

Analyzing Team Based Engineering Design Process in Computer Supported Collaborative Learning

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The engineering design process has been largely implemented in a collaborative project format. Recently, technological advancement has helped collaborative problem solving processes such as engineering design to have efficient implementation using computers or online technology. In this study, we investigated college students' interaction and collaborative learning in the CSCL setting of performing engineering design tasks. To accomplish the research aim, this study compares participating learners' interaction between teams of high and low achievement. We gathered texts, images, and URL links, in their real-time chatting environments and tracked all the histories that mapped their logins and interactions. We conducted content and CORDTRA analyses on the students' online chat conversations. The content analysis results showed similar frequency patterns for both teams at each stage of the engineering design process in CSCL. On the other hand, the interactions by CORDTRA analysis showed different patterns in some stages of the engineering design process and the differences influenced each team's achievements. This study provided strategies on teachers' involvement for successful outcomes in engineering design of CSCL.

Keywords: CORDTRA analysis, CSCL, Engineering design process, Online collaborative learning, Technology education

INTRODUCTION

Diverse efforts have been made to include engineering design process in the recent K-12 education setting. As an impact of these efforts, global STEM (Science, Technology, Engineering, and Mathematics) education communities have paid attention to the employment of engineering design processes (Douglas & Strobel, 2015; Hernandez et al. 2014; Ritz & Fan, 2014). Further, an instance of these efforts is the South Korean government, which has utilized engineering design processes to implement STEAM (Science, Technology, Engineering, Arts, and Mathematics) education (Kim, 2015).

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Engineering design can be defined as, “a systematic intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes, whose form and function achieve clients’ objectives or users’ needs while satisfying a specified set of constraints.” (Dym, Agogino, Eris, Frey, & Leifer, 2005, p. 104). While engineering design has diverse stage models, it follows the process shown in Figure 1 (Eide, Jenison, Mashaw, & Northup, 2002).

The first stage of the engineering design is identifying and understanding existing needs and problems. It is a crucial stage, as it is not possible to solve the problems without understanding their exact nature. The second stage is to find the best solutions for the problems. It covers a process of arranging, analyzing, and finalizing the optimal solution by searching for relevant information and identifying the limitations. The third is to communicate the design after making a final decision about the problem. In other words, this includes the drawing of the final solution and the communication of the design as a report or a presentation.

The engineering design process has been largely implemented in a collaborative project format (Hynes, 2012; Mentzer, Huffman, & Thayer, 2014). The team members define the problem, investigate alternatives, and finalize the best solution by communicating with each other within the team. In other words, they solve the problem using a collaborative learning process. Collaborative learning can be described as a complex activity, in which many learners with specific learning mechanisms interact (Kanselaar, Erkens, Jaspers, & Schijf, 2001). Thus, collaborative learning can be analyzed with many perspectives and methods and is affected by the given task, context, and applicable tools (Baker, Hansen, Joiner, & Traum, 1999).

Recently, technological advancement has helped collaborative problem solving processes such as engineering design to have efficient implementation using computers or online technology. Computer supported collaborative learning (CSCL) is one of the learning science areas that pay attention to how learners learn using technological aids (Stahl, Koschmann, & Suthers, 2006). The participating learners under the CSCL environment create shared knowledge actively and cooperatively through computer networks (Lehtinen, Hkkarainen, Lipponen, Rahikainen, & Muukkonen, 1999). The CSCL environment enables multiple learners in a team to solve the problem without any time and space limitations. Moreover, the learners perform coordinative activities such as time management, coordination of work, and consideration of distribution of knowledge and material, as well as communication activities such as questioning, explanation, and feedback (Rummel & Spada, 2005). Social interaction is a significant factor of the successful learning for learners in CSCL as it affects their academic accomplishment and participation hugely (Abedin, Daneshgar, & D’Ambra, 2011; Kreijns, Kirschner, & Jochems, 2003). Further, these interactions are indispensable for building shared knowledge and it is very significant to investigate the interaction between individual and collaborative learning activities (Banks, Goodyear, Hodgson, & McConnel, 2003; Puntambekar, 2006). Researchers related to the CSCL have used diverse methods for identifying

State of the literature

- The engineering design process has been largely implemented in a collaborative project format.
- Technological advancement has helped collaborative problem solving processes such as engineering design to have efficient implementation using computers or online technology.
- CORDTRA diagram is a tool to visualize the discourse of the teams over time that provides us with a description of the transitional discourse.

Contribution of this paper to the literature

- CORDTRA diagram was largely utilized for comparing the collaborative process between the high-achieved team and low-achieved team.
- The studies drew the CORDTRA diagram and analyzed the patterns using log files and conversation of the interactive tool that the two teams used.
- The CORDTRA diagram can be utilized for analyzing engineering design process in the CSCL environment.

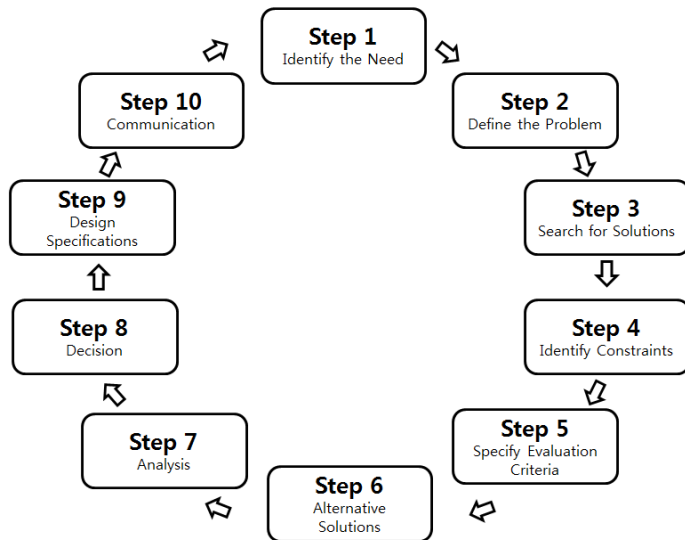


Figure 1. Engineering design process

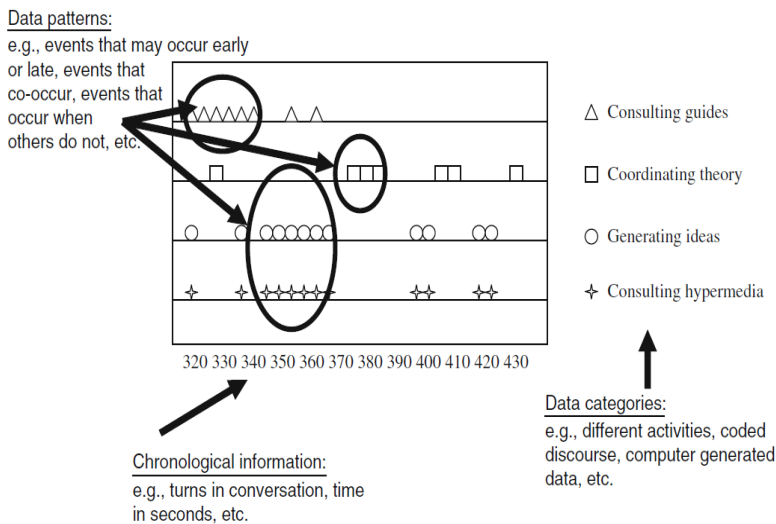


Figure 2. Explanation of CORDTRA (Hmelo-Silver et al., 2008, p.412)

the interactions between the individuals and their collaborative learning activities. Social Network Analysis (SNA) is one of the methods that provides us with a suitable tool to answer several questions, such as who is involved with the collaborative learning task, who are the active participants, and who is participating peripherally (De Laat, Lally, Lipponene, & Simons, 2007). This information can be analyzed for investigating the communication method, content, and outcome over time, using discourse analysis and observation (Chen, Looi, & Tan, 2010).

CORDTRA (Chronologically-Ordered Representation of Discourse and Tool-Related Activity) analysis is presently employed to present the learners' interaction visually. CORDTRA diagram is a tool to visualize the discourse of the teams over time that provides us with a description of the transitional discourse (Hmelo-Silver, Chernobilsky, & Jordan, 2008). Researchers present dots in the time line for each data category after transforming the coded items into data categories as shown in Figure 2. In other words, it is a diagram to combine coded message graph and log data over time, and can be used to analyze the interactive activities qualitatively in the collaborative learning process, by investigating repetitive data trends and

patterns over time. It can investigate the learners' participation both individually and in teams, and identify the history log and transition of the message type.

In prior studies, CORDTRA diagram was largely utilized for comparing the collaborative process between the high-achieved team and low-achieved team (Hmelo-Silver et al., 2008). The studies drew the CORDTRA diagram and analyzed the patterns using log files and conversation of the interactive tool that the two teams used. With a time order through the CORDTRA diagram, researchers identified learners' collaborative learning processes and trends of using the specific tool, by checking how often each team used the tool and the content of their interaction with each other. The CORDTRA diagram can be utilized for analyzing engineering design process in the CSCL environment. Particularly, a huge increase in engineering design activities in the CSCL environment by technological innovation is expected. It can be foundational data for supporting engineering design effectively, by checking what kind of activity the learners concentrate on, the kind of processes they perform, and the kind of tools they utilize

This study aims to investigate college students' interaction and collaborative learning in the CSCL setting of performing engineering design task. To accomplish the research aim, this study compares participating learners' interaction between the high achieved team and low achieved team using CORDTRA diagram presentations. Specific research problems are as follows:

1. What is the frequency of each stage for engineering design in the CSCL environment?
2. What is the level of interaction of each stage for engineering design in the CSCL environment?

METHOD

Participants

The participants were junior undergraduate students in the technology teachers' track in South Korea. They were sixteen (5 male and 11 female students respectively) taking *'Teaching Material and Research for Technology Education'*, a major compulsory pedagogical class for technology pre-service teachers, who also took *'Foundation of Construction Technology'* and *'Foundation of Technology Education'* in their last semester. In this class, participants were already in diverse team activities as specified in the course syllabi.

CSCL Setting

The participants used Google Drive (<https://drive.google.com>) to perform team engineering design projects in a real-time CSCL setting. Google Drive supports a collaborative environment editable by many participants and workable for word processor or presentation documents in real time, as shown in Figure 3. Further, participants easily used relevant software since Google Drive provided the same editing environment as the word processor or presentation. Moreover, they communicated texts, images, and URL links in a real-time chatting environment, tracked all the histories that they logged into, and interacted with each other by using key task items. In this study, researchers created an interactive page for each team and asked team members to join the page. This page provided a diverse set of contents, such as a description of the problem situation, a guideline for using the Google Drive, and a guideline for writing the final report.

Coding

The participants were asked to present all the processes that they used while solving the problem by on-line chatting, and all the conversations were recorded as

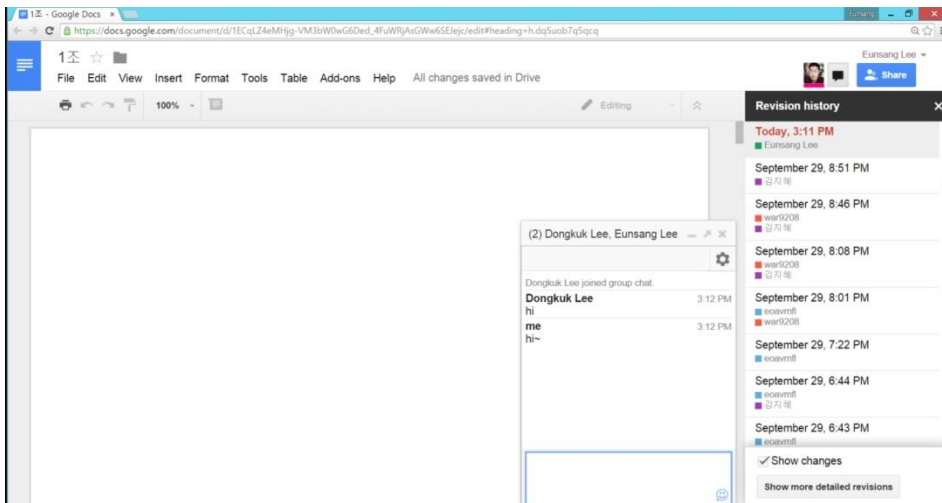


Figure 3. CSCL environment

well. The contents of the chatting forums, of the highest and lowest achieved teams among five teams were analyzed. Transcripts of two teams' on-line chatting contents were then segmented into units of text for the coding process. Each segment represents one idea and segmenting was done independently by two analysts. We checked for reliability and the average reliability for segmenting was 96%. Once the segmenting was complete, the transcript was changed into codes for CORDTRA analysis.

Each segment was coded in terms of two variables in the coding scheme (see Table 1). The first coding scheme was to check the stage of the design process. The code consisted of three stages: (1) Problem identification – task identification, format identification, procedure identification, (2) Implementation – information/idea search, information, presentation, idea presentation, information/idea analysis, information idea convergence, and (3) Evaluation – content evaluation and process evaluation. The second coding scheme was to check the topics of the design process. The code consisted of theme or concept design, play stuff design, function design, expense estimation, layout design, and process table design. Two analysts individually coded each protocol and compared them for resolving all inconsistencies. The average reliability for this coding process was 93.4%.

RESULTS

Frequency counts of content analysis

Frequency counts of all the conversations from the 'designing playground' problem-solving project are shown in Table 2. Team 1 had a larger frequency. Overall conversations of engineering design projects for the theme, 'designing a playground' are shown in Table 1. Regarding the number of conversations at each stage of the engineering design process, Team 1 has 75 (18.6%) at the stage of problem identification, 282 (69.8%) at the stage of implementation, and 47 (11.6%) at the stage of evaluation. On the other hand, Team 3 has 45 conversations (16.26%) at the stage of problem identification, 205 (74.0%) at the stage of implementation, and 27 (9.7%) at the stage of evaluation. It is evident that Team 1 and Team 3 solved the problems by focusing mostly on the implementation stage and both teams had a similar number of conversations at each stage.

Team 1 and 3 had the same descending order of frequency for procedure identification, format identification, and task identification at the problem

Table 1. Coding scheme for protocol data

Type	Code	Definitions	Examples
Stages of the design process	Task Identification	Identifying a task and a condition to carry out	"Should we decide what kind of rides and where to place them on the playground?"
	Format Identification	Identifying a report form	"Um... The photograph is too small, but when we enlarge it, it overlaps to the next page."
	Procedure Identification	Discussing procedures in problem solving	"How about drawing a plan first?"
	Information/Idea Search	To ask members whether they have information in order to find some solutions, or to notify members of the necessary information for problem solving before presenting information or ideas	"At what age could kids go down the slide?"
	Information Presentation	To present objective data based on internet, books etc., not just one's own thought/opinion	"http://navercast.naver.com/magazine_contents.nhn?rid=1491&contents_id=27726. Please read this one first."
	Idea Presentation	To suggest opinion on problem solving method	"It's okay. There is no need to include the slide. The theme is traditional."
	Information/Idea Analysis	To analyze information and ideas suggested by you or others	"By the way, it is a little different from the construction design."
	Information/Idea Convergence	To give concrete shape to the ideas with agreement or disagreement on suggested information or ideas	"I was also going to say that word. ^^ traditional - yes!"
	Content Evaluation	To evaluate the pros and cons of the gathered contents related to the problems	"This arrangement is fine."
Process Evaluation	To evaluate the pros and cons of the process of problem solving	"If the details are not complete, change or add more content."	
Topics of the design process	Theme Design	Decide what to use as a theme and a concept	"I was thinking of traditional. Or, what about safety?"
	Play Stuff Design	To choose what type of rides and equipment (e.g. a bench, a lamppost, road etc.)	"That's why we need to add a seesaw and a swing T.T"
	Function Design	To choose the features and functions of the rides and equipment (including the functions and materials of rides)	"The cushion needs waterproofing. Otherwise, it will get wet when it rains."
	Expense Estimation	Estimated expenses for the rides and playground construction	"By the way, how much is the price estimate?"
	Layout Design	Design and placement of rides and other equipment	"I drew a plan but it is just an outline."
	Process Table Drawing	Write down the construction process	"What contents should we add in the progress schedule?"

identification stage. On the other hand, at the stage of implementation, Team 1 had a descending order of idea presentation, convergence, search, information presentation, and analysis, and Team 3 had a descending order of idea presentation, convergence, search, analysis, and information presentation. It is seen clearly that the main activities at the implementation stage are idea presentation, convergences, and search. At the stage of evaluation, both teams had a descending order of content evaluation and process evaluation. Specific to evaluation, process evaluation was not done as much as content evaluation.

Table 2. Total message frequency of engineering design process

Type		Team 1			Team 3		
		Frequency	Part Rate (%)	Total Rate (%)	Frequency	Part Rate (%)	Total Rate (%)
Problem Identification	Task Identification	18	24.0	4.5	8	17.8	2.9
	Format Identification	20	26.7	5.0	17	37.8	6.1
	Procedure Identification	37	49.3	9.2	20	44.4	7.2
	<i>Sub total</i>	75	100	18.6	45	100	16.2
Implementation	Information/Idea Search	42	14.9	10.4	34	16.6	12.3
	Information Presentation	23	8.2	5.7	24	11.7	8.7
	Idea Presentation	107	37.9	26.5	86	42.0	31.0
	Information/Idea Analysis	19	6.7	4.7	25	12.2	9.0
	Information/Idea Convergence	91	32.3	22.5	36	17.6	13.0
	<i>Sub total</i>	282	100	69.8	205	100	74.0
Evaluation	Content Evaluation	43	91.5	10.6	26	96.3	9.4
	Process Evaluation	4	8.5	1.0	1	3.7	0.4
	<i>Sub total</i>	47	100	11.6	27	100	9.7
Total		404		100	277		100

Analysis on engineering design interaction: CORDTRA analysis

The frequency of content analysis was very similar at each stage. CORDTRA diagrams show engineering design activities in a visual format so that the characteristics and patterns among students or teams during problems solving activities are easily captured. CORDTRA diagram of each team for the overall design process is shown in Figures 4 and 5 respectively. The x-axis represents time (in minutes), and the y-axis represents students who participated in conversations and the conversations themselves.

Problem identification stage

CORDTRA diagrams of Teams 1 and 3 at the stage of problem identification are shown in Figures 6 and 7 respectively. Teams 1 and 3 had superficially similar patterns at the problem identification stage. In the early stages of engineering design, students did format identification only after task identification was completed. Procedure identification was repeated during the overall engineering design process. This is explicit in the following details in terms of conversations and time sequence.

First, Team 1 did task identification between 4 and 110 minutes. The theme of a playground and its functions was mainly discussed between 70 and 78 minutes, and designing the playground and its layout were discussed between 90 and 100 minutes. Task identification of Team 3 was done between 7 and 82 minutes. A conversation did not continue for more than a minute and the subjects of conversations kept changing. A detailed conversation regarding task identification did not take place. The main topics of conversation were the functions of playground equipment and their layouts. Although Team 1 performed in depth task

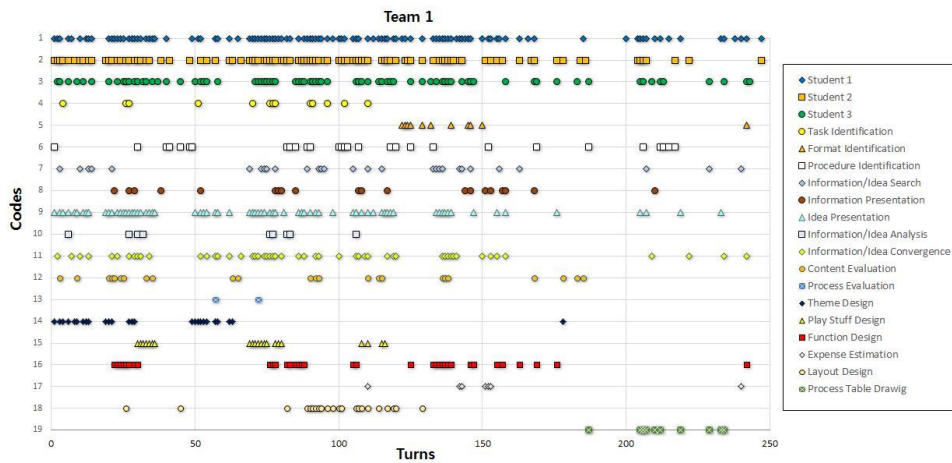


Figure 4. CORDTRA Diagrams of Team 1 (All stages)

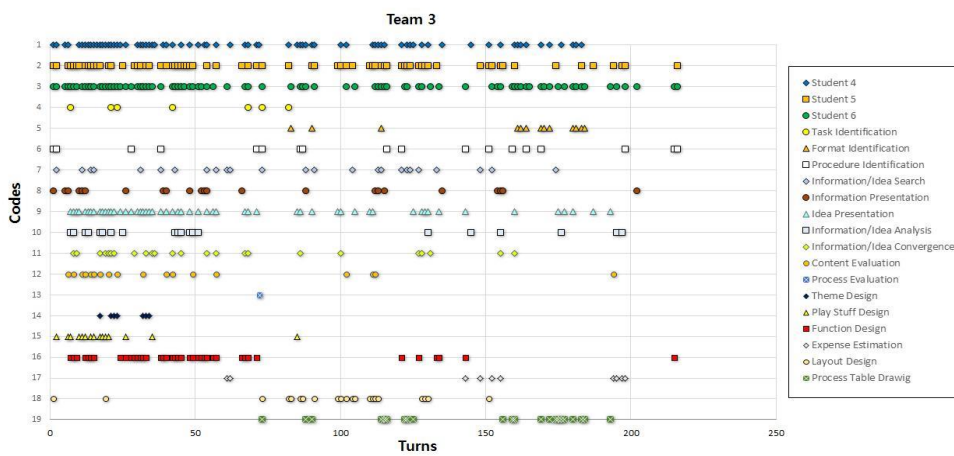


Figure 5. CORDTRA Diagrams of Team 3 (All stages)

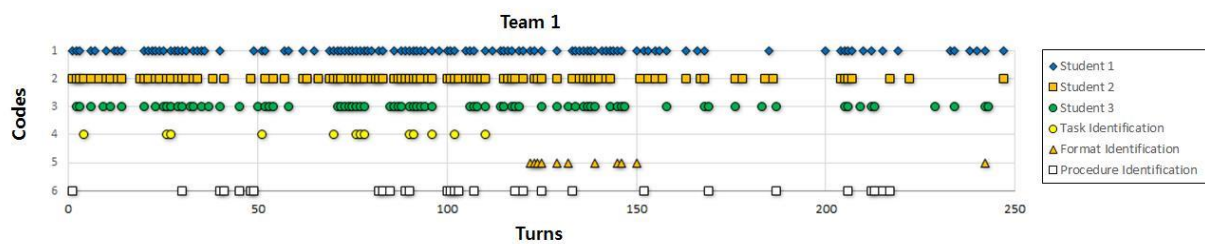


Figure 6. CORDTRA Diagrams of Team 1 (Problem Identification Stages)

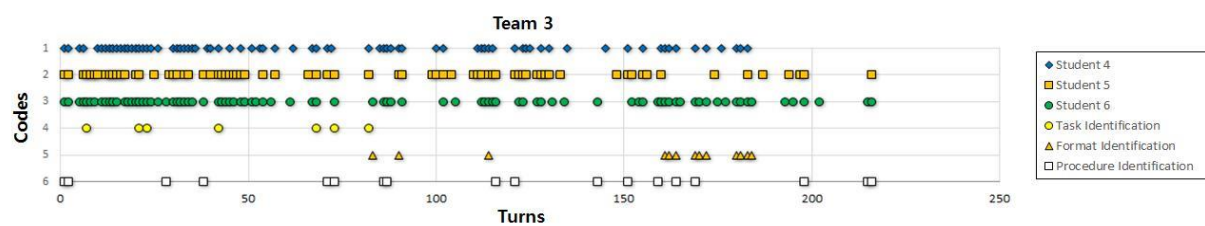


Figure 7. CORDTRA Diagrams of Team 3 (Problem Identification Stages)

identification for a specific subject, Team 3 performed task identification occasionally. Team 1 did format identification between 122 and 150 minutes. Second, during this period, Team 1 checked the requirements for the final report including pictures and margins, and later applied it into the final report. Team 3 did format identification between 83 and 184 minutes. The conversation related to format identification took place mainly between 161 and 172 minutes, which is a time span in the later stages of the overall engineering design process, which was then applied into the final report. Even though both teams worked on their final report, Team 1 mainly did format identification in the middle of the overall engineering design process while Team 3 did so in the later stages of the engineering design process. Third, procedure identification for Teams 1 and 3 took place between 1 and 217 minutes, and between 1 and 216 minutes respectively. Both teams did procedure identification during the engineering design process, and conversations were related to the formation check for the final report.

Implementation stage

Stage-by-stage analysis of the implementation segment

CORDTRA diagrams of teams 1 and 3 at the implementation stage are shown in Figures 8 and 9 respectively. In terms of each code, teams 1 and 3 had superficially different patterns at the implementation stage. First, Team 1 performed the search function between 3 and 240 minutes and Team 3 did the same between 2 and 174 minutes. Both teams used search during the overall engineering design process. Second, Team 1 did information presentation between 22 and 210 minutes and Team 3 between 5 and 202 minutes. Both teams performed information presentation during the overall engineering design process. Third, Team 1 did idea presentation between 1 and 233 minutes and Team 3 between 7 and 193 minutes. Team 1 did most of the idea presentation at an early stage and in the middle of the engineering design process, but Team 3 did the same only in the early stages of the engineering design process. Fourth, Team 1 performed analysis between 6 and 138 minutes and Team 3 between 7 and 197 minutes. Although Team 1 occasionally did analysis in the early and middle stages of the engineering design process, Team 3 did the major chunk of analysis in the early stages of the engineering design process and occasionally in a later stage. Fifth, Team 1 did convergence between 2 and 242

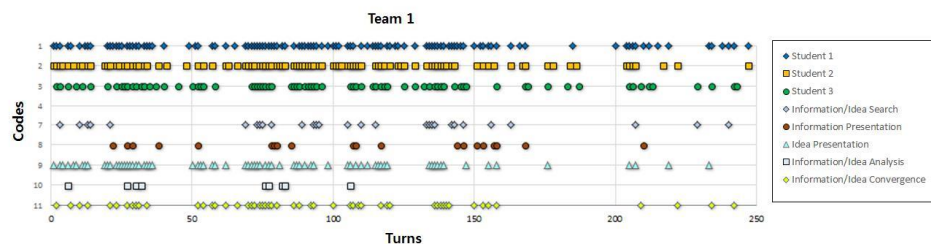


Figure 8. CORDTRA Diagrams of Team 1 (Implementation Stage)

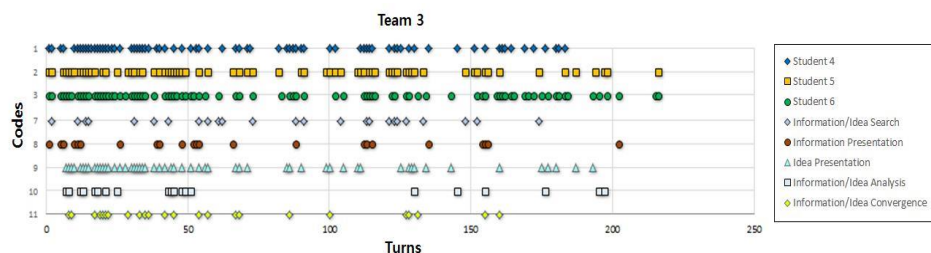


Figure 9. CORDTRA Diagrams of Team 3 (Implementation Stage)

minutes and Team 3 did convergence between 8 and 160 minutes. Team 1 mostly performed convergence in the early and middle stages of the engineering design process and occasionally performed convergence in a later stage. On the other hand, Team 3 performed convergence mostly in the early stages of the engineering design process, performed the same occasionally in the middle, and did not perform convergence at all in the later stages of the engineering design process.

Content analysis in implementation stage

To check how implementation is shown as a result of the engineering design process, a process of working on the final report is reviewed through the CORDTRA diagram. Team 1 solved the problems sequentially and logically as follows: theme selection (1 ~ 21 minutes) → functions design (22 ~ 30 minutes) → playground equipment design (30 ~ 37 minutes) → theme design (49 ~ 63 minutes) → playground equipment design (69 ~ 75 minutes) → functions design (82 ~ 88 minutes) → design/layout (89 ~ 120 minutes) → functions design (133 ~ 139 minutes) → expense estimation (142 ~ 153 minutes) → schedule (187 ~ 234 minutes).

The overall process employed by Team 3 for engineering design was not sequential or logical as seen here: playground equipment design (2 ~ 7 minutes) → function design (7 ~ 9 minutes) → playground equipment design (10 ~ 12 minutes) → function design (12 ~ 15 minutes) → playground equipment (15 ~ 20 minutes) → theme design (21 ~ 23 minutes) → function design [theme design, playground equipment design, expense estimation] (24 ~ 71 minutes) → design/layout[schedule] (73 ~ 87 minutes) → schedule (88 ~ 125 minutes) → design/layout (128 ~ 130 minutes) → expense estimation (143 ~ 155 minutes) → schedule (156 ~ 193 minutes) → expense estimation (194 ~ 198 minutes.)

Evaluation stage

CORDTRA diagrams of Team 1 and 3 at the implementation stage are shown in Figures 10 and 11 respectively. Team 1 and 3 had different patterns superficially at the stage of evaluation. First, Team 1 did content evaluation between 2 and 185 minutes, i.e., Team 1 did content evaluation during the overall process of engineering design. Team 3 did content evaluation between 6 and 194 minutes. Team 3 did most of their content evaluation in the early stages, but not after the middle of the engineering design process. Second, Team 1 did process evaluation at both 57 and 72 minutes. Team 3 did process evaluation only at 72 minutes. (It is quite difficult to define the meaning of process evaluation here due to the lack of frequency of the evaluation activity.)

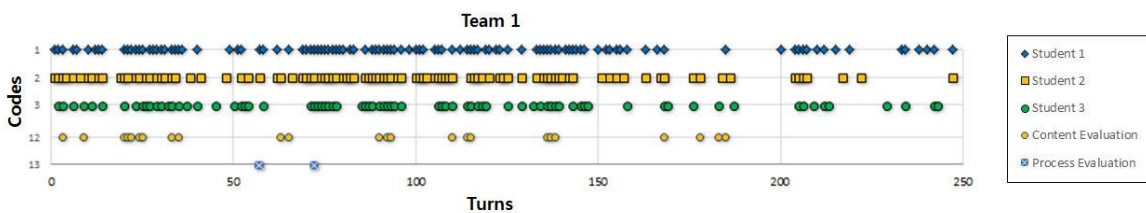


Figure 10. CORDTRA Diagrams of Team 1 (Evaluation Stage)

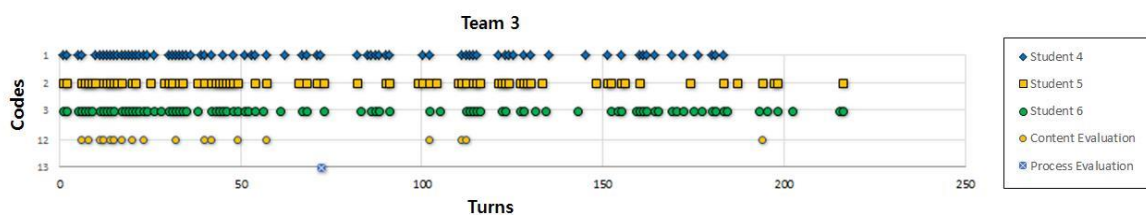


Figure 11. CORDTRA Diagrams of Team 3 (Evaluation Stage)

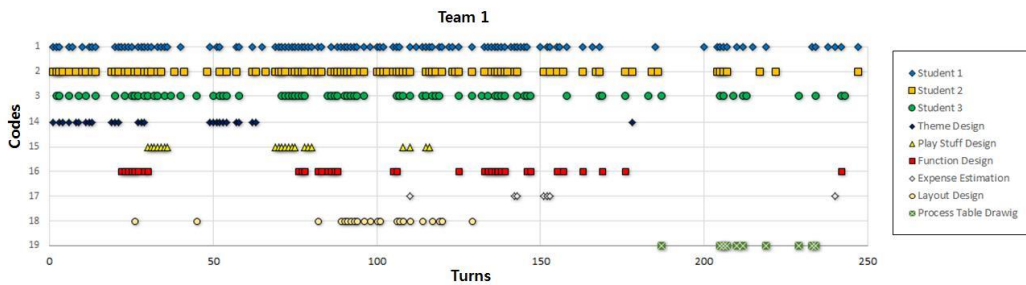


Figure 12. CORDTRA Diagrams of Team 1 (Comprehensive Procedure)

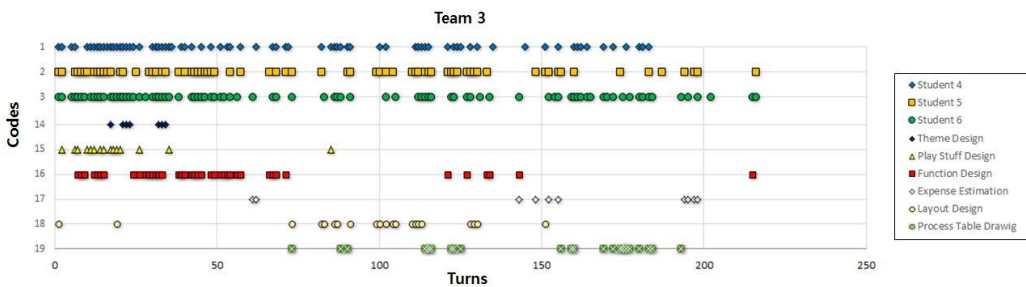


Figure 13. CORDTRA Diagrams of Team 3 (Comprehensive Procedure)

Comprehensive procedure

CORDTRA diagrams of the overall work done by Team 1 and 3 are shown in Figures 12 and 13 respectively. Team 1 and 3 showed differences in the pattern of the overall work done. Team 1 mainly did theme design between 1 and 29 minutes, and 49 and 63 minutes, play stuff design between 30 and 36 minutes, 70 and 80 minutes, and 108 and 116 minutes, and mostly function design between 22 and 30 minutes, 76 and 88 minutes, and 133 and 139 minutes. Further, expense was estimated between 142 and 153 minutes, layout was designed between 82 and 120 minutes, and process table drawing was completed between 205 and 234 minutes.

Team 3 did theme design between 17 and 34 minutes, play stuff design between 2 and 20 minutes, function design between 7 and 71 minutes, and expense estimation between 143 and 155 minutes, and 194 and 198 minutes. However, layout design was not done completely but only occasionally between 79 and 151 minutes, and process table drawing was performed occasionally between 73 and 193 minutes. Although Team 1 did not have many overlaps among subjects to solve problems in general, Team 3 did in the engineering design process. Team 1 focused on a subject for a certain period of time but Team 3 focused rather sporadically on the subjects.

DISCUSSION

The study attempts to support engineering design process effectively in the CSCL environment when an engineering design is assigned, through an analysis of the interaction and co-operative study among students. The frequency of conversations and the interactions of two teams consisting of highly achieved students and less achieved students in engineering design process are shown. The detailed results of this study are addressed here.

Frequency at each stage of the engineering design process in CSCL

First, under the CSCL circumstance, the frequency of each stage of engineering design showed that while generating candidate solutions, the stage that actually

solved the problems covered 70% of the weightage of the overall process in both the teams. The findings showed results similar to previous studies, indicating that students spend most of their time in the solution stage (Atman, Chimka, Bursic, & Nachtmann, 1999; Mentzer, 2014). Students initially engaged in problem identification, found different ideas to solve problems, and converged on an idea through discussions. This process helped them find a pragmatic alternative. A process for generating candidate solutions is critical in engineering design.

Second, procedure identification, format identification, and task identification were seen to be in descending order of frequency in the problem identification of CSCL circumstance. Since there were not specific activities addressed at the stage of problem identification (Atman, Cardella, Turns, & Adams, 2005; Atman et al., 2007), it was quite difficult to find any activities performed at the problem identification stage. Two teams focused on solving problems using any process and format in this study. However, task identification that focuses on problems themselves is comparably less frequent. It is evident that task identification is shared among students in the early stage of engineering design, and problem-solving activities are continuously performed by discussing procedure and format.

Third, idea presentation and idea convergence had higher frequencies in both teams as main activities of generating candidate solutions of the CSCL circumstance. Students had diverse ideas for finding an alternative, and converged on an idea as the alternative from among the different ideas. However, analysis has the lowest frequency and this can be seen in many ways. Students may converge on an idea through their previous experience and/or knowledge and not necessarily their themed conversations. Moreover, to solve the problems under a given time, a stage of analysis was possibly skipped to move quickly to a stage of convergence.

Fourth, CSCL circumstance evaluation mainly involved content evaluation but not process evaluation. Students in two teams continuously evaluated their alternative idea with respect to its quality and contents and wrote it down in their final report if suitable. On the other hand, it can be concluded that there is rarely any evaluation of the engineering design process itself, because students solved problems through a process of continuous communications and co-ordinations in mutual agreement with the engineering design process.

Interaction of each stage of engineering design process in CSCL

First, both teams did task identification in the early stages of the engineering design process and did format identification only after task identification was done. This shows that task identification is indispensable in an engineering design process (Moaveni, 2015) and supports the premise that task identification occurs in an early stage of the engineering design process (Atman et al., 2005). Procedure identification is performed during the overall process of engineering design. A highly achieved team did task identification for specific content well, but a less achieved team did task identification rather sporadically. Task identification helps to decide the problems which the students choose to solve. In the highly achieved team, a discussion of a specific topic took place followed by the procedure. On the other hand, the less achieved team did multi-tasking simultaneously without enough discussion of any specific topic. The highly achieved team did format identification in the middle of the engineering design process, whereas the less achieved team did format identification in the later stages of the engineering design process. Format identification is to check a form or format for a final report. The highly achieved team spent enough time to work on their final report since they did format identification in the middle of the engineering design process. The less motivated team did not have enough time for their final report and several formats were not

correct, since they did format identification in the later stage of the engineering design process.

Second, information search and information presentation were continuously performed during the overall engineering design process at the implementation stage of CSCL. Both teams tried to present information using their previous knowledge and/or internet during the overall engineering design process. The highly achieved team did information presentation and analysis in the early and middle stages of the engineering design process and the less achieved team did the same task only in an early stage of the engineering design process. Convergence was performed vigorously in the early and middle stages of the engineering design process, and occasionally in the later stages of the engineering design process in the highly achieved team. On the other hand, the less achieved team performed convergence in the early stages of the engineering design process, and occasionally in the middle of the process, but rarely in the later stages of the engineering design process. The report contains many ideas without convergence. It does not represent a team's view coherently and possibly downgrades the quality of their report.

Third, the highly achieved team did content evaluation throughout the overall engineering design process but the less motivated team rarely did content evaluation in the later stages of the engineering design process. It can be concluded that, since the less motivated students did not have enough time to work on the report, they rarely evaluated their performance.

Fourth, the engineering design process turns out to be nonlinear in CSCL. Both teams solved problems without any consideration of the sequence of problem identification, implementation, and evaluation, which means they performed each stage multiple times as required, without adhering to any set sequence (McCormick, Murphy, & Hennessy, 1994; Welch, Barlex, & Lim, 2000). This shows the same result as indicated in existing research that problems given offline are solved nonlinearly (McCormick et al., 1994; Welch et al., 2000). Moreover, the highly achieved team vigorously solved problems for a specific subject without any overlaps. However, the less achieved team tried to handle multiple subjects simultaneously. In case of handling multiple subjects at the same time, there is a chance that the subjects cannot be understood in depth and specific parts may be overlooked. Due to the lack of time, task completion may not be possible.

Implications

A summary of designing of teaching and learning in the engineering design of CSCL will be presented based on the findings of this study.

First, the study provided strategies on teachers' involvement (scaffolding and feedback) for successful outcomes in engineering design of CSCL. Open-ended situations like engineering design for solving complex problems must have proper scaffoldings (Hannafin & Land, 1997; Rienties et al., 2012). In the stage of problem identification, since each stage such as task identification, format identification, and procedure identification, is completed at a different time, task identification for each stage can be checked to see whether it is performed well and/or related scaffoldings can be provided. Further, in the implementation stage, related feedback can be provided if there are no specific activities visible such as analysis and convergence. A rubric can be provided for learners to evaluate their contents and processes together in the evaluation stage.

Second, CSCL provides expanded teaching and learning opportunities for engineering design. It is possible for learners to perform a specific task online cooperatively, search related information easily, and apply it to the engineering design process. Since teachers can monitor learning processes of learners in real time, they may seek better and more effective solutions.

Third, this study investigates engineering design process in CSCL. In South Korea, government supports teaching and learning using computers or online technology as an educational policy, and K-12 practitioners utilizes these technologies in the process of teaching and learning. It is necessary for Korean technology education professions (teachers' educator, in-service teacher, pre-service teacher, and researcher) to pay more attention to the implementation of engineering design process using computers or online technology.

Limitations and future direction

First, the students' final product of this study is an online report format. If the final product is an activity for making a model or videotaping, the pattern of interaction could be different. Second, Google Drive, which is very popular and commonly used, is used for engineering design outcomes in this study. If a study is performed under a more structured and complex technology environment, the pattern of interaction could be different. Third, the students who participated in this study are technologically well informed and this study provides a decent internet environment. If participants are not technologically literate or an internet connection is not stable or available, then due to external factors such as help needed for technology, the pattern of interaction could be different. Fourth, if the scaffoldings are continuously provided throughout the engineering design process, the pattern of interaction could be different.

Based on the outputs of this study, the further study is proposed as following. First, this study is based on the comparisons of two different teams – highly achieved and less achieved. To generalize the outputs, the pattern of interaction needs to be studied among all other public teams. Moreover, the characteristics of learners, the degree to which problems are structured, technological environments, and other related variables should be considered. Second, this study addresses the interactions by CORDTRA analysis. Since CORDTRA is a tool to analyze conversations, fine limitations exist, as it is impossible to analyze any information not included in conversations. It is necessary to study interactions using videos, think aloud sessions, brain imaging, behavioral analysis, and various other ways.

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