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Scaffolding Cyber-Enabled Collaborative Learning in Engineering Courses and Its Impacts of on Students' Learning

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Abstract

More engineering faculty and students have realized the importance of the collaborative learning and utilized it to facilitate engineering learning. However, students may not carry out collaborative learning effectively without some instructional support because they may have litter knowledge on how to effectively exchange ideas and share learning, particularly for those who have lower achieving and may benefit more through interactions with their learning peers. Besides, students may have difficulty to find a common time slot suitable for collaborative leaning in a traditional face-to-face manner. This paper is to introduce findings from available cognitive research on supporting effective collaborative learning and present a new instructional framework for scaffolding collaborative learning for engineering students through cyber-enabled online discussion. Within this framework, students are assigned with a shared learning task and required to co-construct their understanding of the course-related learning concepts and co-solve the assigned learning problems with their peers through online discussion. The scaffolding from both social and cognitive perspectives is presented to students to provide a structure of effective collaborative knowledge construction by specifying, sequencing, and assigning roles or activities to students, and providing prompts for them to ask thought-provoking questions. The implementation outcomes indicated that the presented instructional framework provides a platform for students to engage in intellectual exchange with their team peers for co-constructing their knowledge and impacting their understandings of engineering concepts and learning dispositions. The limitations of current findings and suggestions for future implementation are discussed.

Introduction

Collaborative learning can provide unique social interaction opportunities for students to exchange ideas, offer explanations, share multiple perspectives, clarify understandings, repair misunderstanding, and engage in other types of high-level discourse with their peers [1,2], which are usually not available from individual learning. This is because those social interaction processes could provoke internal cognitive processes to externalize learnerss knowledge, monitor each other's learning, negotiate meaning together, and discuss alternative means [3,4], as well as metacognitive processes which are responsible for monitoring, regulating, and evaluating a learners' own learning and thinking [4,5].

More engineering faculty and students have realized the importance of the collaborative learning and utilized it in their engineering teaching and learning. For examples, Koehn et al. had conducted a survey on attitude and perception on the collaborative learning of civil/construction engineering students and found that students and future employers were in favor of collaborative learning [6]. To examine the perception and attitude of students in STEM at a typical HBCU towards collaborative learning through online discussion, the authors of this paper recently have conducted a survey with 251 students majoring in engineering, chemistry, mathematics, physics, computer science, biology at the authors' institution. The survey results revealed that the majority of students believes that participating in collaborative learning and helping others' learning could help themselves better organize and understand what they have leant. The difficulty in scheduling time for a face-to-face meeting is also reported by students. The majority of students think the instructor should provide strategies for guiding students to participate in the on-line discussion to achieve better team learning outcomes. They also more likely tend to believe that if the average grade of the team members is accounted in the final grade of each individual student, it could more likely promote good collaboration for learning.

In the STEM teaching practice, Soundarajan has proposed and implemented Peer Instruction into on-line collaborative learning in the STEM courses, in which the collaborative learning assignments are key parts of those courses and included two parts: the background part and the main part of the assignments [7]. In their implementation, students were assigned into teams with a specific problem in according to their answers to the background part assignment. In the teamwork, students took different roles in different tasks. Students' grades were determined by both their individual and group work. Bohorquez and Toft-Nielsen employed collaborative learning in a problem-oriented medical electronics laboratory to develop biomedical engineering students' expertise and self-efficacy [8]. In their collaborative learning, students were assigned with specific course-related projects and required to work collaboratively with their team members. They were also required to co-tutoring each other and switch role assignments in different projects. In the project evaluation, both personal accountability and team performance were considered. In their open feedback, students claimed the effectiveness of problem-oriented method and collaborative learning. Dong and Guo have implemented Collaborative Project-based Learning Model (CPBL) in their undergraduate computer-networking curriculum [9]. In the CPBL model, students were required to think collectively to complete the assigned project. The results of CPBL implementation demonstrate improvement in students' acquisition of key concepts and hands-on skills. Based on the lessons learnt from the implementation of CPBL, Dong and Guo suggested that effective collaboration would not occur naturally and the instruction support is needed to help students to engage in collaborative learning through identifying their roles, allotting team resources, maintaining effective communication, and evaluating project progress. Li et al. had implemented the cyber-enabled collaborative learning for computer science students [10]. Their efforts mainly focus on students' perception and satisfaction on participating in such learning. They did not mention any support for collaborative learning.

In general, the authors of aforementioned and other similar implementations of collaborative learning in engineering courses mostly focused on providing course requirements and assignments as means to engage students in collaborative learning. Even though some of them realized the importance of providing the support for students' collaborative learning, those authors did not offer a detailed systematic support framework to guide students' collaborative learning. Without some form of explicit instruction or guide, collaborative learning among students may not occur effectively. This is because students may not have the skills or knowledge for conducting effective collaborative learning. Besides, students may have difficulty to find a time slot suitable for everyone to do traditional face-to-face collaborative leaning. In available research literature, however, findings on how to effectively supporting students' collaborative leaning have been available from cognitive science research development. Those findings could provide the theoretical and methodological basis for engineering faculty and students to facilitate the effective collaborative learning.

The goal of this paper is to present the scaffolding based on the cognitive research findings for supporting cyber-enabled collaborative learning of African American students in their engineering learning. The cyber-enabled collaborative learning in this context means that students work in a team on course assignments as shared learning tasks through online discussion with their peers to co-construct of their understanding of the course related learning concepts and co-solve their learning problem. In order to promote effective intellectual exchange among student team members to achieve optimal learning outcomes, the scaffolding is presented to students in form of question prompts to provide a structure of collaborative knowledge construction from both social and cognitive perspectives, which are intended to provide guidelines for students to develop thought-provoking questions and direct their cognitive process respectively.

Theoretical and Methodological Background

To help students to carry out effective collaborative learning, cognitive science researchers have developed and studied various instructional support, which can guide the effective group interaction, so that students can engage in cognitive, metacognitive, and socio-cognitive processes at a high-level to achieve optimal learning outcomes [24]. The support is usually provided in the form of the script that "specifies, sequences, and assigns roles or activities to collaborative learners" [5]. Such a script involves "a sequence of actions where each actor has a specific part to play and pre-specified actions to take, which is somewhat like the script of a play where action and stage directions are prescribed by the playwright" [5]. The purpose of such script is to specify rules to make learners to equally participate in activities for "establishing and maintaining shared conceptions and can approach a problem from multiple perspectives" [5].

The Scripted Cooperation is one example of such scripts for facilitating social processes in collaborative learning and had been adopted and studied by several researchers [11,12,13]. This script particularly specifies the two roles: recaller and listener, and a specific sequence of activities, such as summarization, feedback, and joint elaboration, as well as exchange of roles between learning partners for the next portion of content. The script requires both learning partners first read learning contents and take notes; then one partner act as the recaller to summarize the learning contents, while the other partner act as the listener to listen and check for errors and omissions in the recaller's summary. When the recaller has finished summarization, the listener provides feedback on errors, distortions, or omitted contents. Then, two learning partners work together to elaborate on the learning contents by adding details and generating examples to link the new contents to what they already know. Another example of the scripted collaboration is the Reciprocal Teaching developed by Palincsar et al.[14]. In this approach, learning partners in small groups are required to take turns to act in different roles (questioner, summarizer, clarifier, and predictor) and follow a scripted sequence of activities of reading the book, asking questions about the content, and summarizing and clarifying the content. An additional role of the prompter, who is responsible for inducing the prompts into the interaction process, may also be assigned to one of the learners.

King found that students were often unable to ask thought-provoking questions related to the learning task spontaneously [15], and developed the guided peer question prompts for students to ask such questions [16]. These prompts are question stems that learners can use to respond to and complete, so that learners can choose a few question prompts from a larger list and generate several content-specific questions by 'filling in the blanks.' Examples of these prompts includes "What does ... mean?", "Explain why ...", "What would happen if ...?" [16]. Similar question prompts for encouraging inquiry-based learning had been developed by Swan and Pead [28] and adopted by the Project PRIMAS (Promote Inquiry-Based Learning In Mathematics And Science) to promote inquiry-based learning in math and science inquiry-based learning continues at both primary and secondary levels across Europe (http://www.primas-project.eu). Examples of such question prompts include "What do you already know that might be useful here?", and "What sort of diagram might be helpful?" [28].

Research on the implementation of Reciprocal Teaching has demonstrated learning gains in text comprehension through pre-post achievement measures. However, it is not clear whether those gains can be attributed to the roles students play or simply to the additional processing of material [17]. King had conducted empirical studies to reveal that the guided peer questioning promoted more knowledge acquisition than the collaborative learning without instructional support [18]. King claimed that "the guided peer questioning could prompt the high level interaction, including activities such as asking thought-provoking questions and integrating new knowledge" [19]. Hron et al. had developed and implemented a script similar to the guided peer questioning to guide the collaborative learning between two learners in a text-based environment[20]. The group of two students was asked to identify and correct mistakes in faulty diagrams. Agreement between two learners had to be reached in a conversation cycle, which starts with initial suggestions and is followed by either agreement or disagreement. For each disagreement, both learners had to provide an explanation. The study conducted by Hron et al. showed that the learners guided by the script made less effort in coordinating their problem-solving processes as well as less control in their dialogue, enabling them to have more effective dialogues for their co-construction of knowledge [20].

Collaboration scripts have been also implemented and studied in Cyber-enabled collaborative learning environments. For example, Nussbaum et al. provided learners with a number of prompts called note starters, similar to the question stem developed by King [16], e.g., "My theory is ...." or "I need to understand……", [21] which students could choose when they start to write a message in text-based computer-mediated learning environments. These note starters are implemented into the text window, which discussants use to formulate messages in the online debate. The findings of the study by Nussbaum et al. show that note starters could encourage students to disagree and explore alternative perspectives in comparison to the collaborative learning without this interface design [21].

Weinberger conducted experimental research on effects of both social and epistemic (cognitive) cooperation scripts on cyber-enabled collaborative learning through web-based discussion board[24]. Subjects in this research are colleague students of Educational Science. The social cooperation script adopted in this research specified two roles for each of three students in the collaborative learning team: (a) analyst, who is responsible for the preliminary and concluding analysis of one learning case and responding to criticism from the learning partners (Weinberger 2003), and (b) construct critic, who is responsible for criticizing the analyses of the two other cases presented by the learning partners [24]. The findings from this research suggested that social cooperation scripts can motivate learners to engage in a more conflict-oriented social mode and may make the learning task more difficult, leading to more learning efforts, which might be important for the learners' knowledge acquisition. The epistemic scripts may make students to take more individual approaches to the learning task, and may make the learning task easier, leading to overconfidence of learners. Besides, epistemic scripts may eliminate students' metacognitive learning activities [24].

Wieland has investigated the impacts of different levels of computer-supported collaboration scripts on students' learning processes and outcomes [5]. In this study, the subjects were high school students, who collaborated through online discussion in a simulation-based learning environment and received two different types of instruction. Students under the precise instructional guidance (PIG) treatment condition were assigned roles in the simulations throughout the discussion and received precise instructions on how to post messages. The other students were in the general instructional orientation (GIO) groups. They received more general instructions, and but were not assigned with a certain role. The research findings suggested that students in the GIO groups (with less specific scripts) asked more questions and exchanged superficial information, while students in the PIG groups (with more specific scripts) made suggestions supported by personal beliefs, experiences, and information from the learning materials. Students in the PIG groups significantly outperformed those in GIO groups. The research findings imply that the level of scaffolding affects both learning processes and learning outcomes [5].

Instructional Framework for Scaffolding Collaborative Learning in Engineering Courses

Student teams and collaborative learning assignment

Based on research development and findings from cognitive science, authors have adopted and implemented an instruction framework for scaffolding collaborative learning in engineering courses at authors' institution. In each participating course, students form a four-member team and are assigned with collaborative learning tasks for selected specific learning concepts and problems. They are given with clear requirements and grading criteria, as well as script and question prompts as scaffoldings for supporting their collaborative learning. Three collaborative learning tasks can be assigned in each course: two for important concepts; the other for a sophisticated problem related to the selected important concepts. Collaborative learning process for assigned tasks can last for about two months. Student teams are required to construct their understanding and solve the problem together through online discussion by following the provided scripts as the external scaffoldings.

The collaborative learning task is a critical part of collaborative knowledge construction. Slavin suggested that the grading criteria for collaborative learning have to include both individual accountability and group accountability for successful collaborative learning, and emphasized the group reward and individual responsibility as necessary conditions for collaborative knowledge construction [22]. Cohen has identified several task criteria that need to be considered for promoting both social and cognitive processes of collaborative learning [23]. The simple learning task that requires only one correct answer or solution is not suitable for collaborative learning, because students may not need to construct and maintain shared understanding to solve such simple task through collaboration [23]. Thus, the assigned task should be complex, so that students have to share their efforts, competencies, and resources to solve it. Furthermore, the task should be motivating in order to maintain student teams' engagement and persistence. These criteria should be considered when instructors for each participating course develop and assign the collaborative learning tasks.

Table 1 Prompts of Social Collaboration Script and Prompts of Epistemic Cooperation

Prompts of the social collaboration script to support the roles of collaborative learning [24]	**Prompts of the epistemic cooperation script to apply the concepts of Weiner's attribution theory to problem cases** [24]
Prompts for the constructive critic	Case information, which can be explained with the attribution theory
These aspects are not clear to me yet:	Relevant terms of the attribution theory for this case:
We have not reached consensus concerning these aspects:	- Does a success or a failure precede this attribution? - Is the attribution located internally or externally?
My proposal for an adjustment of the analysis is:	- Is the cause for the attribution stable or variable? - Does the concerned person attribute himself/herself or does another person attribute him/her?
Prompts for the case analyst	
Regarding the desire for clarity:	Prognosis and consequences from the perspective of the attribution theory:
Regarding our difference of opinions:	
Regarding the modification proposals:	Case information which cannot be explained with the attribution theory:

Scaffolding for social interaction in collaborative learning

Social cooperation scaffolding is adopted to facilitate the social processes in collaborative learning, which is based on combination of the social collaboration script by Weinberger [24] and question prompts by King [5]. This scaffolding not only specifies roles and sequenced activities of each team members, but also provides question prompts for their interaction activities. The goal of the scaffolding is to engage the team members in task-related social interaction. Generally, each student in a four-member team is assigned in turn with one of four roles: (a) the questioner, who is to ask question or present his/her understanding about the learning task; (b) the explainer, who answers the questions or finds errors in presented understanding of learning partners; (c) the prompter, who reviews the question and answer provided by learning partners, and remind the questioner and explainer to organize their questions and answers by applying provided prompts properly; and (d) the commentator, who exams both viewpoints from questioner and explainer, make comments or suggestions for the presented answers, and then make summarization. Once this cycle is completed, team members take turn to switch their roles for the next cycle of questioning and answering interaction.

To facilitate students to ask thought-provoking questions for different roles at different phases of social and cognitive process, social interaction oriented prompts developed by educational researchers are provided to students through both the online system and collaborative learning assignments before their collaborative learning, aiming to help students to generate thought-provoking questions for their online discussion. Those adopted prompts include social interaction prompts [24] in Table 1 (left side), question stem prompts developed by King [5], and inquiry prompts developed by Swan and Pead [17] and adopted by PRIMAS (http://www.primas-project.eu). Students are required to read these prompts before they start their online discussion. The prompter in the team particularly uses those questions as prompts to remind other team members to organize their thinking and questions by applying these prompts. These question prompts are intended to help students inspire each other's thinking and learning through social interaction in the group.

Scaffolding for Cognitive Processes in Collaborative Learning

Cognitive cooperation scaffolding has been adopted to facilitate cognitive processes through question prompts on the specific problem case assigned in the collaborative learning task. Fisher at al. had initiated such scaffolding with the objective for guiding team members' cognitive processes that are related to the particular problem, the specific theory for solving the particular problem, and the relations between the problem and the theory [25]. The implemented scaffolding is adopted from the cognitive cooperation script presented by Weinberger [24] as illustrated in Table 1 (right side). Those prompts were questions for reminding the students of the problem solving procedures to facilitate students to identify relevant problem information, relate the concepts of the relevant theory to the problem information, and finally identify the problem information that can or cannot be explained with the relevant theory [24].

Implementation Procedures

The presented instructional framework has been implemented in two engineering courses: CIV 222 Engineering Mechanics and CIV 320 Structural Analysis in the Fall of 2013 with total student number of ninety-six. The students in each class were randomly selected to form four-member teams for collaborative learning assignment through online discussion. The online discussion was carried out through group e-mails due to unexpected technical issues in using other online platform. Students were assigned with problems or course project as they usually received in normal courses. However, the selected problems or course project were required to be carried out by student teams through the collaborative learning. The requirements for the collaborative learning and grading criterions are presented in Table 2. Besides, Scaffolding for social interaction (See Table 3), and Scaffolding for cognitive processes specific for the truss analysis problem in the course of Structural Analysis (see Table 4) were also provided to student teams selectively in according to their team groups (see Table 6).

Table 2 Collaborative Team Learning Requirement and Grading Criteria

Collaborative Team Learning Requirement
One learning objective of this course is to develop teamwork skills and communication (discussion) skills. You and your peers are required to form the learning team and to collaboratively learn subjects and concepts related to the course project or homework assigned to you. To facilitate and demonstrate your communication and collaboration, the communication and discussion should be conducted and recorded through the online system.
Grading criteria
The average grade of the team members on the collaborative team learning assignment, as well as on the tests of the domain-specific concepts related to the concepts assigned in the collaborative team learning assignment, will be accounted as 10% of individual grade of the collaborative learning assignment or tests of the above domain-specific concepts. To encourage students to actively participate in collaborative team learning through online discussion, the quantities and qualities of individual's posting on the discussion board will be evaluated as the participation grade and accounted as 10% of individual grade of collaborative team learning assignment.

Table 3 Scaffolding for Social Interaction in Collaborative Learning

To facilitate your team learning, each team member is required to take the following role assignment in turn and follow the provided prompts for asking questions.

Role assignment: in your team, team members are assigned with specific roles, and will take turn in playing these specified roles as specified below:

- the questioner who will ask question or present her/his understanding about the learning task;
- the explainer who will answer the questions or find errors in presented understanding;
- the prompter who will review the question and answer, and remind the questioner and explainer to organize their question and answer by selecting proper prompts provided; and
- the commentator will exam both viewpoints from questioner and explainer, make comments or suggestions for presented answers, and make summarization.

Once this cycle is completed, team members take turn to switch role for the next cycle of questioning and answering interaction.

Prompts for asking questions: the interaction-oriented prompts in the attached tables* can be used to facilitate you to generate questions for your collaborative learning

Note: * the tables contain question prompts adopted from Table 1 and others developed by King and by Swan et al.

Table 4 Scaffolding for Cognitive Process in Collaborative Learning for Structural Analysis

1 For establishing free body diagram, you may think and ask following questions

- How to correctly replace supports of a whole structure system with unknown supportive forces or reactive forces to draw a free body diagram of the whole structure system.
- How to correctly cut a part of whole structure, bring with all external load and support, and add the internal force at the cut section of structure member to a free body diagram of the partial structure.

2 For writing equilibrium equations for a given free body diagram, you may think and ask following questions

- How to choose the orientation of the coordinate system and establish the coordinate system for writing equilibrium questions
- How many force components should appear in the specific equilibrium question
- Do the force components need to be decomposed and what is their orientation angle for doing the decomposition
- What point should be chosen for writing the moment equilibrium question

3. For drawing the shear and moment diagram, you may think and ask following questions

- How many segments should be the structure system divided
- How to determine the internal shear and moment at both ends of the selected segment
- How to determine the sign of the internal shear and moment at both ends of the selected segment
- What type line can be used to connect the shear or moment between two ends of the selected segment

Besides, the prompts in the right column in Table 1 should be considered.

Note: This is specific for the structural analysis course assignment

Evaluation Data Measurement and Data Collection Method

The presented outcomes of students' learning processes were obtained from instructors' observation and the students' self-reported survey and will be divided into two dimensions: social interaction process and cognitive process, and further divided into eight sub-dimensions (see Table 5) based on the Knowledge Co-Construction Model developed by Fischer et al. [25]. In students' self-report survey, their learning processes, along with students' perception on the scaffolding and satisfaction on their learning experience, were collected from valid students' response in 1-5 Likert Scale. The presented learning outcomes were obtained from pre- and post-tests by using tests and standard instrument and include: (1) course-related knowledge measured by using domain-specific concept inventory (see Table 8); and (2) learning disposition (motivation, and cognitive and metacognitive skills) measured by Motivated Strategies for

Learning Questionnaire (MSLQ) developed by Pintrich et al. [26] . All those data were obtained in quantized formats.

Table 5 Presented Outcome Variables

Outcome Variables	Dimensions and Sub-Dimensions		Instruments
Learning Process	Social processes: Social modes of co-construction [25]	Externalization	Students' self-report survey on collaborative learning process
		Elicitation	
		Quick consensus building	
		Integration-oriented consensus building	
		Conflict-oriented consensus building	
	Cognitive processes: Epistemic (cognitive) activities [25]	Construction of problem space	
		Construction of conceptual space	
		Construction of relations between conceptual and problem space	
Learning outcomes	GPA		Grades
	Knowledge (Deep understanding of important concepts)		Concept inventory
	Disposition (Motivation and learning skill), Experience, and Satisfaction		MSLQ, self- report survey

The above-presented outcomes were collected and measured and quantified by using instrument below.

- Self-Report Survey on students' collaborative learning process. Students responds to the self-report survey based on the extent of participation, frequency of using certain prompts, and compliance with scaffolding procedures. The scores from the survey were used as the quantified index of students' utilization and compliance of prompt-based cooperation scaffolding.
- Self-Report Survey on students' experience and satisfaction on the assigned collaborative learning.
- MSLQ: Motivated Strategies for Learning Questionnaire (MSLQ) by Pintrich et al. [26] contains self-reported questionnaires on motivation, self-efficacy, cognitive strategy use, metacognitive strategy use, and management of efforts. This instrument will be adopted to measure the change of students' cognitive strategies and metacognition, motivation, and self-efficacy.
- Concept inventory: A concept inventory is a criterion-referenced test designed to evaluate whether a student has an accurate working knowledge of a specific set of concepts. Typically, concept inventories are organized as multiple-choice tests in order to ensure that they are scored in a reproducible manner, a feature that facilitates administration in large classes.

To reveal impacts of the proposed instructional framework and its components, the student teams in the two engineering courses were randomly selected into four groups as shown in Table 6. Evaluation data collection procedures and phases are outlined in Table 7.

Table 6 Different Students' Team Groups and Corresponding Instruction

Team Groups	Instructional Materials Provided to Students
A	Collaborative learning requirement in Table 4 only
B	Collaborative learning requirement in Table 4 with Social Interaction Prompts in Table 5
C	Collaborative learning in Table 4 with Cognitive Process Prompts in Table 6
D	Collaborative learning in Table 4 with both Social Interaction Prompts in Table 5 and Cognitive Process Prompts in Table 6

Table 7 Evaluation data collection procedures

Phases	Contents	Duration
(1) Pre-tests	Demographics , computer experience, GPA	Two weeks
	Knowledge in selected learning subjects (concept map)	
	Learning disposition measured through MSLQ	
(2) Collaborative learning through online discussion	Online discussion for collaborative learning	10 weeks
	Students' Self-report on collaborative learning process	
	Instructors' observation of students' collaborative learning	
(3) Post-tests and debriefing	Learning disposition measured through MSLQ	Two weeks
	Knowledge in selected learning subjects (concept map)	
	Learning experience and Satisfaction, comments	

Results from Analysis of Collected Data

The results of the mid-term survey on students' online collaborative experience are shown in Table 8. They demonstrate that the students in the groups (B, C, and D) with scaffolding generally had higher level of perception or collaboration activities than those in the control group (A) without scaffolding on online collaborative learning. However, students in the cognitive cooperation-scaffolding group (C) showed lower levels when they were asked "the members in my group collaborate with each other effectively, " "It motivates me to learn through the use of online discussion," and "Team online discussion makes me reflect on the course content in a deeper level". This result is in accordance to the finding by Weinberger [24], i.e., students following the cognitive scaffolding tended to study solitarily and easily due to the guideline provided in the cognitive process scaffolding, which might compromise the process of collaborative learning.

The results from the satisfaction survey from post-test data collection are demonstrated in Table 9. They reveal that students in the groups with scaffolding (B, C, and D) had more satisfaction over online collaborative learning than those in control group (A) in general. Particularly, students who received the Social Interaction scaffolding in the group B had highest satisfaction on the online collaborative learning. However, students receiving both social and cognitive cooperation scaffolding in the group D expressed lower level of satisfaction. This could be explained by the finding of Mayer, Heiser and Lonn: cognitive overload in hypermedia environments can be a problem for some learners [29]. More scaffolding might increase students' cognitive load by thinking too much about both social and cognitive strategies for online discussion, leading to the lower satisfaction over the online collaborative learning. Another reason might be because students received the scaffolding from both scaffolding expected more from the online collaborative learning, which in turn led to their lower satisfaction over the whole process.

The online collaborative learning processes were measured by the students' self-report survey in its eight sub-dimensions as demonstrated in Table 5. Their results among four different groups reported in its two main dimensions and are shown in Table 10. Those results indicate that students in the groups with individual scaffolding (B and C) demonstrated more engagement in social and cognitive process in the collaborative learning in comparison with the students in the group without scaffolding (A). However, students in the Group D, who received the scaffolding for both social interaction and cognitive process did not show any advantage in both social process and cognitive progress over students in other groups, which might result from cognitive overload as discussed in the previous section.

Table 8 Students' Online Collaborative Learning Experience from Mid-Term Survey (N=64)

Survey Questionnaires	Student Group	Mean	Std. Deviation
It is easy to communicate with my team members through the online discussion.	Group A	2.88	0.96
	Group B	2.56	1.59
	Group C	2.60	1.59
	Group D	3.29	1.45
I know how to discuss properly with team members to help me learn the concept and find the solution through the online discussion process.	Group A	2.50	1.03
	Group B	3.19	1.32
	Group C	3.47	1.41
	Group D	3.41	1.42
The members in my group collaborate with each other effectively.	Group A	3.31	1.01
	Group B	3.19	1.60
	Group C	2.93	1.62
	Group D	3.41	1.46
The online discussion process is effective in helping me to learn the course content.	Group A	2.56	1.03
	Group B	2.50	1.46
	Group C	3.00	1.51
	Group D	3.06	1.43
It motivates me to learn through the use of online discussion.	Group A	2.75	1.13
	Group B	2.81	1.28
	Group C	2.40	1.50
	Group D	3.06	1.60
I follow the guideline for online discussion provided by instructors through online system.	Group A	3.19	1.11
	Group B	3.25	1.48
	Group C	3.53	1.06
	Group D	3.47	1.42
The guideline for online discussion provided by instructors through online system helps our team remain engaged in collaborative learning.	Group A	2.94	0.93
	Group B	3.06	1.34
	Group C	2.93	1.53
	Group D	3.00	1.50
The team members post question or content relevant to the course content.	Group A	2.94	1.34
	Group B	3.16	1.41
	Group C	3.67	1.40
	Group D	3.35	1.41
Team online discussion makes me reflect on the course content in a deeper level.	Group A	3.00	1.09
	Group B	2.81	1.22
	Group C	2.73	1.49
	Group D	2.88	1.58
I frequently respond to the post from my group members through online discussion.	Group A	3.38	1.36
	Group B	3.25	1.39
	Group C	3.53	1.59
	Group D	3.41	1.33

Table 9 Students' Satisfaction on Online Collaborative Learning (N=70)

Question	Intervention Group	Mean	Std. Deviation
The team-based discussion through online system is very import tool and I am interested at using them for my learning and problem solving.	Group A	2.42	1.08
	Group B	3.67	1.00
	Group C	3.08	1.16
	Group D	2.70	1.34
The team-based discussion through online system is practical and useful in helping learn and master important concepts in the course.	Group A	2.58	1.08
	Group B	3.22	1.20
	Group C	3.00	1.21
	Group D	3.00	1.33
The instruction materials for the team-based discussion through online system are organized effectively.	Group A	2.58	1.08
	Group B	3.67	1.22
	Group C	3.00	1.21
	Group D	2.30	1.34
The instruction materials for the team-based discussion through online system are presented clearly.	Group A	2.92	1.16
	Group B	3.56	1.24
	Group C	3.00	1.04
	Group D	2.60	1.17
The instruction materials for the team-based discussion through online system help me participate in online discussion and effectively exchange ideas with other team members.	Group A	2.42	1.08
	Group B	2.78	1.39
	Group C	3.08	1.31
	Group D	2.70	1.34

Table 10 Students' Learning Process (N=67)

	Intervention Group	Mean	Std. Deviation
Social Process	Group A	2.76	0.80
	Group B	3.10	0.72
	Group C	3.20	0.86
	Group D	2.66	1.08
Cognitive Process	Group A	2.84	0.78
	Group B	3.23	0.86
	Group C	3.19	1.01
	Group D	2.79	1.22

The impacts of scaffolding on students' learning dispositions measured by Motivated Strategies for Learning Questionnaire (MSLQ) are revealed by comparing results between the post-test and the pre-test in terms of size effect. The comparisons among the four student groups are demonstrated in Table 11. Those results reveal the following impacts of the scaffolding on the students' learning dispositions. The social interaction scaffolding can increase students' Intrinsic Value on learning, and also increase the students' Test Anxiety. This may be because the social interaction scaffolding promotes more social interaction among peers in regarding the learning subject and may cause more peer pressure, which make students feel the importance of learning and test score. The cognitive process scaffolding can enhance students' self-efficacy and cognitive strategy use. This consists with the findings by Weinberger [24], i.e., under cognitive process scaffolding, students feel that they are able easily solve the problem at hand, leading to students' overconfidence, and also makes students to realize the importance of cognitive strategies. However, when both social interaction scaffolding and cognitive process scaffolding were provides together to students, they may cause cognitive overload and lead to negative impacts on the students' learning disposition. The results also indicate that offering scaffolding to students may negatively affect their self-regulated learning skill development, because they relied more on external scaffolding rather than internal regulation on their own.

Table 11 Students' Motivational and Self-Regulated Learning Components (N=34)

Measurement	**Group**	**Pre-Test**		**Post-Test**		**Growth**
		Mean	Std. Deviation	Mean	Std. Deviation	Effect Size*
Self- Efficacy	Group A	6.04	0.55	5.71	0.76	-0.44
	Group B	5.95	1.10	5.84	1.17	-0.10
	Group C	5.70	0.90	6.03	0.47	**0.70**
	Group D	5.46	0.97	5.39	1.18	-0.06
Intrinsic Value	Group A	6.12	0.68	6.03	0.56	-0.16
	Group B	5.94	1.35	6.32	0.61	**0.62**
	Group C	6.03	0.84	6.24	0.66	0.31
	Group D	6.19	0.70	5.76	1.26	-0.34
Test Anxiety	Group A	3.60	1.70	3.95	1.52	0.23
	Group B	4.93	1.05	5.71	0.90	**0.87**
	Group C	3.39	1.86	3.57	1.93	0.10
	Group D	4.80	2.08	3.88	1.67	-0.55
Cognitive Strategy Use	Group A	5.43	1.03	5.33	.54	-0.18
	Group B	5.85	0.82	5.85	1.23	0.00
	Group C	5.53	0.96	5.77	0.48	**0.51**
	Group D	5.70	0.91	5.62	1.06	-0.07
Self-Regulation	Group A	4.67	0.83	5.00	0.79	**0.42**
	Group B	5.22	0.48	5.52	1.20	0.25
	Group C	4.75	0.52	4.81	0.71	0.09
	Group D	5.09	0.96	4.61	0.71	-0.67

Note: * Effect Size = difference between means of post-test and pre-test divided by the Std. deviation of post test

Table 12 Students' Concept Acquisition (N=22)

Group	Pre-Test		Post-Test		Growth
	Mean	Std. Deviation	Mean	Std. Deviation	Effect Size*
Group A	24.00	16.73	92.00	10.95	6.21
Group B	23.33	19.66	96.67	8.16	**8.98**
Group C	26.67	10.33	86.67	20.66	2.90
Group D	36.00	16.73	84.00	21.91	2.19

Note: * Effect Size = difference between means of post-test and pre-test divided by the Std. deviation of post test

The impacts of scaffolding on students' understanding on learning subjects measured by the concept inventory are revealed by comparing results between the post-test and the pre-test. The comparisons among the four student groups are demonstrated in Table 12. The results in Table 12 indicated that the students in the Group B with social interaction scaffolding gained more progress in learning than that for students in other three groups. This may suggest that the social interaction scaffolding is effective in helping students to develop deeper understandings of their learning subjects, likely due to that it promotes effective social interactions among students for the collaborative learning. However, the cognitive process scaffolding may have negative impacts on students' development of deeper understanding of learning subject in comparison to those in the control group (A). This may be attributed to that the cognitive process scaffolding to make the problem solving easily and prevent students from understanding the learning subject in depth. The students who received both social interaction scaffolding and cognitive progress scaffolding had lowest gaining in learning subjects in comparison to those in the control group (A). This may be due to both cognitive overload and negative impact of cognitive progress scaffolding.

Students' Comments and Instructors' Observation and Reflection

Besides the analysis results from analysis of data from the aforementioned tables, students were also asked to provide their own account, comments, or suggestions on the collaborative learning through online discussion and the scaffolding. In their self-reported learning experience, most of students claimed benefit from the team-based discussion through online system in mastering the subjects, and the majority of them attributed the benefits to the social process of the team-based online discussion. However, based on their self-reports, most of their discussion were only at the category of externalization and elicitation, such as, "(we can) exchange information;" "… it gives me the chance to see how others think aside from myself;" "(I am) able to check work against others;" "… it gives me the opportunity to seek help on things I don't know;" and "… it was easy for (me) to ask a team member a question." Most of those who benefit from online collaborative learning could clearly indicate some important learning concepts they mastered from the online discussion, like "column," "truss," "joint," "section method," "taking moment," "internal forces," and so on, in which "team work" is the most frequently mentioned concept they mastered.

A few students provided some negative comments and complained of uncooperative team members or lack of experience in online collaborative learning. They listed some factors that prohibited them from benefiting from the assigned collaborative learning, which include "it is hard for other team members to collaborate;" "…all team members were not involve;" "…lack of communication, team members left out or neglected;" "…its forgetful to go online for a discussion with the team members;" "it's easier to communicate and learn in person;" "(I need) clearer concept of requirements for discussion;" and "…too much is expected and not knowing enough information." When asked for suggestions, lots of students requested more detailed instruction and mentioned that online collaborative learning was not a usual method for them. Almost all of them reported that much more time were spent on learning on their own than that on online collaborative learning.

The course instructors observed fact that students tended to engage in more interaction with their peers for their learning subject with the online collaborative assignment than they did in the class without collaborative learning assignment. The most teams can initiate questions regarding the learning contents through online system. They come together to the instructor office to ask questions that they could not solve by themselves. This is indication that providing collaborative learning assignment can prompt students' interaction with their peers. However, not all questions were answered by team members through the online system. Some students preferred engaging in the face-to-face discussion. Some students preferred communicating with other via their cell phone using text messages, rather than group e-mail, because some students had never used e-mail system.

The reason for the complaint on uncooperative team members may be attributed to that the online discussion is not a synchronic one and students could hardly find time to discuss online at the same time after class. Therefore, most students could not get prompt response or feedback from their team members. This delay might make some students who wait for the responses to feel that their peers were not cooperative and became frustrated, even though their peers might respond as soon as they saw the message online. This asynchronous online discussion might affected students' participation interest and prevent them from achieving better results from online collaborative learning. This calls for improvement in this area in future implementation.

It is instructors' judgment that some students might not really perceive the value of collaborative learning, and still prefer learning by themselves. Second, they are familiar with internet and online chatting, but they might lack of skills in learning collaboratively through on line discussion and fail to communicate smoothly online for a certain time to achieve a specific learning objective. Third, lack of simultaneous feedback also affected students' participation in learning through online discussion. Fourth, students might also need more time of scaffolding for them to apply the skills for achieving more profound learning.

Limitation of This Paper and Future Research and Improvement

Even though the proposed scaffolding was implemented in two engineering courses with ninety-six students, not all students participate in evaluation data collection process, and some students did not complete the survey questionnaires. This results in different and small sample size in collection of some data and leads to that the sample sizes in each of four different groups may not be large enough to reveal the statistic significance. For example, there were only twenty-two students in CIV 320 who took both pre-test and post-test of concept inventory. Besides, the presented learning process data were mainly obtained from students' self-report surveys and may contain subjective biases of participating students. Thus, findings based on the results from analysis of available data only reveal the possible trend of impacts of the proposed scaffolding and needs further confirmation with more data as preliminary conclusions. Thus, the future research should include data collected from more participating students to reveal the impacts of the scaffolding among different student groups with the statistic significance. The students' learning processes should be further characterized and evaluated in the future research based on more objective-based data, such as students' online discussion threads. The first-year implementation also suggests that dedicated platform for online discussion for collaborative learning should be provided with ability for closely monitoring students' participation. Besides, students should be assigned with carefully designed assignments or project, which requires close interactions among the individual team members in order to complete the entire project or homework, so that students could engage in more collaborative learning.

Conclusion

Although sample sizes of four different implementation groups from available data are varied and may be sufficiently large to demonstrate different impacts with statistic significance, results from analysis of those data may reveal the general trend of the impacts of the presented scaffolding on students' collaborative learning process and outcomes. The implementation outcomes indicated the following preliminary conclusions.

The presented instructional framework based on the proposed scaffolding can provide a platform for students to engage in more collaborative learning with their team peers for co-constructing their knowledge than they did in traditional settings. The social interaction scaffolding may improve intellectual exchange among student team members and lead to enhancing students' satisfaction on online collaborative learning, social process for collaborative learning, intrinsic value on learning, and learning performance. Meanwhile, it may also increase students' test anxiety. The cognitive process scaffolding may improve students' collaborative learning process, self-efficacy, and cognitive strategy use, but may negatively impact students' learning performance measured by using concept inventory test. When both social interaction scaffolding and cognitive process scaffolding were provided to students, they might cause cognitive overload for students, and did not yield the desirable collaborative learning process and outcomes. Besides, when the two types of scaffolding were provided to students separately or jointly, they may negatively impact on students' self-regulated learning skill development. The further evaluation or research should be carried out to further confirm the above preliminary conclusions based on more samples and more objective data without subjective biases. The new means for improving students’ learning engagement should be considered and included in the online collaborative learning.

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