

ACHIEVEMENT OF JOINT PERCEPTION IN A COMPUTER SUPPORTED COLLABORATIVE LEARNING ENVIRONMENT: A CASE STUDY

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ABSTRACT

The case study focuses on the interactional mechanisms through which online collaborative teams co-construct a shared understanding of an analytical geometry problem by using dynamic geometry representations. The collaborative study consisted of an assignment on which the learners worked together in groups to solve a ship navigation problem as described in the Virtual Math Teams (VMT) environment. In this paper, a single group's problem solving activities were qualitatively analyzed to understand how they achieved a sense of joint perception of their shared workspace as a navigational chart which encodes the physical relationships between landmarks in the form of angle and distance measures. The analysis of the excerpts indicated that the initial struggles and their resolution in interaction as participants mastered the use of dynamic features in their shared workspace helped them gradually develop a shared understanding of the key spatial relationships among landmarks encoded in the 2D chart.

Keywords: Computer supported collaborative learning, joint perception, CSCL, Virtual Math Teams (VMT).

INTRODUCTION

Computer Supported Collaborative Learning (CSCL) can be defined as 'the field concerned with how ICT might support learning in groups' (Ludvigsen & Mørch, 2009). Learners employ various computer-mediated-communication (CMC) technologies in order to communicate with their group members in a CSCL environment. CMC capabilities offered in such an environment can be categorized as either synchronous (e.g., via a chat facility or video conferencing), asynchronous (e.g., via a wiki, forum or e-mail), or a combination of both (Janssen, et al., 2007).

Measurement in CSCL attempts to observe, capture, and summarize individual and group behavior, from which researchers can make inferences about learning products and processes (Gress, Fior, Hadwin, & Winne, 2010). Assessment focuses on learner performance and takes two different forms; product or process assessment. While product assessment investigates final deliverables to evaluate whether a skill has been applied or a specific concept has been learned, performance assessment focuses more on the learning process (Retalis, Petropoulou, & Lazakidou, 2010).

Learning process in CSCL is highly related with fields of Social Constructivism which investigates how social interaction affects the development of cognition. The theory of Vygotsky considers people with their interior knowledge and explains that learners can internalize external knowledge as they interact with their peers and instructors. In this aspect, collaboration can be respected as a way to support formation of learners'

knowledge through the interaction with other learners. Similarly, the Shared Cognition Theory deals with gaining knowledge and skills through the surrounding environment. The theory considers the environment in which learning occurs rather than the cognitive process independent from the learning context (Kumar, 1996). Although the environment covers both physical and social contexts, the theory especially focuses on the social one that enables peers to build their learning. More specifically, the approach considers the collaboration as a process of forming and sustaining a shared conception of a problem.

In CSCL, learning is characterized as a collective meaning making process mediated by ICT technologies where different perspectives are negotiated and refined towards a common goal in interaction (Stahl, Koschmann, & Suthers, 2006). The co-construction of a joint problem space (Sarmiento & Stahl, 2008) and the achievement of reciprocal perspectives towards shared constructions in a shared space (Zemel & Çakir, 2009) are vital to the success of collaborative learning. Providing tools to help collaborators develop such a level of shared understanding is an important design goal in CSCL.

In this paper, we investigate how a group of students co-construct a shared problem space and interactively develop a joint perception of a geometry problem in an online CSCL environment called Virtual Math Teams. In order to accomplish objectives of the study, we focus on the sequential organization of chat postings and shared drawings to observe how participants used the affordances of this online environment to work towards a solution to their common task. In particular, we focus on the role of dynamic representations on the development of shared mathematical understanding in this setting.

METHODOLOGY

Research Design

The purpose of this study is to investigate how a group of students co-construct a shared problem space and interactively develop a joint perception of a geometry problem in an online CSCL environment called Virtual Math Teams. Qualitative methods have been employed in order to provide a deep understanding of the research problem.

The research questions of the study can be stated as follows:

- How the learning group showed progress while solving a geometry problem in an online collaborative environment?
- How the group achieved joint perception in their shared workspace?

Setting

The study has been performed in the context of a graduate level course named Situated & Distributed Cognition in one of the state universities in Turkey. As part of their coursework, registered students of the course were required to enter a collaborative online session to solve one assignment by using tools of the Virtual Math Teams (VMT) online platform.

The VMT allows groups of learners to work on problems through online discussion and collaboration (Stahl, 2009). The VMT environment has three main components: lobby, chat rooms, and wiki. The lobby provides the list of chat rooms which are organized under a collection of problems or topics to explore and discuss. The chat rooms support synchronous communication among learners with text-chat and a shared whiteboard for drawing and organizing ideas. Moreover, the latest version of VMT allows dynamic geometry constructions in the shared drawing area by emulating GeoGebra objects. Due to the complexity of the dependencies among dynamic objects, the current version of VMT implements a turn-taking protocol where only a single user is given the editing rights at a given time. No such restriction applies to the chat. Finally, each chat room is linked to a corresponding wiki page, which allows learners to publish their findings in the Internet.

Participants

Participants of the study were graduate students of Cognitive Science department in one of the state universities in Turkey. The students have different educational backgrounds and will get MSc or PhD degree after graduation. Eleven students, 7 female and 4 male registered to COGS 557-Situated and Distributed Cognition Course. The students were divided over two groups of four students, and one group of three students.

The paper focuses on excerpts from a single chat session that belongs to one of the teams of the course. The team was selected since they completed the collaboration session and provided an appropriate solution. The selected team has 4 members who were named as PF, SK, DO, and PO for ethical considerations. Demographic characteristics of students were provided in the Table-1.

Table 1. Demographic Characteristics of Students

Subject Handle	PF	SK	DO	PO
Gender	Female	Female	Male	Male
Grade	PhD	Masters	Masters	PhD
Undergraduate major	Foreign Language Education	Computer Science	Electric and Electronics Engineering	Physics
Current GPA	3.00-3.50	3.50-4.00	3.00-3.50	3.00-3.50

Procedure

Students were initially told about the aims of the assignment in class. The problem in the assignment was explained to students in the following format:

"According to the chart there is a lighthouse located at (4, 8) and a bridge on (12, -6). These are the two landmarks that you are expected to use in order to answer the following question:

- *The gyrocompass in the alidade reads that the lighthouse is located at 30.96 degrees and the bridge is at 105.95 degrees from the ship's perspective. Given the locations of those landmarks, draw the line of position (LOP) from each landmark and find the x, y coordinates for the ship."*

The assignment was based on navigation problems described in Hutchins (Hutchins, 1995), which was the core reading for the course. In this assignment, students worked with their teammates to solve a few basic navigation problems in the VMT environment. While collaborating online, students employed the chat function for the information share and used the Geogebra Tab as a navigational chart. Students brought information about the world (given in the questions) to this dynamic representational medium. Students were informed about the GeoGebra environment, which was appropriate to simplify the navigation task. The chart is the 2D Euclidean space where location will be determined by x-y coordinates (no latitude/longitude degrees, no Mercator projection issues). Directions are represented as follows: North indicates positive y-axis; South indicates negative y-axis; East indicates positive x-axis; and West indicates negative x-axis. Gyrocompass angles are given with respect to North (for instance 0 degrees is North, 90 degrees is East, 180 degrees is South, 270 degrees is West). The axes in the chart indicate nautical miles. The students were expected to locate the landmarks on the 2-D space, translate the compass reading from the ship's perspective to the map and connect the two LOPs to deduce the location of the ship. After completing their chat session, students were expected to summarize their team's answer to the assignment on a Wiki page.

Data Collection

After the online collaboration session ended, we have obtained student data from chat log files which were automatically generated by the VMT tool. The chat log file consists of date, start time, post time, duration, and event type related to each activity of the learner. Remaining columns are allocated for indicating chat messages and other activities of students. For instance, the activity can identify when the learner joins or leaves the room, demonstrates content of chat postings or provides detailed information about GeoGebra activities of learners. Additionally, we used the replay functionality of the VMT to investigate the sequential unfolding of chat and dynamic geometry constructions during the online session.

Data Analysis

At the beginning, we aimed to understand how participants organized their interaction into long sequences (i.e. chunks of activity) by applying Conversation Analytic (CA) methods. For this purpose, we have investigated chat logs to detect where new activities were initiated and where current activities were terminated. That is, we tried to identify transitions where learners are either (1) closing one activity and initiating another one or (2) pausing or temporarily suspending the ongoing activity and starting a new topic inserted within the larger activity (Zemel, Xhafa, & Cakir, 2007).

We employed the content analysis approach in order to analyze students' collaboration in the VMT environment. Content analysis adopts a qualitative perspective and tries to identify learners' contributions to collaborative study. The purpose of content analysis is to investigate learner contributions in online discussion environment, and to analyze the type of contribution (Fournier, Kop, & Sitlia, 2011). In our study, we employed the content analysis in order to investigate how the group co-constructed a shared problem space and interactively developed a joint perception.

RESULTS

Initially, we detected long sequences of activities that group members were involved in. Moreover, we have identified number of messages based on chat postings and GeoGebra activities of learners. Table-2 demonstrates the long sequences of topics that group talked about.

Table 2. Sequence of Topics of the Group

Topic Number	Topic Name	Number of Chat Posting	Number of GeoGebra Actions
T1	Testing functions of GeoGebra	0	9
T2	Exchanging greetings	7	0
T3	Recognizing the assignment	41	0
T4	Using functions of GeoGebra	42	27
T5	Solving the question	109	349

According to our findings in Table-2, we can summarize learners' actions as follows. Initially, two members (SK and DO) of the group joined to the VMT environment and tried to understand usage of GeoGebra by using its various functions such as drawing lines or inserting points with specific coordinate values (T1). Secondly, other two members (PF and PO) have joined to the conversation, so salutations were exchanged among the newcomers and prior ones (T2). Thirdly, learners attempted to comprehend requirements of the assignment by sharing their understandings (T3). Fourthly, one of the learners volunteered to explore the functions of GeoGebra, while she was being directed by knowledgeable members of the team (T4). Next, learners tried to understand and solve the question in the assignment (T5). Since our focus is on how the group members collaboratively developed a solution of the question, we focused on T5. We conducted an

interaction analysis of excerpts obtained from T5 to explore learners' achievement of joint perception in the following sections.

Locating the Landmarks on the Chart

After obtaining the document of the assignment and reading the questions, the group began to discuss possible solutions. PO made the first attempt and offered that they needed to mark locations of the landmarks (i.e. the lighthouse and the bridge) in the coordinate plane of the GeoGebra environment. Therefore, PO started to discover GeoGebra functions by aiming to perform marking these locations. At the same time, PF attempted to do the same task as PO. Yet, PF recognized PO's work and gave up doing. PO drew axis, put grids and landmarks (i.e. Point A and Point B). The resulted work of PO was provided in the Figure-1. The point A represents the lighthouse located at (4, 8) and the point B represents the bridge on (12, -6).

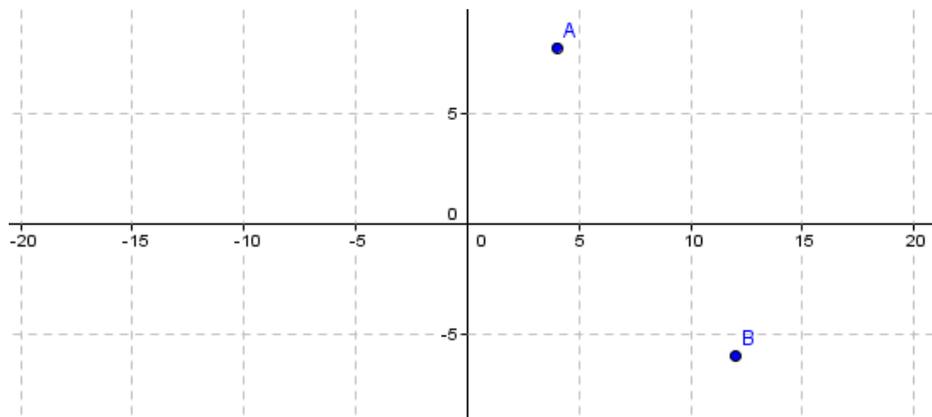


Figure 1. PO draws A to demonstrate the lighthouse and B to demonstrate the bridge

However, SK and PF stated that they couldn't see any drawings of PO. Hence, DO directed SK and PF to view drawings in the GeoGebra environment. This points to a usability issue involved with VMT. Toggling grid lines and adjusting zoom levels were local to each client, meaning they violate the WYSWIS principle. In other words, when a user toggles the grids, the grids may not be visible to all other members. Likewise, if a participant is zooming into a specific area, he/she may not be able to observe the drawings added to other sections of the GeoGebra board. The group members noticed the asymmetry in their perspectives and directed each other to establish a shared view where they can adequately monitor what is going on.

In order to achieve progress in problem solving, PO continued to work and attempted to draw lines with specified angles, but failed to organize the objects in the desired way. These were the initial trials of the group where they explore some of the relevant functions of the GeoGebra environment. In the following episodes the group proceeded with a discussion on how to reflect the angle information given in the problem on the workspace.

Line-of-Position Plotting on the Chart

The problem solving process of the group started with PF's suggestion to make a plan and start working according to this plan. More specifically, PF offered that they can identify the steps and then begin to work based on those steps (107). DO accepted the suggestion of PF (108). Afterwards, DO offered three steps for the solution (109-114). The steps were stated as follows; "step1: draw a straight line which cuts point A and which makes 30.96 degree with north (Y axis), step2: draw a straight line which cuts point B and which makes 105.95 degree with north (Y-axis), step3: label the intersection of the lines as ship position." PO confirmed the steps proposed by DO by stating that the intersection would provide the position of the ship. DO suggested that he could make a try to draw lines

(116,117). Initial trials of DO were provided in Figure-2. He drew a line passing through A (4,8) and the origin (0,0). However, in the question it was required that the line passing through point A should make 30.96 degrees with the Y axis (assuming positive Y-axis corresponds to north). This means that the initial solution proposed by DO didn't meet the requirements of the correct line of position drawing.

Table 3. Learners' Discussions between lines 107 and 117

ID	Time	Author	Message / Activity
107	13:23:49	PF	Guys, I think maybe we can discuss what steps we should take for each question and then start to working on that plan
108	13:24:28	DO	Yes
109	13:24:37	DO	I have an answer for the first step
110	13:25:02	DO	Answer1:
111	13:25:17	DO	3 steps
112	13:25:21	DO	step1: Draw a straight line which cuts point A and which makes 30.96 degree with north (Y axis)
113	13:26:18	DO	step2 draw a straight line which cuts point B and which makes 105.95 degree with north (Y-axis)
114	13:27:00	DO	step3: label the intersection of the lines as ship position
115	13:27:04	PO	intersection will give us the fix position of the ship
116	13:27:43	DO	I can draw it
117	13:27:48	DO	at least try <i>Initial trials of DO were provided in the Figure-2</i>

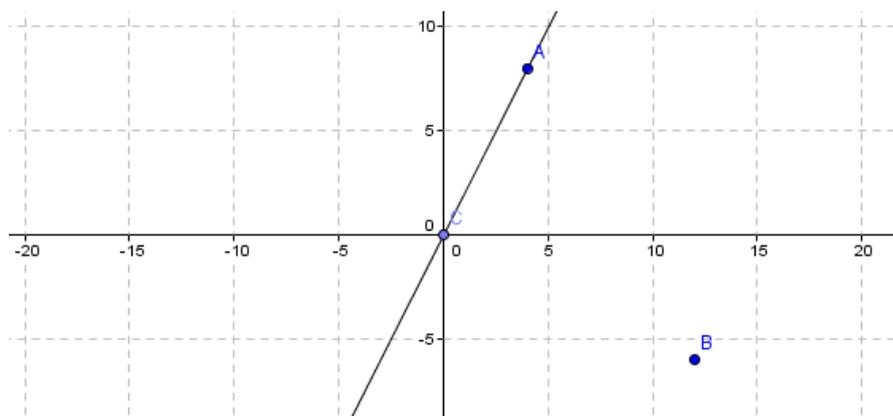


Figure 2. DO draws a line between the point A (4,8) and the origin (0,0)

DO performed several attempts to draw a straight line with a specified angle value, but couldn't succeed in that. Therefore, DO asked others if they knew how to draw a line with an angle of 30 degrees from another line (121-122). As a response to this question, SK guided DO by explaining the appropriate option to draw the line with a specific angle (123). She does this with a reference to the tooltip message associated with the button providing the desired function. Since the locale of the participants were in Turkey, Geogebra buttons were displayed with Turkish tooltip messages to the participants. At the same time, PF stated that she might be able to tell after trying out different options of GeoGebra (124). DO couldn't find the location of the option offered by SK, hence asked for her help (128). SK elaborated by mentioning the place of the top-level icon that leads to the desired button (129) and its order in the toolbar (131). In GeoGebra drawing features are presented in a hierarchical way which requires an extra click on the top-level button to make more options available. DO responded that he found the option based on SK's description (130). Next, PO suggested that they could draw a line making that specific degree and move its end to point A. She additionally stated

that this task was similar to using a parallel ruler. PF provided an affirmation to this suggestion by saying that "it is the way that we should do" (133). In the meantime DO was trying to draw a line with specific angle but couldn't succeed again, and hence decided to give up the control (134). Following DO, PO also tried to draw lines based on previously stated guidelines but couldn't succeed as well.

Next, DO stated that he had solved the problem by employing basic analytics (142). Similarly, PO indicated that she knew the solution but couldn't draw it on the shared workspace (143). DO repeated the first step for the solution by stating that they should "draw a line which makes 30.96 degree with north and slide it till it hits point A" (146-148). PF confirmed the suggestion of DO and explained the second and third steps (149). She said that they should draw a line passing through the point (12, -6) and having 105.95 degree with the north. She also mentioned the key observation that the ship should be located at the intersection of these lines. To summarize, the group agreed on the steps of the solution but couldn't draw it on the chart by using the GeoGebra functions.

Table 4. Learners' Discussions between lines 121 and 149

ID	Time	Author	Message / Activity
121	13:31:25	DO	I need 30 degrees
122	13:31:36	DO	how can I get it any idea?
123	13:31:54	SK	there is a "verilen ölçüde açı" option
124	13:31:57	PF	let me try it and then I will tell you
125	13:31:59	PO	can i ask something
126	13:32:10	PO	do we know that we are on the x axis
127	13:32:39	SK	is there any coordinate plane, because i cannot see anything other than point A and point B
128	13:32:44	DO	where is it exactly SK
129	13:33:22	SK	DO it's under "açı"
130	13:33:30	DO	ok little triangle
131	13:33:40	SK	the 8th item on the toolbar
132	13:34:54	PO	like they use the parallel ruler, we can draw a line making that specific degree and move its end to point A
133	13:35:58	PF	I think it is the way that we should do
134	13:37:14	DO	I give up guys
135	13:37:24	DO	Any one who take control
136	13:38:06	DO	cleaned up all mass
142	13:42:53	DO	I solved the problem with basic analytics
143	13:43:05	PO	i know how to do it but cant:)
144	13:43:53	DO	but anyways
145	13:43:57	DO	it is not important
146	13:44:04	DO	solution for step1:
147	13:44:11	DO	Draw a line which makes 30.96 degree with north
148	13:44:31	DO	and slide it till it hits point A
149	13:44:46	PF	it is true, I think, then we should do the same for (12, -6) and 105,95 and then the intersection is the place of the ship

Locating the Ship

SK took the control (159) and began to produce some drawings. While SK was working on the drawing, PF tried to solve the problem by conducting drawings on a piece of paper (160).

Table 5. Learners' Discussions between lines 159 and 167

ID	Time	Author	Message / Activity
159	13:49:54	SK	can i try something after you finish DO
160	13:49:56	PF	i am doing it on the paper :))
161	13:58:04	PF	in the meanwhile that SK is trying, I think we can look at the chapter 3-4 slides, slides number :17,18,19
162	13:59:34	PF	However, I do not know how we should do it by geogebra
163	14:04:18	PO	i need to be away for a few minutes, but i'll be back, my friend forgot her key, i need to help her:)
164	14:06:54	PF	ok, we are here :) <i>Initial drawings of SK were demonstrated in the Figure-3</i>
165	14:07:14	PF	SK could you please explain what you have done so far :)
166	14:09:12	SK	i just draw the first line of position
167	14:09:24	SK	sorry it took time to explore the geogebra tool <i>Continued to work on the GeoGebra environment, her finalized drawings were provided in the Figure-4</i>

PF decided to do the drawing on paper since she was confused about using GeoGebra functions (162). In addition, PF suggested essential information for the solution of the problem (161). She mentioned the slide numbers in the lecture notes of the course that contained a similar example. However, PF subsequently stated that she didn't know how to do this by the GeoGebra tool (162).

SK continued to work on the problem through functions of GeoGebra; her initial drawings were provided in Figure-3. She inserted the point C to represent the Lighthouse and added point E to represent the Bridge. Additionally, she drew a line passing through point C and having 149.04 degree with respect to north (i.e. the y-axis). Notice that $180 - 149.04 = 30.96$, which is the angle given in the problem statement. So, SK seemed to figure out a way to draw a line with the desired angular relationship with respect to north. After this progress towards the solution, PF asked SK whether she could explain what she had just drawn (165). In response to this question, SK stated that she just drew the first line (166).

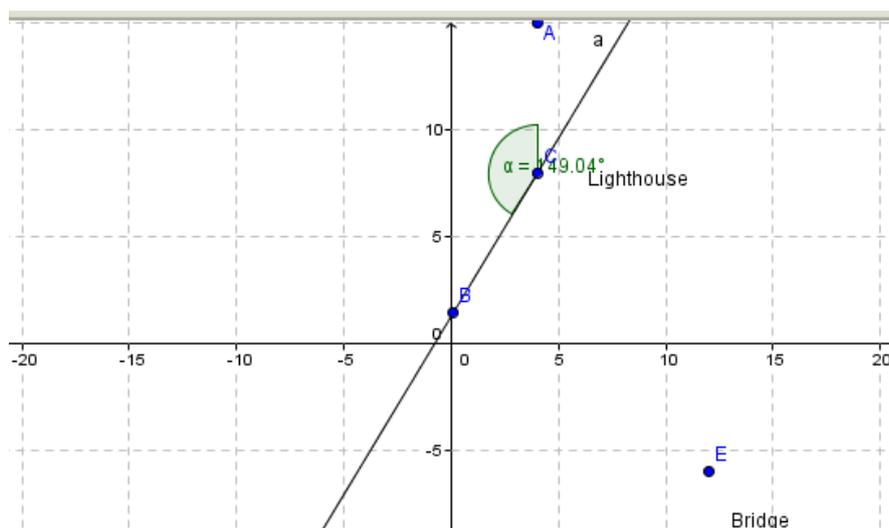


Figure 3. SK draws a line passing through point C and having 149.04 degree with the north axis

SK continued her drawing and finally proposed the solution provided in the Figure-4. SK solved the problem by drawing the first line crossing the lighthouse with 149.04 degrees and the second line crossing the bridge with 74.05 degrees, and marked the intersection of these lines as the location of the ship – Point C.

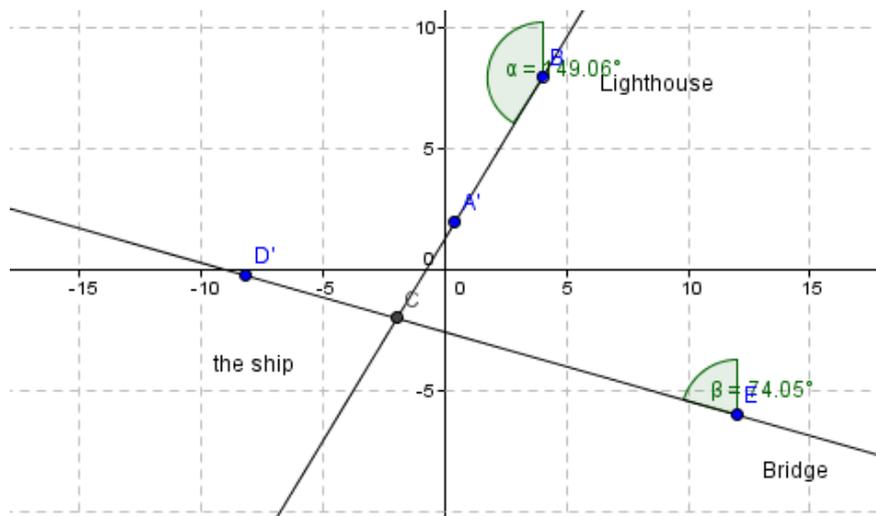


Figure 4. SK draws a line passing through point E and having 74.05 degree with the north axis

SK suggested explaining the steps that she followed (175) and DO approved this offer (176). In order to explain the line passing through the lighthouse, SK stated that for the lighthouse to be 30,96 degrees from the perspective of the ship, it should be 149,06 counterclockwise from the lighthouse (177). DO asked why SK used the degree value – 149,06 instead of 30,96 which was the value provided in the question (178). Also, PF agreed with DO (179). Next, PF asked that “E point is the Bridge, B is the lighthouse and C is the ship, right?” (180). PF’s message displays her understanding of what each point represents in the new drawing. DO confirmed SK’s solution (181) and congratulated her on this work (182). However, SK was not sure about the solution and asked for ideas of other group members (183). PF thought that the solution was correct but stated that she had doubts about applying the subtraction operation on the angle computed from the ship’s perspective (186). In short, it seems there is not much disagreement among group members about the validity of SK’s solution proposal, but they were ambivalent about the use of the subtraction method and its relationship to angular measures obtained from the ship’s perspective.

DO asked SK again whether she could explain her work (187). SK stated that the first action they should perform is inserting landmarks (i.e. lighthouse and bridge) into the coordinate plane (189). DO continued on this explanation by indicating that they should consider the location of the lighthouse from the ship’s perspective and hence should perform appropriate operation to find the line of position (190). SK identified this operation as using alternate interior angle (191) and provided its Turkish equivalent term (i.e. iç ters açı) from the educational content of the high school (194). DO confirmed explanations of SK (192). DO asked SK how she could draw the line by only using specified angle option (195). As a response, SK provided a detailed explanation as follows. She stated that she “needed to create points A and D as virtual north in order to specify the angles” (197). Additionally, she indicated that the system automatically created A’ and D’ points (198). Therefore, she explained that she had added two lines: the first one was between Lighthouse and A, and the second one was between Bridge and D (199). DO expected a confirmation related to representations of A (for Lighthouse) and D (for Bridge) (200) and SK provided the affirmation (201). PO thought that the first question was completed (202).

Table 6. Learners' Discussions between lines 175 and 204

ID	Time	Author	Message / Activity
175	14:17:36	SK	now let me explain what i have done
176	14:17:42	DO	Ok
177	14:17:56	SK	for the lighthouse to be 30,96 degrees from the ship perspective, we should 149,06 counterclockwise from the lighthouse
178	14:18:03	DO	SK why don't we see 30.96 but 149.06 (180-30.96)
179	14:18:41	PF	DO, I see
180	14:18:57	PF	E point is the Bridge, B is the lighthouse and C is the ship, right?
181	14:19:12	DO	by the way you did it correctly
182	14:19:21	DO	congrats :)
183	14:19:32	SK	:)
184	14:19:41	SK	does it seem ok?
185	14:19:59	DO	$74.05 = 180 - 105.95$
186	14:20:06	PF	I think it is right, the only doubt that I have is that you have minus the ship perspective from 180.,
187	14:20:48	DO	how did you do it explain please
188	14:20:55	DO	:)
189	14:21:38	SK	we first needed to put the lighthouse and bridge on these position on the coordinate plane
190	14:21:45	DO	the angle with north is 30.96 in lighthouse
191	14:22:22	SK	and than, because L is 30,96 degrees from the ship's perspective, we need an operation to find the line of position using alternate interior angle
192	14:22:27	DO	it is ok PO did that
193	14:23:13	DO	drawing the lines :)
194	14:24:41	SK	"iç ters açılı" from high school :)
195	14:25:57	DO	how could you draw it by only using specified angle option?
196	14:26:02	PO	ok im back
197	14:26:48	SK	i needed to create points A and D as virtual north in order to specify the angles
198	14:27:44	SK	it gave A' and D' automatically
199	14:27:58	SK	and i only added the lines between Lighthouse and A' & Bridge and D'
200	14:28:04	DO	ok A for Lighthouse and D for bridge
201	14:28:39	DO	Ok
202	14:28:39	SK	yes, exactly
203	14:28:55	PO	so first question is done
204	14:29:16	SK	Hopefully

DISCUSSION

In the excerpts presented above group members collectively discussed and developed a graphical solution to the navigation problem they were given. As part of this process the group had to associate the locations of the two landmarks on the shared map and figure out how they should use the angular information given from the ship's perspective on those landmarks. In other words, they had to develop a joint perception of the objects and their relationships encoded in the shared scene.

Initial attempts of students were towards understanding the problem and discovering functions of the tool. Learners' understanding and statement of the problem can be interpreted as a trigger activity which is proposed as the initial phase of the Progressive Knowledge Building Inquiry cycle, and defined as an activity that involves question

statement and encourage learners to propose ideas and solutions (Hakkarainen, 2003; White & Frederiksen, 1998). Identification of the VMT's functions is the second goal of the group and considers the indication of landmarks in the GeoGebra environment. Although one member located the landmarks on the chart, other members experienced problem about displaying these insertions. This problem was actually related to difference in students' perspectives in using the tool. It was solved with the collaborative directions, which demonstrates the construction of a shared view through peer support. This can be also identified as a collaborative effort (Chan et al., 2001), which considers that learners exhibit attempts to assist others in understanding the common problems.

Problem solving process of the group started with their preparation of a plan. According to this plan, they should initially draw two lines by considering point and degree values. In this way, they would be able to find their intersections and discover the location of the ship. In order to draw lines, some members demonstrated some tries by employing different functions of the VMT. This can be considered as idea generation according to the study of So et al. (2010) since members proposed their ideas for the solutions of questions during the collaborative study. Although members offered ideas, they couldn't achieve drawing the lines with expected conditions. Yet, members' struggles in drawing the lines lead to share of knowledge towards using appropriate functions of the tool and collaborative decision towards the steps of the solution. This process can be viewed as organization of ideas which offer that existing thoughts are combined for the generation of final decision (Stahl, 1999).

Once the group figured out what drawings had to be done, what they needed to finish the task was to find a digital equivalent of a hoey, which integrates angles with straight lines in a single physical artifact in the context of real-world navigation. This device makes the application of angular orientation on the map from the ship's perspective transparent. However, the group had to invent a functionally equivalent way of drawing lines in a digital environment, similar to the way a hoey is used over a paper map. The main challenge faced by the team was involved with the way Geogebra represents and displays angles. Geogebra requires the selection of three points where each pair of points defines a line. The angle is drawn either as an interior or exterior angle depending on the order of clicks on the points. Clicking on the points in the clock-wise order produces the angle representation inside the intersecting lines (i.e. interior angle). This seemed to be the most confusing aspect for the group members even after they figured that the angles that are given are from the ship's perspective and read in reference to the north. After the initial trials and problems related to process of drawing lines, one member took the control in online collaborative environment and attempted to follow the decided steps of the group. Her approach for solving the question was novel and appropriate. She solved the problem by using the exterior angle value to draw the line passing through a land mark. That is, her trials in using the functions of the tool resulted in successful drawing of expected lines and discovery of the ship location. The member also transferred her knowledge and experience to other members for explaining the solution and responding to questions of other members. The group's progress towards the solution of the problem can be respected as transfer of knowledge from one member and other members' confirmations to the solution, hence can be considered as the group's symmetric knowledge advancement according to one knowledge building principle offered by Scardamalia (2002) since all members gained knowledge by their joint efforts.

CONCLUSION

Overall, this case study demonstrates how a group of participants achieved a joint perception of a navigation problem that requires peculiar forms of spatial reasoning. The medium in which the team had to co-construct their solution triggered breakdowns in interaction at multiple stages. Although this points at key usability issues in the existing design of the environment, some of these challenges turned out to be productive for the team as their resolution led them to think about the problem in new ways. In particular, they were able to grasp the need for a reference line to draw angles, and design a method

to represent angles by aligning the ship's perspective with respect to the landmarks. The dynamic nature of the environment allowed team members to witness the process in which the angles were added and manipulated in the shared space. Texts, drawings and the animated evolution of representations in the shared space mutually informed each other and facilitated collective meaning making. Through this discussion the team collectively developed a better understanding of the reasoning practices and navigational artifacts employed by real navigation team, which is evidenced in the sequential organization of their chat messages and drawing actions.

The study has significant theoretical implication that demonstrated students' collaboration process and identified their collective building of knowledge from a broad aspect. This is aligned with the theory of Knowledge Building which offers that learning proceeds with the process of creating new cognitive artifacts and enhancement in current understanding as a result of collective goals, group interactions, and combination of ideas (Scardamalia & Bereiter, 2003). The findings also provide practical implications for instructional designers that the system should be improved for better functionality in the collaboration process.

One of the limitations of this study was related to its scope. That is, analysis of one team out of three teams was performed with this study. The future study could analyze collaboration of all teams in the course and additionally perform comparisons with regard to teams' progress. The second limitation was related to the inadequate instructor support during the collaboration. In a future study, instructor could take the facilitator role in the process and provide assistance about the functionalities of the tool. In this way, students could allocate more time for the generation of ideas and construction of knowledge. As a result, the future study could mainly focus on students' progress.

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