Tracing the Knowledge Building Process through Discussions Mediated by a CSCL Environment: A Case Study

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ABSTRACT
This case study demonstrates the use of interaction analysis techniques to explore students' knowledge building process evidenced in time-stamped logs of a CSCL environment that consists of chat, shared whiteboard, and wiki features. The study was performed in a graduate level course, which covers online assignments that expect students to collaboratively discuss questions regarding statistical methods in chat sessions and share their solutions by co-authored wiki documents. More specifically, by applying the Progressive Knowledge Building Inquiry cycle, we investigated how learning groups enhanced their understanding of variables concepts of statistics in their collaborative activities in one of the assignments. The results cover learners' progress in their chat discussions and wiki submissions.

INTRODUCTION
The Knowledge Building (KB) theory proposes that knowledge is produced through mutual goals and negotiation of diverse viewpoints (Scardamalia & Bereiter, 2003). The theory offers a distinction between learning and knowledge building that considers the learning as an internal process which results in changes in beliefs, attitudes, or skills. Yet, knowledge building is respected as the process of construction or modification of public knowledge. According to the theory of knowledge building, learning is progressing by forming new cognitive artifacts as a result of common aims, group conversations, and synthesis of ideas. The process should advance the current understanding of individuals in a team and should aim to improve the understanding of what is known about topics or tasks.

Twelve "Knowledge Building principles" were developed for the purpose of various goals such as instructional guidelines, technology design definitions, and fundamentals for investigating existing practices (Scardamalia, 2002, p. 9-12):

- **Real Ideas, Authentic Problems:** Knowledge problems are caused by the aims of understanding the real world. Ideas are offered like real structures.
- **Improvable Ideas:** Ideas of individuals are respected as improvable objects.
- **Idea Diversity:** Idea diversity is essential for the development of knowledge. Ideas are constructed through comparisons, combinations and arrangements with other ideas.
- **Rise above:** The continuous development of ideas and understanding allow students build high level concepts.
- **Epistemic agency**: Individuals attain a personal and mutual responsibility in order to achieve knowledge building purposes.
- **Community Knowledge:** Knowledge Building attempts to advance collective knowledge of individuals.
- **Democratizing Knowledge:** All members of the learning groups are expected to make contributions to the knowledge development.
- **Symmetric Knowledge Advancement:** The transfer of knowledge is not only from more knowledgeable to less knowledgeable ones. The structure should be like that all members gain knowledge through their mutual efforts.
- **Pervasive Knowledge Building:** Students' contributions are important factors for collective knowledge building.
- **Constructive Uses of Authoritative Sources:** Knowing a discipline refers knowing authoritative sources that contribute to the current knowledge.
- **Knowledge Building Discourse:** With the help of discursive activities of the community, the knowledge is enhanced and transformed.

- **Concurrent, Embedded, and Transformative Assessment:** Assessment aims to identify problems while the process continues and integrated to the works of the community. Internal assessments are performed by the community to ensure that community work addresses to expectations of external assessors.

According to the knowledge building theory, one significant sense of the team should be functioning mutually rather than gathering individuals. This purpose of teams can be achieved by different Web 2.0 tools such as blogs, wikis, virtual worlds and CSCL environments, as well as with discussion tools integrated to learning management systems. Computer-supported Intentional Learning Environments (CSILE) project is the first attempt to provide schools with technology for the purpose of achieving knowledge building communities (Scardamalia & Bereiter, 1994). CSILE with its up-to-date variation named as the Knowledge Forum was offered as an instructional software to support collaborative knowledge building activities by demonstration of ideas in textual, audio, graphical, and video formats, and the organization of instructional artifacts. The project principally considers the production of knowledge by the collaborative study of learners and assistance of teachers. Hence, the distributed cognition model was applied, and social formations and discourse characteristics were considered in this social learning environment. The study investigates characteristics of knowledge building communities in three categories (Scardamalia & Bereiter, 1994). The first one considers that the focus should be on problems instead of knowledge types or topics. The depth of understanding is accomplished through argumentation and active participation. The second category offers that the community is a decentralized and open learning environment that facilitates collective knowledge building. More knowledgeable learners are expected to take participative roles in the learning process rather than standing outside the community. Participation of less knowledgeable learners is also significant to detect which topics are difficult to understand and whether explanations are adequate for understanding. The third category proposes that technology provides learners with access to databases, videos and other resources as well as live experts and more advanced learners. The other large-scale implementation of the knowledge building theory was performed by the Learning through Collaborative Visualization (CoVis) Project which aims to transform traditional science learning by the use of networking technologies which provide students with collaborating with distant students, instructors and scientists (Edelson & O'Neill, 1996). The envisioned and implemented learning environment supports and facilitates inquiry oriented collaborative activities through collaboration and communication tools like desktop video teleconferencing, shared software environments for remote/realtime collaboration, access to the World Wide Web resources, a multimedia scientist's notebook and scientific visualization software. This project is still being pursued for supporting science education at urban schools in Illinois, USA.

Some methods have been proposed for the assessment of group or community knowledge as they are captured in knowledge artifacts in environments such as CSILE and CoVis. In general, assessment can be performed in terms of group products, like a report, a plan, a software application, a design artifact, etc. Yet, group works may not be a well-defined, coherent product, and products may not represent contributions and understandings of all group members. Hence, it becomes difficult to investigate the development of knowledge at the individual and group levels by only investigating the knowledge artifacts. In majority of online learning contexts, online discussions are considered as the main learning activity and online activity logs are treated as the groups' main knowledge building outputs. Studies focusing on time-based organization of these logs trace the knowledge building trajectories of every group and individual. However, such an undertaking results in challenges, because of emergent structures and discontinuities in interaction. As an alternative method, some researchers employ peer assessment methods for the investigation of group learning, which searches for indication of learning considering students' reflections on each other's activities, omitting the need for applying detailed log analysis (Strijbos & Sluijsmans, 2010). In spite of these benefits, the investigation of group products brings additional duties on the students and assessments of their peers and the group work may be too narrow in coverage for a complete analysis of knowledge building processes (Hong & Scardamalia, 2014). In addition, alternative methods have been proposed for the investigation of knowledge building. For example, learners may submit portfolios to deliver reflections on their learning throughout their collaborative study. In other assessment method, students are required to conduct some tasks named as "guided inquiries" that investigate what they explored together, where the goals, key questions and procedures are submitted by teachers or facilitators (van Aalst, 2012). Portfolios and guided inquiry activities provide researchers with more evidence related to learning through knowledge building at the individual level. On the other hand, these approaches are inadequate in terms of assessment of group level phenomena and accounting for what causes learning outcomes evidenced in portfolios or guided inquiry exercises.

Statistics that capture various sides of knowledge building activities are also used for assessment purposes. The majority of research employs assessment measures like average number of notes created, notes read, notes revised, words per note etc (Hong & Scardamalia, 2014). Although these kind of measures are effective in

detecting behavioral patterns of learners and interaction patterns of groups, they are not suitable for analyzing contents of the knowledge elements the groups are working on. In order to get rid of this problem, content analysis methods are generally applied to examine the knowledge content produced by learners. Procedures and a set of knowledge building principles are offered for the assessment of activities in collaborative learning environments (Scardamalia & Bereiter, 2003).

Every course is structured according to its learning goals, content and plan. This structure indicates the concepts that students should understand and think about. According to knowledge building theory, learning is not seen just a simple knowledge acquisition process, instead it is an active process of social inquiry in terms of a social constructivist perspective. Therefore, while collaborating to comprehend the course concepts, students may have problem in understanding some of them, and may build special terms and behaviors while making a discussion regarding problematic issues. This kind of practices or shared concepts developed by learners while discussing about problems is of theoretical importance for knowledge building theory and CSCL field. After the learning session ends, the teacher or a system designer may attempt to understand whether the session is effective or not for the learners, and which instructional gains learners acquire throughout the session. In the collaborative learning context, learners' gains are parallel to their interaction in the group. In order to explore these benefits, one can collect the protocol data of the session, then make a deep analysis and examine the benefits (Inaba, 2002). Moreover, it is significant to trace these developments based on instructional goals of the collaborative activity.

In this research, we analyzed learners' interaction in a CSCL environment according to some key concepts of a course and explored the outcomes they achieve by the help of the research that we performed. For our purposes, the qualitative analysis is especially significant to provide interpretations about the knowledge building processes supported by chat and wiki activities. In this study, we considered sentences of chat messages as the unit of analysis and examined them based on Progressive Knowledge Building Inquiry cycle (Hakkarainen, 2003; White & Frederiksen, 1998), which generally begins with a trigger activity and covers four major stages; (a) idea generation, (b) idea connection, (c) idea improvement, and (d) rise above. The details of the cycle were provided in the Methodology section. The remainder of the paper is organized as follows. In the section 2, we presented our methodology. We dedicated the section 3 for providing findings of the study. In the final section, we presented the summary and implications of the results for researchers and practitioners.

METHODOLOGY

We conducted the study in the setting of a graduate level course of one large university in Turkey. This course integrates major concepts of empirical research and experimental design. The instruction was performed in a face-to-face manner and assignments were collaboratively conducted in online means. In total, the course has 15 registered learners. Each learner was assigned to a group and five teams were constructed. Teams were required to execute course assignments by collaboratively studying online in the Virtual Math Teams (VMT) environment (figure-1), hence their whole interaction could be investigated. The aim of the assignments was to provide students with extending their understanding of key statistics concepts by collaborative studies where they perform a specific type of analysis by using SPSS software. During their works in assignments, teams initially conduct online chat meetings, then submit their solutions as online documents.

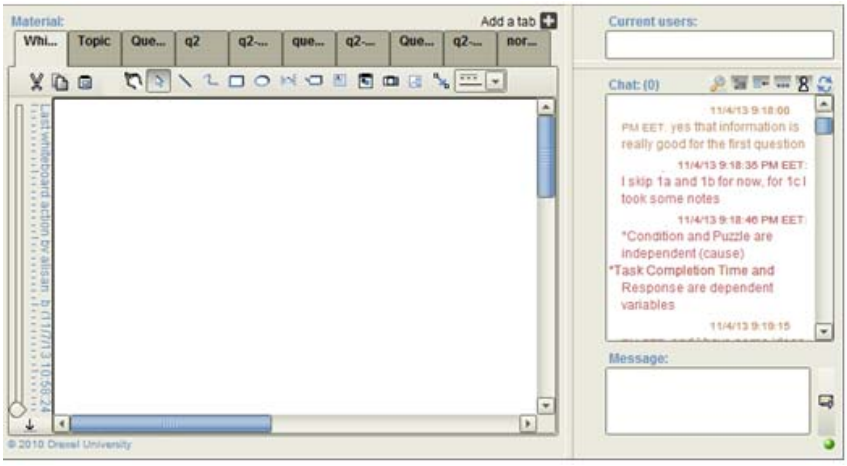

Figure 1 – VMT Environment

Throughout the term, learning teams collaborated on seven assignments and shared their solutions as co-authored reports in the online wiki environment. The chat tool of the VMT enables students to collaborate in a synchronous manner. In the chat context, learners can additionally use the whiteboard tool to explain their work by constructing shapes or submitting screenshots of their SPSS outputs. After the discussion ends, students summarize results of their work as Wiki outputs which covers both textual information and visual demonstrations. After the term completed, we gathered teams' data which includes chat logs produced by the VMT system and the wiki content submitted by teams for each assignment. The chat log principally involves teams' textual messages and whiteboard activities with corresponding author and time information. The wiki content is submitted online, structured in terms of assignment questions, and consists of both textual and graphical elements to provide explanations for solutions.

In this research, we aimed to employ methods for evaluating knowledge building processes which were observed in multiple media (chat and wiki) and multiple time periods (synchronous and asynchronous). For this purpose, we attempt to apply qualitative interaction analysis methods in order to detect whether learners show conceptual development or not. In order to investigate learners' knowledge construction process in the VMT system, we considered their verbal interaction related to assignments of the course. Knowledge construction is seen as a social and dialogical process where learner participation is significant. We employed sentences of messages as the unit of analysis and investigated them according to the Progressive Knowledge Building Inquiry cycle (Hakkarainen, 2003; White & Frederiksen, 1998), which starts with a trigger activity and consists of four main phases; (a) idea generation, (b) idea connection, (c) idea improvement, and (d) rise above. Trigger activity often covers the question statement that allows learners to offer ideas and solutions. The stages are explained as follows (So et al., 2010):

- **Idea generation:** In this stage, students produce ideas or questions about the theme or topic. In other words, in their collaborative activity, students propose their ideas and related intentions for the answers of questions.
- **Idea connection:** In this stage, learners compare and contrast diverse ideas for the purpose of idea connection.
- **Idea improvement:** Learners search for new information and knowledge in this phase.
- **Rise above:** This phase considers learners' reflections about their own learning. More specifically, "students think about what they have learnt, how this new knowledge has helped them in answering their initial questions about the theme or topic of study, and what new perspectives of knowledge has been built from the activities" (So, et.al, 2010, p. 482).

We explained our research with a case study which focuses on learners' progress in identifying the scales of variables. The chat logs and wiki content that were analyzed as part of the case study were obtained from the first assignment, which included the following instructions:

> *In an eye tracking experiment a researcher asked participants to solve two puzzles in 3 different conditions; namely picture, blank and fixation. 94 subjects attempted two different puzzles called Towers of Hanoi and River Problem. The task completion times and the responses provided by the participants are displayed in cogs536_hw1.sav.*
> *In the Towers of Hanoi (TOH) puzzle the goal is to move all the disks on peg A to peg C so that the disks will appear in the same order in size (i.e. smallest on top). A larger disk cannot be placed on top of a smaller disk at any intermediary state of the solution. Given this restriction the participants were asked to figure out what would be the minimum number of moves required to reach the desired state (i.e. all disks are on peg C, ordered from smallest to largest).*
> *In the river problem (RP) subjects are given a situation where a man buys a sheep, a wolf and a box of cabbage from a village across a river. The man has to use a boat to return home, but the boat can only load one of the sheep, wolf and the box of cabbage at a time. If he leaves the wolf and the sheep on the same side, the wolf will eat the sheep and if he leaves the sheep and the cabbage on the same side alone, the sheep will eat the cabbage. Subjects are asked what would be the minimum number of trips required to pass all items across the river without losing any one of them.*
> *Each participant was informed about the rules of the puzzle and then randomly assigned to one of the puzzle groups, and then to one of the picture, blank and fixation conditions. In the picture condition, subjects were presented a picture that represents the initial state of the problem as a visual aid. In the blank condition subjects look at a black screen after they finish reading the instructions. In the fixation condition participants have to fixate on a cross sign located at the center of the screen (i.e. their eye movements were restricted) while they are thinking about the problem.*
> *In each condition participants pressed the SPACE bar when they are ready to report the answer. The duration between the slide presenting the question and the key press is considered as the task completion time. Participants then entered their answers into the box that appear after they press the space button.*

Given the description above, answer the following questions with your teammates:
a. What are the dependent/independent variables? What do you think is the goal of this study?
b. On what scale are the variables measured (i.e. nominal, ordinal, interval, ratio) and why? Note: don't just say that a variable is measured at the interval scale, but also justify your answer by mentioning the properties satisfied by that variable.

RESULTS

In this paper, we present results of first assignment belong to the team-1. Demographic characteristics of team-1's students are provided in the Table 1.

Table 1: Demographic characteristics of students

Subject Handle	**A_S**	**G_C**	**Y_A**
Gender	Male	Female	Male
Grade	PhD	Masters	Masters
Undergraduate major	Physics	Foreign Language Education	Electric and Electronics Engineering
Graduate major	Biomedical Engineering	Cognitive Science	Cognitive Science
Current GPA	3.00-3.50	3.00-3.50	3.00-3.50

Learners' Knowledge Building Process

Topic: Dependent and Independent Variables

The team's discussion about the variables concept was initiated with the question of A_S in line 64 for detecting variables in the study. As a reply to this question, G_C considered the type of dependent variable and offered that the task completion time is in this type (line 65). The question covers an experiment that examines effects of three conditions on participants' task completion time and responses, hence G_C classified the task completion time in correct way. In order to be sure about this offer, G_C requested for ideas of other members (line 66). A_S thought in similar way and offered G_C to share this idea in the whiteboard area by stating her contribution to this question (line 67). Yet, this solution was not sufficient since the response variable should be considered as the other dependent variable. Analysis of the messages between lines 64 and 68 based on Progressive Knowledge Building Inquiry cycle leads to the next interpretations. Initial message (line 64) involves the question (i.e. variables), therefore it is a trigger activity that encourages members to produce ideas about the variables. In the message in line 65, G_C offered the "task completion time" as a dependent variable, which classifies this activity in the phase of *idea generation*. In the line 67, A_S stated his agreement about this idea.

Table 2: Learners' Discussions between lines 64 and 75

Line	**Date**	**Post Time**	**Chat Message / Whiteboard Activity**
64	11.07.2013	5:52 PM	A_S: what about the variables?
65	11.07.2013	5:53 PM	G_C: task completion time is dependent;
66	11.07.2013	5:53 PM	G_C: right?
67	11.07.2013	5:54 PM	A_S: I think the same, so lets you add it by 4 tildes :)
68	11.07.2013	5:54 PM	G_C: ok :)
71	11.07.2013	5:57 PM	G_C: how about the independent variables?
72	11.07.2013	5:57 PM	A_S: experiment condition?
73	11.07.2013	5:58 PM	A_S: picture, blank, fixation
74	11.07.2013	5:59 PM	G_C: well yes, i believe
75	11.07.2013	6:00 PM	A_S: I believe so :) Ok I write it

After finding the dependent variable, G_C wanted to identify independent variables (line 71). As an offer, A_S stated that experiment conditions (i.e. picture, blank, fixation) are independent variables (line 72,73) and G_C confirmed this offer (line 74).This was a right solution since the experiment considers effect of conditions on participants' task completion time and responses. In parallel to the team's decision, A_S propose to share the solution (line 75). As in the messages in lines between 64 and 68, the team has a similar performance between messages in lines 71 and 75 in terms of Progressive Knowledge Building Inquiry cycle. In the message in line 71, G_C indicated the question (i.e. independent variables), hence encouraged members to generate proper solutions, which can be considered as trigger activity. In the messages in line 72 and 73, A_S provided his idea by stating experiment conditions as independent variables, which demonstrates the phase of *idea generation*. In lines 74 and 75, members approved this idea.

Wiki Reflection of Dependent and Independent Variables

The wiki output consists of the team's all decisions in the chat environment about the variables concept. As offered in the chat, G_C reported the results that "The task completion time is the dependent variable. Independent variables are the experiment conditions, namely, picture, blank and fixation. The puzzle type is another independent variable."

Topic: Scales of Variables

The team started to discuss about scales of variables, which were decided in the previous discussion. G_C proposed that the task completion time is on ratio scale (line 79). A_S provided confirmation to this idea and advised G_C to share it in the whiteboard environment (line 82). G_C wrote the solution and provided rationale that "the task completion time is measured on the ratio scale since it is the response time that is shown in milliseconds." This interpretation was not actually appropriate for the ratio scale. G_C tried to provide further justification but stated that she couldn't find the content related to the scales of measurement (line 83). Thus, A_S indicated that he could wait while G_C was looking for the content (line 84). After some time, G_C provided the further interpretation that "each response says something about the performance of each participant under a certain condition" in the whiteboard area and stated the completeness of the interpretation (line 86). However, these solutions do not demonstrate the appropriate reasoning about ratio variables. She could indicate the representation of identical intervals in the scale and the existence of meaning regarding ratio of values.

Table 3: Learners' Discussions between lines 79 and 92

Line	Date	Post Time	Chat Message / Whiteboard Activity
79	11.07.2013	6:04 PM	G_C: for part d, i think task completion time is on ratio scale.
82	11.07.2013	6:04 PM	A_S: Okey, you write it then :)
			G_C wrote "The task completion time is measured on the ratio scale since it is the response time that is shown in milliseconds" to the whiteboard
83	11.07.2013	6:10 PM	G_C: I will add my justification in a minute. I just lost the slides that explains the scales of measurement
84	11.07.2013	6:10 PM	A_S: okey... I'm waiting
85	11.07.2013	6:10 PM	G_C: ok
			G_C continued to add justification by writing "each response says something about the performance of each participant under a certain condition." to the whiteboard
86	11.07.2013	6:11 PM	G_C: i think it's ok now
87	11.07.2013	6:12 PM	G_C: what about the other variables?
88	11.07.2013	6:17 PM	A_S: independent variables are in nominal scale? they are ordered in numbers
89	11.07.2013	6:19 PM	G_C: yes, definitely, moreover i think we can even take the puzzle group here since they are also categorical ??
92	11.07.2013	6:19 PM	A_S: Okey..your are right...
			G_C wrote "The independent variables are all measured on the nominal scale since they display categories." to the whiteboard

In the next message, G_C expected her team members' opinions about the scales of other variables (line 87). A_S answered that independent variables are in nominal scale and they are ordered in numbers (line 88). G_C provided confirmation to this offer and additionally offered to consider puzzle group in nominal scale since they have some categories (line 89). A_S approve the idea of G_C (line 89). Then, G_C reported the solution in the whiteboard that "The independent variables are all measured on the nominal scale since they display categories. "Although the final solution was correct, one could criticize A_S's first statement that nominal scale refers to a variable ordered in numbers. The appropriate interpretation should consider existence of more than two categories. According to Progressive Knowledge Building Inquiry cycle, in the messages in lines 79, 88, and 89, the team stated answers and a line of reasoning for detecting the scale of a variable, so they are considered in the phase of *idea generation*. The messages in lines 82, 89 and 92 showed agreements to these ideas.

Wiki Reflection of Scales of Variables

As a report, G_C shared the solution that "The task completion time is measured on the ratio scale since it is the response time that is shown in milliseconds and each response says something about the performance of each

participant under a certain condition" and A_S indicated the statement that "The independent variables are all measured on the nominal scale since they display categories."

DISCUSSION AND CONCLUSION

In order to investigate how learners accomplish knowledge building in their collaborative study in chat environments, we analyzed the verbal interaction among learners in the VMT system while they were discussing about assignment related content. By applying the Progressive Knowledge Building Inquiry cycle (Hakkarainen, 2003; White & Frederiksen, 1998), we investigated how learning groups enhanced their understanding of major concepts of statistics in their collaborative activities. The Progressive Knowledge Building Inquiry cycle begins with a trigger activity and covers four phases; (a) idea generation, (b) idea connection, (c) idea improvement, and (d) rise above. The results showed that learning groups' discussions usually started with the trigger activity which consists of the textual statement or number of the question. Then, learners' activities continued with idea generation and idea connection stages. Members' solutions offered for the question showed the phase of idea generation. However, idea connection, idea improvement and rise above phases were absent in our results. Comparisons and decisions regarding the solutions demonstrated the idea connection phase. During the idea improvement phase, learners utilized proper sources for the answer of the question, which wasn't considered as preference of our learners. The reason may be that they preferred to consider knowledge and experience of their peers in a collaborative learning environment. During the rise above phase, learners provided reflections about their existing understanding. Our findings are parallel with the study of So et al. (2010), which applied content analysis to Knowledge Forum postings for investigating learning teams' improvement in terms of their ideas. Results of the study showed that learners lacked the ability of improving their ideas and providing sources in their solutions.

We considered the content where the "variables" concept was discussed by the team. Our goal is to investigate how learners made progress during chat activities while working on this concept. We presented the corresponding results for the Team-1. That is, we showed learners' conflicts, explanations, opinions, and final solutions regarding the concept. In addition, we investigated adequacy of their final solutions. In summary, these results explored the instructional advantages that learners acquired in their collaborative study.

Wiki output is structured according to questions of the assignment. Therefore, each wiki segment directly maps onto a question. For each question, we firstly applied interaction analysis to chat segment and then applied the content analysis to wiki output. We compared the wiki content with the solutions offered in the chat environment, therefore discovered the similarities and differences in the final wiki solution as compared to the solution provided in the chat environment. Furthermore, we examined the adequacy of the content provided as the solution of the question. In this regard, our analysis is consistent with the completeness aspect of the final product of the assessment framework offered for the evaluation of the wiki based team work (Putro, Carbone, & Sheard, 2014). With the completeness attribute, the framework examines the sufficiency degree of the final product as compared to task specifications. Yet, the framework additionally investigates the integration and synthesis of individual contributions by the cohesiveness attribute, which can be added to our methodology as a future study.

On the basis of first assignment that team-1 discussed in the chat, we presented the analysis results of wiki content after the interaction analysis of their chat discussions. As in the former stage, we considered the wiki content where the "variables" concept was covered as the solution of the questions and provided the content analysis results of wiki output. While some of the decisions taken in the chat environment were directly reflected to the wiki content, some additions or removals were performed in the wiki content as compared to chat discussions. The content analysis of wiki output enabled us to identify similarities and differences in the finalized wiki solution in comparison to solution decided in the chat environment. Additionally, we revealed the adequacy of the wiki content provided for the solution of the question. These results are important to understand efficiency of team-1's chat discussions in these concepts and solving questions.

In order to check reliability of our content analysis, we applied the interrater reliability and compared interpretations performed by two different researchers. As a result, the percent agreement was found as 87%, which highly satisfies the reliability.

First limitation of this research was its scope. Its scope was limited to a graduate course of Informatics Institute in a public university in Ankara, Turkey. Other limitation was that we investigated data of one team out of five teams in the course. The future study could consider all teams of a course. The chat corpus had two main challenges for the analysis that it covers non-English words and it had noisy structure. Hence, we were required to perform preprocessing of data before conducting the main analysis. Through the interaction analysis, we

analyzed learners' knowledge building in variables concept of the course content. The future study could make an investigation according to all concepts of the course. We performed analysis of wiki contents in parallel to contents of chat discussion. In other words, wiki content submitted as an answer of a question was analyzed if this question was discussed in the chat environment. As the future study, all wiki outputs could be in consideration by our study.

REFERENCES

Edelson, D. C., & O'Neill, D. K. (1996, April). The CoVis Collaboratory Notebook: computer support for scientific inquiry. In *Annual Meeting of the American Educational Research Association, New Orleans, LA, USA*.

Hakkarainen, K. (2003). Emergence of progressive-inquiry culture in computer-supported collaborative learning. *Learning Environments Research, 6*, 199–220.

Hong, H. Y., & Scardamalia, M. (2014). Community knowledge assessment in a knowledge building environment. *Computers & Education, 71*, 279-288.

Putro, I. H., Carbone, A., & Sheard, J. (2014, January). Developing a framework to assess students' contributions during wiki construction. In*Proceedings of the Sixteenth Australasian Computing Education Conference-Volume 148* (pp. 123-131). Australian Computer Society, Inc..

Scardamalia, M. (2002). "Collective Cognitive Responsibility for the Advancement of Knowledge". In: B. Smith (ed.), *Liberal Education in a Knowledge Society*. Chicago: Open Court, pp. 67–98

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The journal of the learning sciences*, *3*(3), 265-283.

Scardamalia, M., & Bereiter, C. (2003). Knowledge Building. In *Encyclopedia of Education. (2nd ed., pp. 1370-1373)*. New York: Macmillan Reference, USA.

So, H. J., Seah, L. H., & Toh-Heng, H. L. (2010). Designing collaborative knowledge building environments accessible to all learners: Impacts and design challenges. *Computers & Education, 54*(2), 479-490.

Strijbos, J. W., & Sluijsmans, D. (2010). Unravelling peer assessment: Methodological, functional, and conceptual developments. *Learning and Instruction*, *20*(4), 265-269.

van Aalst, J. C. W. (2012). Knowledge Building: Rationale, Examples, Design, And Assessment. *Computers In New Zealand Schools*, *24*(3).

White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction, 16*(1), 3–118.