyzer's Information & Discussion Platform in enhancing their deeper understanding of knowledge via its interactive mechanism with peers. Also, the Web Bookmark Sharing Function provides group members with more chances to refer to others' findings and learn how to think when searching for information on the Internet.

Table 4
Analysis of each item of the usefulness of Collab-Analyzer

Items	N	Mean	SD
1. I believe the learning content could become more plentiful when using the Collab-Analyzer system.	224	5.16	0.85
2. Using Collab-Analyzer could help me solve problems.	224	5.08	0.91
3. Using Collab-Analyzer could concentrate my attention more on the learning content than when using other searching systems.	224	4.93	1.05
4. Using Collab-Analyzer could help me deeply understand the learning content.	224	5.04	0.94
5. Using Collab-Analyzer could improve my information searching and problem-solving abilities.	224	5.09	0.94
6. The discussion platform of Collab-Analyzer could help me share information with group members, which increases my thinking ability.	224	5.11	0.99
7. The Web Bookmark Sharing Function of Collab-Analyzer could promote my information-searching competence.	224	5.20	0.90
8. I believe that using Collab-Analyzer could promote my learning achievement more than using other computer-assisted learning systems.	224	5.08	0.90
9. Overall, I think Collab-Analyzer could facilitate my understanding of the learning contents.	224	5.17	0.82
Overall questionnaire	224	5.10	0.91

The subscale *ease of use* refers to the extent to which one believes using the technology will be free of cognitive effort. The higher the score, the greater the ease of use. As shown in Table 5, the overall mean score of ease of use reaches 5.12, suggesting that the students believe Collab-Analyzer is easy to manipulate in the learning activity, especially for items 10, 11, and 15.

Table 5
Analysis of each item of ease of use of Collab-Analyzer

Items	N	Mean	SD
10. I think it is easy for me to manipulate Collab-Analyzer.	224	5.17	0.97
11. I didn't spend much time and effort to learn Collab-Analyzer.	224	5.09	1.03
12. I think it is easy for me to search for information using Collab-Analyzer.	224	4.98	1.03
13. I think it is easy for me to discuss with members using the discussion platform in Collab-Analyzer.	224	5.07	0.97
14. I think it is easy for me to share my web bookmarks with group members by using the bookmark sharing function of Collab-Analyzer.	224	5.26	0.86
15. Overall, I think it is easy for me to use Collab-Analyzer thoroughly.	224	5.15	0.99
Overall questionnaire	224	5.12	0.98

These three items, which refer to whether the students spent much time manipulating the system the first time they used it, all had high mean scores, indicating that it was easy for students to learn the functions of Collab-Analyzer in a short time. However, item 12 shows a mean score of 4.98, which is less than the score for the other items. This could be due to the limitation enforced by Collab-Analyzer that students can only open one browsing window at a time (i.e., they need to close the currently opened page before trying to browse a new web page), so that the system can correctly detect the operations performed by the students on individual windows. Such a limitation could be inconvenient to them when they try to compare the differences between the searched web pages.

As for the items relating to collaborative context, item 13 and item 14 have mean scores of 5.07 and 5.26 respectively, indicating that Collab-Analyzer's discussion platform function made it easy for students to interact with peers. Also, the bookmark sharing function means it was easy for group members to refer to others' findings and learn how to think when searching for information on the Internet.

Analysis of teachers' evaluation of Collab-Analyzer

Teachers' points of view provide substantial feedback on the usefulness of a new learning system. Sixteen teachers from three universities were invited to experience Collab-Analyzer by playing the roles of both the students and the teachers. That is, they were asked to answer the questions via the student interface of Collob-Analyzer first; following that, they were allowed to browse the learning logs via the teacher interface before answering the questionnaire. The overall mean of the questionnaire reached a high score (mean = 5.14), indicating that most of the teachers had highly positive responses to the Collab-Analyzer system, as shown in Table 6. In particular, several survey questions with high scores, including item 4 (mean = 5.25) and item 5 (mean = 5.19), show that the teachers strongly agreed that the students' learning logs recorded in Collab-Analyzer can help them understand the students' learning status, and thus allow them to adjust the pedagogical design accordingly. The other item with high agreement is item 8, indicating that most of the teachers would like to keep employing Collab-Analyzer in other curricula.

Table 6
Questionnaire of teachers' evaluation of Collab-Analyzer

Items	N	Mean	SD
1. Collab-Analyzer can help teachers better understand students' learning status.	16	5.00	0.73
2. It is easy to manipulate Collab-Analyzer.	16	5.13	0.81
3. Collab-Analyzer can facilitate students' understanding of problems.	16	5.25	0.45
4. Collab-Analyzer provides valuable learning logs of students to teachers in its pedagogical design.	16	5.25	0.58
5. Collab-Analyzer provides 18 quantitative indicators to teachers for further investigation of students' insufficient ability.	16	5.19	0.54
6. Collab-Analyzer can improve students' problem-solving ability.	16	5.00	0.73
7. Collab-Analyzer can improve students' web-based information-searching ability.	16	5.06	0.93
8. I am willing to employ Collab-Analyzer in other curricula.	16	5.25	0.58
9. I would recommend Collab-Analyzer to other teachers.	16	5.13	0.50
Overall result	16	5.14	0.65

Analysis and comparison of different interactive types of students

There were four indicators (i.e., CI_1 to CI_4 in the "relevant information-sharing ability" factor), which could be considered as a "social learning status" that group members presented in a group. Thus, teachers could understand the difference in learning logs among students with different interactive types. Interactive types can be classified as high, moderate, and low based on the mean score of the individual interactive indicators, CI_1, CI_2, CI_3, and CI_4. The maximum score of each indicator was 1; consequently, the total score of the four interactive indicators was 4 at most. The cut-off scores for high and low interactive students were based on the students' total score of the four interactive indicators. Those with an average in the top 27 percentile (mean $\geq$ 2.18) were classified as high interactive group and those whose average was in the lower 27 percentile (mean $\leq$ 1.62) were identified as low interactive group based on the statistical approach proposed and adopted by previous studies (Dukmak, 2009; Rastogi, 1991). The remaining students were grouped as moderate interactive.

To further examine the learning performance of different interactive types of students, individual students' problem-solving performance was evaluated to present which interactive type had higher learning achievement. Analysis of variance (ANOVA) was employed to analyze the post-test of problem solving competence (dependent variable) among the three different interactive types of students (independent variable). Table 7 shows that the high interactive type students outperformed the other two interactive types ($F(2, 221) = 15.59$, $p < 0.001$). This suggests that students could construct knowledge and deepen their understanding to solve given problems via a highly interactive process among group members.

Table 7
ANOVA of students' problem-solving scores among different interactive types

Interactive Type	N	Mean	SD	F	Post hoc (Tukey HSD)
(1) High	75	81.77	12.09		
(2) Moderate	74	77.12	13.16	15.59^{***}	(1) > (2) > (3)
(3) Low	75	70.11	13.36		

$^{***}p < .001$

To evaluate the difference in individual indicators among different interactive types of participants, ANOVA was performed. Table 8 shows the analysis results of individual indicators for different interactive types of participants, showing that for some of the indicators (I_2, I_6, I_7, I_8, I_9, I_{12}, and I_{13}) there were significant differences among the three groups. For keyword-adopting competence, the indicator I_2 shows that high and moderate interactive students would use more search attempts for answering the question than low interactive students. For question-answering competence, the indicators I_6, I_7, I_8, I_9, and I_{12} indicate that high and moderate interactive students have better question-answering competence as seen by their visiting and revisiting, adopting different pages for answering the question, and spending time browsing the bookmarked and adopted pages than the low interactive students. That is, students who have high- and moderate-type interaction are willing to take time to seek and identify information relating to the given question. For relevant information-selecting competence, however, most indicators present no significant difference among the three interactive types of student except for the indicator I_{13}. This means that no matter how interactive students are, no significant difference existed in the time they spend selecting relevant information for the given question.

To sum up, the results show that students of high interactive type were also equipped with higher relevant information-sharing competence than those of moderate and low interactive types. That is, those with high relevant information-sharing competence could have better keyword-adopting and question-answering abilities than other types of students and be willing to share what they have found during the learning process.

Discussion and conclusion

Researchers have emphasized the importance of engaging students in learning to solve problems via collecting information from the Internet, organizing knowledge, and reasoning from the Internet resource in school settings (Bilal, 2002; Goldstein & Levin, 1987; Mayer, 1992). Moreover, several previous studies have also reported the difficulty of enhancing students' high-order thinking performance via merely observing and imitating teachers' cognitive skills in traditional learning contexts. In other words, a more effective learning approach is needed to help students acquire both cognitive and meta-cognitive skills (Chen, 2008; Chen, 2010; Kay, 2011; Zamani & Shoghlabad, 2010), which has encouraged the development of web-based problem-solving environments and activities. That is, the individual student is able to reflect on what keywords and web pages are being used by group members through online discussions; thus, helping them to improve cognitive and meta-cognitive skills during the collaborative learning process.

Table 8
ANOVA of individual indicators among different interactive types of participants

Indicator	Interactive Type	N	Mean	SD	F	Post hoc (Tukey HSD)
I_1	(1) High	75	3.95	1.41	0.42	
	(2) Moderate	74	4.19	1.69		
	(3) Low	75	4.04	1.62		
I_2	(1) High	75	11.85	5.93	6.86^{**}	(1) > (3) (2) > (3)
	(2) Moderate	74	11.53	6.32		
	(3) Low	75	8.64	5.22		
I_3	(1) High	75	379.61	247.89	1.28	
	(2) Moderate	74	422.57	257.94		
	(3) Low	75	456.27	362.80		
I_4	(1) High	75	14.23	9.81	2.42	
	(2) Moderate	74	15.41	10.58		
	(3) Low	75	11.93	8.94		
I_5	(1) High	75	782.36	578.76	0.19	
	(2) Moderate	74	825.36	559.46		
	(3) Low	75	770.32	567.48		
I_6	(1) High	75	5.36	1.94	43.48^{***}	(1) > (2) > (3)
	(2) Moderate	74	4.43	1.91		
	(3) Low	75	2.71	1.41		
I_7	(1) High	75	728.60	289.16	258.16^{***}	(1) > (2) > (3)
	(2) Moderate	74	301.82	82.02		
	(3) Low	75	85.48	51.36		
I_8	(1) High	75	5.07	4.10	6.95^{**}	(2) > (3) (1) > (3)
	(2) Moderate	74	5.19	4.38		
	(3) Low	75	3.05	3.25		
I_9	(1) High	75	491.41	505.52	11.75^{***}	(1) > (2) > (3)
	(2) Moderate	74	396.85	360.33		
	(3) Low	75	192.77	245.92		
I_{10}	(1) High	75	5.69	4.58	0.99	
	(2) Moderate	74	6.54	5.45		
	(3) Low	75	7.04	7.34		
I_{11}	(1) High	75	181.00	169.73	1.99	
	(2) Moderate	74	240.77	269.59		
	(3) Low	75	254.81	268.22		
I_{12}	(1) High	75	2.25	1.86	7.03^{**}	(1) > (2) > (3)
	(2) Moderate	74	1.73	1.65		
	(3) Low	75	1.28	1.19		
I_{13}	(1) High	75	0.88	1.38	4.23^{*}	(3) > (2) > (1)
	(2) Moderate	74	1.07	1.06		
	(3) Low	75	1.56	1.87		
I_{14}	(1) High	75	0.65	1.14	0.59	
	(2) Moderate	74	0.55	1.00		
	(3) Low	75	0.48	0.78		

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

On the other hand, previous studies have indicated that learning in a collaborative problem-solving context could be more beneficial to students than learning in an individual problem-solving context (Mason & Watts, 2012). Moreover, a collaborative information-searching method could increase the diversity of searching strategies adopted by students and the correctness of the search results (Morris, 2008). Therefore, this study attempts to propose a web-based collaborative problem-solving system, Collab-Analyzer, which is not only equipped with a collaborative mechanism for group members to solve problems, but also facilitates teachers in analyzing students' collaborative learning logs based on 18 quantitative indices. Four major abilities of students, classified as keyword-adopting ability, relevant information-selecting competence, question-answering competence, and relevant information-sharing ability, can be collected in 18 quantitative indices of Collab-Analyzer.

To examine the effectiveness of the proposed learning system, 224 university students and 16 teachers participated in the experiment. The research findings show that the teachers had positive perceptions of Collab-Analyzer in terms of promoting students' web-based problem-solving ability and information searching ability because the students were able to improve their quality problem-solving strategies via the discussion platform (Mason & Watts, 2012; Yazici, 2005). This finding is consistent with previous research, implying that students can learn more diverse strategies in searching for resources on the Internet (Amershi & Morris, 2008; Morris, 2008).

As for the questionnaire of acceptance of Collab-Analyzer, the students expressed high agreement on both scales of *usefulness* and *ease of use*. The overall mean score of usefulness reaches 5.10, implying that the students believe Collab-Analyzer could be useful in the course. Among the items of the subscale, the students think that because Collab-Analyzer is equipped with a discussion platform function, it could enhance their deeper understanding of knowledge via its interactive mechanism with peers. Also, the Web Bookmark Sharing Function provides group members with more chances to refer to others' findings and learn how to think when searching for information on the Internet. Moreover, the overall mean score of *ease of use* was high, suggesting that the students thought Collab-Analyzer was easy to use in the learning activity. Collab-Analyzer is equipped with an Information & Discussion Platform and the students thought this made it easy for them to interact with their peers. Also, the Web Bookmark Sharing Function made it easy for group members to refer to others' findings and learn how to think when searching for information on the Internet.

We have also demonstrated how Collab-Analyzer can be used to examine the difference in the learning performance of the different interactive types of students, with the results showing that high interactive type students have more significant learning performance than less interactive students. This indicates that the students could construct relevant information and deepen their understanding to solve given problems via a highly interactive process among group members. Moreover, to evaluate the difference in individual indicators among the different interactive types of participants, the results show that students of high interactive type were also equipped with higher relevant information-sharing competence than those of moderate and low interactive types. That is, those with high relevant information-sharing competence could have had better keyword-adopting and question-answering abilities than other types of students. Accordingly, they were willing to share what strategies they used and what they found to solve problems during the learning process via the information-sharing mechanism.

The real-time Information & Discussion Platform in Collab-Analyzer can, at present, only transmit messages in the form of text. In the future, the discussion platform will be developed to allow for more diverse forms of messages, such as pictures, drawings, and voice exchange. These forms of message exchange would not only improve the quality of communicative messages for students, but also provide teachers with more evidence to deeply understand students' learning status. In addition, more experiments need to be conducted to understand more about the views of the students and teachers on Collab-Analyzer. We plan to adopt field research methods in future experiments, such as focus groups, field observations and interviews. It is expected that we can find out more about why the students and teachers hold the views they do, and their views at the start of the experiment and after they have become competent users of the Collab-Analyzer. Also, it would be useful to ask them for suggestions about any improvements would like to see in the system. We also anticipate conducting more experiments on different courses with different levels of subjects, such as the Social Studies course in elementary schools, the Social Science course in vocational high schools, and the Natural Science courses in high schools, to further investigate the performance of the proposed approach.

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