Online versus face-to-face collaboration in the context of a computer-supported modeling task

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Abstract

In this paper, the differences between online and face-to-face collaboration in the context of a computer-supported modeling task are examined. A mathematical problem was designed and given to the participants. Their modeling process using ModellingSpace, a collaborative computer-supported educational environment, was closely monitored. Sixteen ninth grade students participated in the study, who worked in groups of two. Half of the groups worked face-to-face, whereas the rest collaborated online. The data analysis focused on the identification of cognitive modeling strategies. The obtained results suggest that pairs who worked online emphasized on analysis and synthesis and demonstrated a higher learning gain, whereas face-to-face pairs needed the teacher's support and demonstrated stronger social interaction. Despite the fact that the actions of face-to-face dyads were more in number, the dyads that worked online seemed to present more task oriented actions. Regarding the interactions, in both groups a mutual exploration of the problem is depicted. Moreover, few disagreements were observed. The findings, which are discussed extensively, may have a number of implications for the design of learning programs and the facilitation of collaborative tasks.

Keywords: *face-to-face and online collaboration, modeling, problem solving, ModellingSpace*

1. Introduction

Collaborative learning is defined as the support provided towards the educational goals, through a coordinated and shared activity (Dillenbourg, 1999). In such a context, the size of the group varies and the learning process depends on the learning object. Common applied strategies in the context of collaborative learning are story production, argumentation over an issue, problem solving etc. (Dillenbourg, 1999). Collaborative learning existed in different fashions and forms even before the era of computational technology. However, new tools that technology introduces should be applied to foster deeper interaction and further development of collaborative learning (Koshmann, 1996). In this context, the design of technologically supported educational tools integrates characteristics of social interaction (Vygotsky, 1978) and communication between peer students, between students and teachers, between amateurs and experts in a specific learning field. A computer-supported collaborative activity is distinguished according to the place (face-to-face or online) and time (synchronous or asynchronous) in which is realized (Avouris, Karagiannidis, & Komis, 2008; Dimitriadis, Karagiannidis, Pomportsis, & Tsiatsos, 2008; Komis, 2004; Koshmann, 1996).

However, the influence of different collaboration types on the process, on the interactions as well as on the students' learning outcome still remains unclear. Firstly, it is of significant interest whether a synchronous face-to-face (f2f) collaborative process influences the students' interactions and differentiates their problem solving approaches compared with online collaboration. In this direction, several studies examine particular factors during the collaborative activity. Basque and Pudelko (2004) report that the difference between f2f and online groups lies in the speed and the facility of sharing process, which seem to be lower in the last group. Moreover the study of Jonassen and Kwon (2001) presents the type of the students' comments and the protocols of their communication in f2f and online communication through a given problem solving activity. The students' comments in the online communication were fewer and were focused mainly on the activity, whereas in f2f communication the students interacted less intensively and followed a linear step sequence. Meyer (2003) argue that the students who worked online focused on task and represented higher order thinking, whereas f2f demonstrated direct interactions and more active role engagement. According to Suthers, Girardeau, and Hundhausen (2003) deictic gestures in f2f are replaced by students' representations and verbal interactions in online collaboration. Michinov and Michinov (2008) introduced f2f collaboration during an online collaborative learning session. They observed that the task-focused interactions and the participation were reduced, while issues of coordination and emotional regulation were augmented. Another study on the collaborative modeling process (Fidas, Komis, Tzanavaris, & Avouris 2005) examined the way that students managed to solve a problem using multiple and effective interactions, heterogeneous recourses and divergent capacities. In the aforementioned setting, each dyad developed more message exchanges, a more complete and concise model and deeper discussions.

Concerning the learning gain besides the two types of collaboration, several studies examine the models' quality and students' post-tests. In particular, Tutty and Klein (2007) examined the impact of online and f2f collaboration on the students' learning outcome, using post-tests and the total project's assessment. Virtual groups appeared to be more efficient than f2f groups in the total project, whereas the last were more successful in the post-test procedure. Comparing the performance between the two environments Dell, Low and Wilker (2010), as well as Horspool and Yang (2010) didn't find any significant differences in learning performance. As a result, they argue that the use of a well-designed task and a mixture of f2f and online approach would be of important value. As far as the former issue is concerned, Collier and Yoder (2002) suggest some important guidelines concerning the online process such as carefully prepared instructor interventions, introduction of collaborative oriented tasks, strategies for motivating inquiry and details for the assignment of roles across the students.

Sins, Savelsbergh, Joolingen, and Hout-Wolters (2011) emphasize on both the previous factors, i.e. the way the chat influences the students' argumentation and the models quality, while they work in modeling, using a computer-supported collaborative environment entitled Colab. Their study involved 44 students (16-18 years) of mixed abilities. Initially, they received a lecture for about 2 hours related to the Colab tool functionality. Subsequently, they collaborated in dyads in order to construct the required model. The students' actions were coded and grouped into 5 large groups: analyzing, inductive reasoning, quantifying, explaining and evaluating. The time spent on the actions' categories was examined and correlated with the models' quality. In general, the modeling performance did not differ between the f2f and the online condition, whereas in online communication the time spent on surface reasoning found to be significantly shorter (Sins et al., 2011).

Taking into consideration all the aforementioned research efforts, the goal of the study presented in this paper was to closely monitor and analyze the collaboration between the students while solving a mathematical problem. In this study, a computer-supported modeling process is adopted. This process is based upon models' creation and testing using variables, relations and different representations modes, since it can be effectively integrated into a problem solving activity (Jonassen, 2006). Moreover, it introduces a high cognitive load to the students (Sweller, 1988). The activity was mediated using the ModellingSpace educational software (Dimitracopoulou & Komis, 2005). ModellingSpace is an open learning environment that permits construction and exploration of models of different physical phenomena using various representations in a collaborative manner. The system uses multiple alternative representations and allows the construction of abstract simulations with appropriate modeling tools.

In order to design of the modeling activity, we took into consideration the following studies. Lazakidou and Retalis (2010) give emphasis on the importance of the adopted instructional method, because it evokes positive learning gains. In particular, Lazakidou and Retalis (2010) argue that the design consists of three stages: observation, collaboration and semi-structured-guidance, whereas the problem has a realistic context. However, apart from the pedagogical design aspects that have to be followed, interaction design of the ModellingSpace plays a significant role in how these principals come into real practice. The models that a student can create with ModellingSpace allow the use of qualitative, quantitative and semi-quantitative relations for real world entities that represent primary concepts (Avouris, Komis, Margaritis, & Fidas, 2004). Thus, learning becomes a side effect of a direct manipulation activity, characterized by actions on objects representing entities or on concepts meaningful to the students. The tasks of visually representing entities and their properties and simulating their changes according to a chosen relationship supports students' abstract thinking and reasoning, which are considered demanding but useful processes for young learners (Dimitracopoulou, Komis, & Teodoro, 2003). Moreover, Panselinas and Komis (2009) examined the scaffolding collective thinking as a means of interaction between the students and educational gain. The findings of the aforementioned study were used to design the context of the activity presented to the students.

Finally, concerning data analysis, Komis, Ergazaki, and Zogza (2007) provide a novel approach to analyze collaborative modeling tasks. It emphasizes on the stages of the cognitive procedure used in the problem solving process and was adopted as the basic analysis tool in the presented study. It is based on the activity theory (Engeström, Miettinen, & Punamaki, 1999), on the model analysis OCAF (Avouris, Dimitracopoulou & Komis, 2003) and on the approach introduced by Stratford, Krajcik, and Soloway (1998) for the cognitive strategies' modeling. In addition, the theory of Mercer (1995) relating to the types of interactions that the participants produce (disputational talk, cumulative talk, exploratory talk) was also adopted as a means to better anticipate the collaboration process.

As discussed previously, some studies' findings regarding the differences between the f2f and the online collaboration appear to contradict each other. Therefore, given the importance of the topic, more studies could provide further insight towards the understanding of this issue. In this direction, the present study examines the differences between the two collaborative settings. In particular, the goal was to investigate the effect of f2f and online collaboration on: a) students' problem solving approaches, b) student-student interactions and c) the learning outcome, in the context of a computer-supported quantitative modeling learning activity. The rest of the paper is organized as follows: Initially, the method of the study is described, followed by the data presentation and analysis. Finally, the results are compared with previous studies and discussed.

2. Methodology

2.1 Study's objectives and questions

The aim of the study was to examine the differences between online and f2f collaboration in the context of a computer-supported modeling task. In specific, the questions of the study were:

a) How the collaboration's type influences the students' modeling processes while solving a mathematical problem?

b) Did the students' interactions who worked online significantly differentiate compared with that of students who worked f2f?

c) Is the students' learning outcome differentiated due to the different collaboration type?

2.2 Research Design

A mixed research method was adopted. Mixed research involves the use of both qualitative and quantitative approaches, thus providing complementary views while analyzing the obtained data. The aspects to meditate when planning a mixed method are timing, weighting and blending the two kinds of data regarding the two methods (Creswell, 2009). In the present study, emphasis was given to the qualitative research, while the data were combined during the interpretation stage. The participants' actions were encoded in order to identify patterns and types of collaboration. In addition, a case study design was adopted in order to obtain a precise and complete view of the collaboration process (Cohen, Manion, & Morrison 2008). The case study is considered as an appropriate method in the context of collaborative learning, since it emphasizes on the exact environment of each research setting (Avouris et al., 2008).

2.3 Data acquisition tools and techniques

Observation was the main technique used to collect data, as well as reliable tools based on video capture. Observation is widely used for data acquisition as it allows the researcher to experience and in the same time investigate the actions as they take place and not as secondary data (Cohen et al., 2008). It also enables the researcher to choose if she should be part of the activity (preliminary observation) or not (secondary observation). The former observation type was applied in the present study. Moreover, pre-test and post-test comparisons of students' performance were performed and provided insight to the third research question.

The Camtasia Studio software was used to capture the computer's screen as well as the students' activity in the classroom. In both settings (f2f and online) the users' low-level actions in ModellingSpace were recorded and analyzed. Finally, the students' notes as well as the researcher's recordings were included in the data analysis process.

2.4 Participants and activity description

The study was carried out in spring 2010 in an experimental high school located in a semi-urban area. In particular, it took place in the Informatics' laboratory and in the Technology's classroom. Sixteen 9^{th} grade students participated in the study, 5 girls, 11 boys, aged 15. The groups were formed according to their pre-test performance in order to minimize differences between them.

The activity refers to modeling a solution to a mathematical problem. It is included in the Mathematics course and introduces the concept of the linear equation. Students have already been taught this concept around the first months of the school year. As a result, they are in some extend familiarized with it. After a discussion with the students, we verified that all of them acquired the minimum knowledge required for the activity. However, they faced difficulties concerning the variables and confused them with the numbers-constants of the problem. In order to approach these difficulties an appropriate problem was structured. The students had to find the constants and the variables (both dependent and independent) of a problem, in order to create the required linear equation. The problem is well structured and only one answer is correct, which further simplified the process of students' model assessment.

2.5 Research tool and procedure

The selected research tool was ModellingSpace, presented in detail in the previous section. ModellingSpace supports the student in constructing models in various curricula, such as Mathematics, Physics, Biology, etc. (Dimitracopoulou et al., 2004). A typical modeling process using the ModellingSpace software is the following: Firstly, the entities are introduced by the students on the shared collaborative space. Then, the suitable relations are established. The types of relations supported are three: qualitative, semi-quantitative and quantitative. Afterwards, the students can examine the validity of their model, obtain indicative measurements and test alternative representations.

In the present study, students had to build a quantitative model and make use of quantifiable variables and the algebraic relation $y=ax+b$. Finally, the students had to test their results by setting the initial conditions and the values of independent variables. The model uses algebraic relations to calculate the values of dependent variables. In Figure 1, the correct approach to the problem given to the students is presented. The task's authenticity (Jonassen & Kwon, 2001) was crucial in order to motivate the students. Students had to calculate the cost of a cell phone plan, taking into consideration the fixed minimum monthly fee, the charge for messages and chat time, as well as the prepaid talk time and messages. Students were well familiarized with the aforementioned concept, since they all had mobile phones.

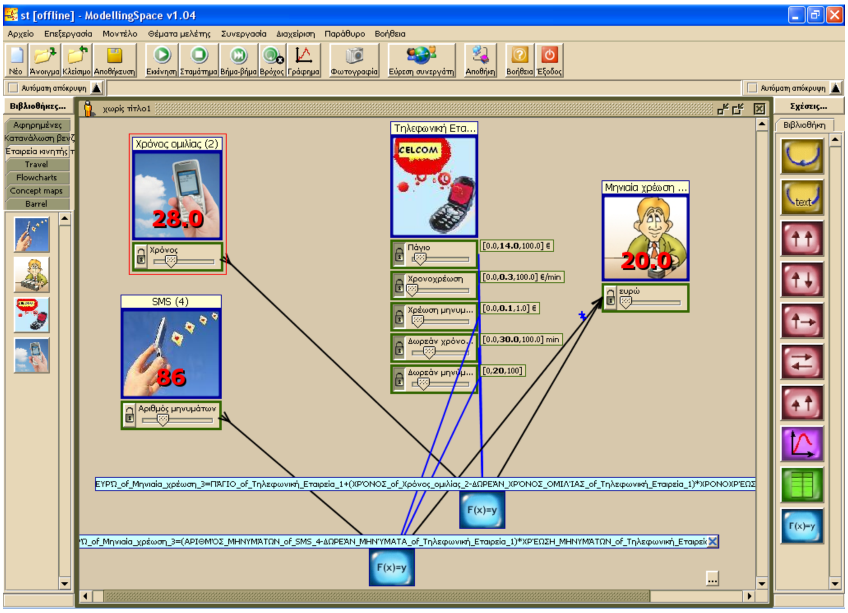

Fig. 1. Implementation of the quantitative model presented to the students using the ModellingSpace environment

During the first day, the students received a presentation related to the topic and the way to construct a model and its components (entities, characteristics and relations). Subsequently, an introductory problem was resolved by the teacher using ModellingSpace. Next, the students used ModellingSpace to resolve a more difficult problem. This process took place in the computer's laboratory, while the students worked in dyads of their preference. A similar problem (pre-test) was given to the students, in order to find the entities, their characteristics and the variables (dependent and independent) and then to record the relations among the characteristics of entities and to apply an example.

The second day, the students' dyads were separated in two equivalent groups, according to their pre-test performance. In particular four students' dyads collaborated in the same computer (f2f) and the rest four dyads collaborated using different computers (online). Each dyad with the teacher's presence worked in separate time. All students were given a well-structured activity sheet to provide the opportunity to the students to work autonomously, but in an organized and aligned manner. Finally, during the third day, a post-test was given to the students, which contained the same questions as the pre-test. Pre-test and post-test were carried out using paper and pencil. The researcher participated during the whole process, and she also took the role of the teacher.

3. Data analysis

The ActivityLens data analysis software was used to examine the collected data, since it supports video recorded data analysis (Fiotakis, Fidas & Avouris, 2007). The teacher participated in the f2f activity, when the students requested her support. An initial researcher's observation indicated that the online students gave more attention on the tool and considered less important the teacher's support. Even though the teacher remained supportive and encouraging for both groups, only f2f dyads seemed to interact with the teacher. On the contrary, in online collaboration the students focused on the task and the teacher participated only during the first steps of the activity's comprehension.

Moreover, the two environments differ on the tools used. In particular, f2f students' dyads used the speech, the computer, gestures as well as paper andpencil. On the contrary, online students' dyads used the chat and the modeling window. The analysis categories presented in Table 1 were derived from the study of the students' actions examined in video recorded data and in log files. Most of the categories were extracted by studying in detail one dyad. The categories presented in Table 1 appeared in the actions of all dyads.

In the low level activity analysis, the students' actions were grouped according to their type: tools' usage or interaction with the participants. As demonstrated in Table 1, the categories A, B and C comprise the actions with chat or speech tool. Category D includes actions carried out using the computer tool. Furthermore, the actions of teacher are included in group A. The rest of the elements presented in the B, C and D groups refer to the students' actions.

Table 1. Categories of Analysis (adapted from Komis et al., 2007).

A) Teacher		24	Comprehensive question
1	Reading instructions	25	Answer to above
2	Collaboration motivation	26	Actions' articulation
3	Collaboration instructions	27	Cognitive hint
4	Organizational instructions	28	Technical hint
5	Encouragement	**D) ModellingSpace**	
6	Technical guidance	29	Insert Entity
7	Cognitive support	30	Delete object
8	Reward	31	Select all properties
B) Student's questioning		32	Display property value
9	Procedural question	33	Show/Hide property value
10	Procedural answer	34	Change property value
11	Comprehensive question	35	Move/resize Entity
12	Comprehensive answer	36	Set object to front
13	Technical question	37	Property details
14	Technical answer	38	(Un)lock property
C) Student		39	Insert Relationship
15	Agreement	40	Add a constant
16	Confirmation	41	Change Equation
17	Contestation	42	Save model
18	Disagreement	43	Run model
19	Ambiguity	44	Stop model
20	Examination	45	Partner requested for the key
21	Ascertainment	46	Partner gave the key
22	Colleague exhortation	47	Partner refused the key
23	Arithmetical question		

The 47 possible actions, presented in Table 1, were examined and organized to categories which reflect the research questions. For the first question concerning the influence of the learning setting on the students' expressed actions, the evaluation scheme proposed by Komis et al. (2007) was adopted since the categories derived from the first level analysis were approximately similar to this scheme. According to this, the low level categories are included in the following wide categories: analysis (entities and properties), synthesis (relationship's insertion), testing and interpreting, technical and cognitive support. In the present study, the low level categories could be grouped based on the above categories, whereas social interactions emerged as a new category.

The obtained scheme is presented in Table 2. The *analysis* category comprises elements D29 to D38. Since *synthesis* refers to the relationship's insertion, it includes the actions D39, D40 and D41. The *control and execution* actions, referring to the model testing and not the entity's introduction are D43, D44 and D34. The technical support group includes mainly the questions of category B and the teacher's support A, both presented in Table 1. The social interactions are represented mainly through group C which also includes the actions depicting teacher's efforts to motivate as well as the key transition for the online groups.

Table 2. Categories' grouping.

Actions	Categories
D29 to D38	I. Analysis
D39, D40, D41	II. Synthesis
D34, D43, D44	III. Control – Execution
A5, A7, A8, B11, B12, C27	IV.a Cognitive Support
A1, A4, A6, B9, B10, B13, B14, C28	IV.b Technical Support
A2, A3, C, D45, D46, D47	V. Social Interactions

For each dyad, the number of actions for each category was counted. Then, for each type of collaboration the mean values and their differences were calculated. The results are presented in Table 3.

Table 3. Number of actions per dyad and per category of analysis (% diff: percentage difference).

		Analysis	Synthesis	Control Execution	Cognitive Support	Technical Support	Social Interactions	Total
Face-to-face	1	23	6	1	35	28	53	146
	2	39	10	2	29	32	74	186
	3	77	12	6	82	50	191	418
	4	18	6	1	52	41	116	234
On line	5	68	11	11	23	10	69	192
	6	70	18	7	1	1	39	136
	7	68	13	13	12	1	45	152
	8	105	12	16	7	18	54	212
f2f average (SD)		39.25 (26.71)	8.5 (3)	2.5 (2.38)	49.5 (23.76)	37.75 (9.81)	108.5 (60.92)	246 (120.18)
Online average (SD)		77.75 (18.19)	13.5 (3.11)	11.75 (3.77)	10.75 (9.32)	7.5 (8.19)	51.75 (13.05)	173 (35.08)
% diff = (f2f-online)/f2f		-98%	-59%	-370%	78%	80%	52%	30%

The differences between the groups who worked f2f versus those who worked online found to be significant in the control execution, cognitive support and technical support categories (Mann Whitney U test, $U=0$, $p=0.03<0.05$, $U=0$, $p=0.028<0.05$, $U=0$, $p=0.029<0.05$ respectively). On the contrary, in the analysis, synthesis, and social interactions categories, no significant difference was found for the f2f groups versus the online groups (Mann Whitney U test, $U=3$, $p=0.19>0.05$, $U=1.5$, $p=0.08>0.05$, $U=2$, $0.11>0.05$ respectively). However, even in these categories, strong differences in the total number of actions were recorded (Table 3). The students who worked online were reported to need less support overall in their actions. The teacher gave an answer to the preliminary students' questions and then the students supported each other for the rest of the activity. The students seemed to focus on the analysis procedure and interact with each other mainly through manipulation of the entities, their characteristics, their position on the shared collaborative space and their size. Moreover, they were involved in synthesis and control execution activities more than the face-to-face dyads.

In contrast, the f2f dyads seemed to seek for support from their colleague as well as their teacher's more frequently. They gave less emphasis on the analysis procedure throughout the software, since they could interact with each other using paper and pencil. As far as the social interactions are concerned, they were found to be more frequent in f2f collaboration, thus representing a significant percentage of students' total actions. The sequence of actions was examined for both groups. It seems that they worked in a linear way, without returning back and forth from analysis to synthesis activities. To better illustrate the aforementioned ascertainment, the diagrams of two characteristic dyads are shown in Figure 2 and 3, respectively. The points show the students' actions during time, the bold points represent the control actions, the rest categories are grouped vertically.

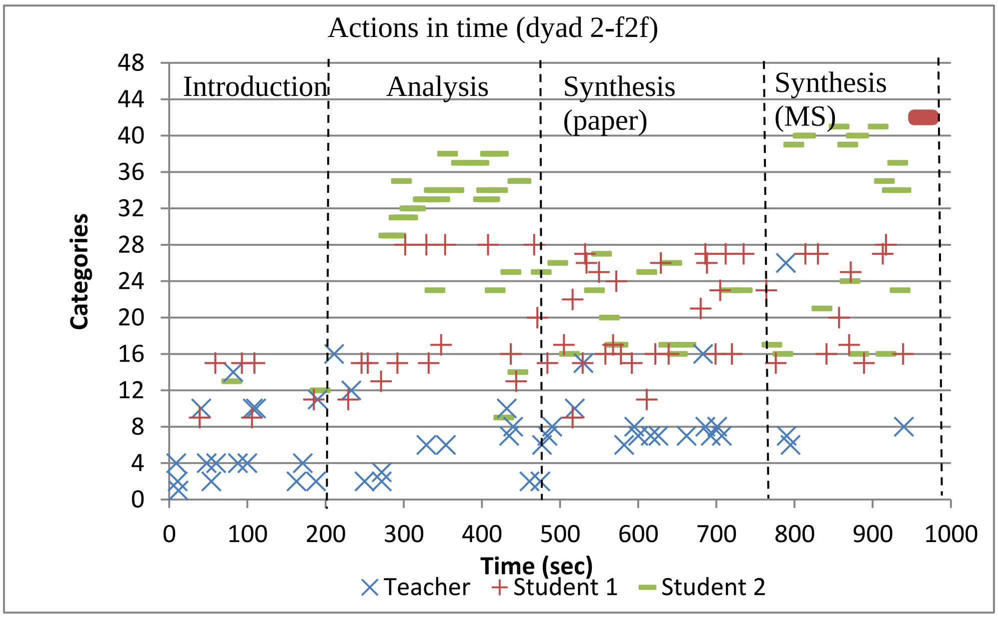

Fig. 2. Timeline of students' actions (f2f dyad)

Figure 2 represents the participants' actions over time. For the first 5 minutes approximately, the teacher explained the task and the students confirmed their understanding. Subsequently, for the following 4 minutes the students started slowly interacting with each other, while Student2 introduced the entities and selected their properties. Meanwhile, Student1 gave technical support where needed. In this time period, the students were engaged with the analysis process, while at the same time received teacher's support. The third time period has the longest duration and includes the students' interactions towards construction of the linear equation. Students wrote their ideas in the same paper and argument about the data of the problem. The most frequent type of interactions seems to be the agreement and the comprehensive questions and answers. The role of the teacher remained supportive, providing cognitive support and rewarding the students' progress. The last subsession comprises the synthesis and the control activities. Finally, Student2 manipulated the software, introduced the equation and executed the model, while both students interacted and agreed upon the requested actions. Teacher didn't participate strongly in the final stage of collaboration.

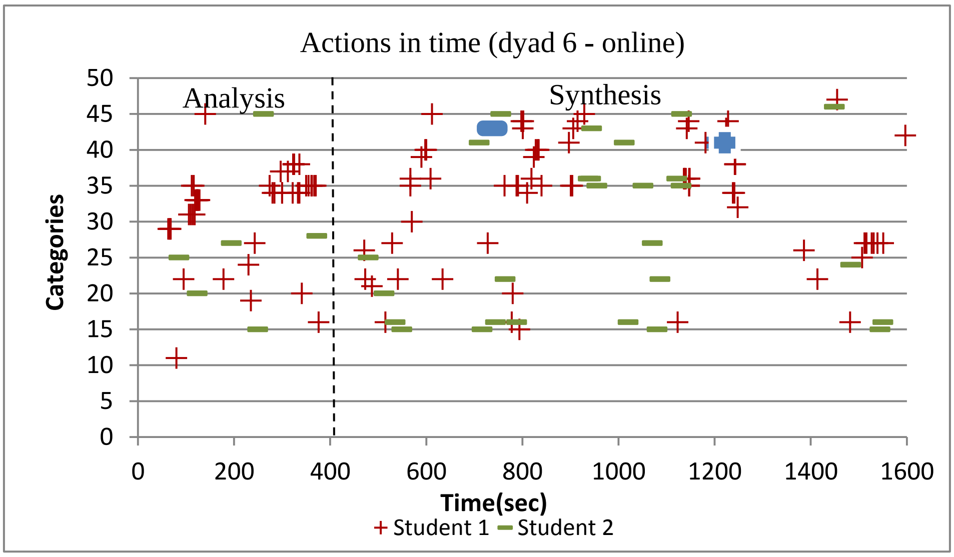

Fig. 3. Timeline of students' actions (online dyad)

The activity of a representative online dyad is presented in Figure 3. For the first 7 minutes, the students introduced the entities to the shared collaborative space and positioned them appropriately and selected their properties. In this time period, they interacted, obtained a mutual understanding of the presented problem and they agreed upon the entities' characteristics. Contrary to the f2f activity presented in Figure 2, there is no teacher intervention. In the second large part of the procedure a strong exchange in roles is presented. Students discussed and found out the linear equations. Afterwards, they introduced them in the software and executed the model in order to control the result. The observed behaviour differentiates from the f2f condition, in which the synthesis is carried out separately in paper and the solution is added to the model. Moreover, online dyads tested the model twice, contrary to the f2f peers who executed the model at the end of the process (see Figure 2). As a result, for online collaboration the synthesis comprises chatting, entering equations and controlling, while the paper is replaced with the chat tool.

As far as the second question of the study is concerned, the framework proposed by Mercer (1995) was applied. According to Mercer (1995), the types of talking and thinking can be classified in three categories: disputational talk, cumulative talk and exploratory talk. In particular, disputational talk refers to disagreements and individual decision making, cumulative talk, in which the speaker builds positively but uncritically to what the other has said and exploratory talk, in which partners engage critically but constructively with each other's ideas. The low level categories presented in Table 1 were mapped accordingly and the results are presented in Table 4.

Table 4. Interaction categories.

Actions	Categories
C17, C18	Disputational talk
C15, C16	Cumulative talk
B, C19-C25	Exploratory talk

Subsequently, the actions' frequencies in each group were counted, as shown in Table 5.With the notable exception of dyad 5, all groups showed a high degree of interaction. In specific, all dyads interacted by researching mutually the problem's resolution. Exploratory talk was the most frequent, followed by the cumulative talk and the disputational talk actions, which were found to be very rare (6.7% and 9.9% of the students' total actions for the f2f and online groups accordingly). In the online collaboration condition, students presented less verbal interactions between them. In total, both students of each dyad interacted equivalently and distributed similar number of comments.

Table 5. Number of actions per dyad and per category of interaction according to Mercer's (1995) model.

<table>
<tr><th colspan="2"></th><th>Disputational talk</th><th>Cumulative talk</th><th>Exploratory talk</th><th>Total</th></tr>
<tr><td rowspan="4">Face-to-face (F2F)</td><td>1</td><td>2</td><td>8</td><td>26</td><td>36</td></tr>
<tr><td>2</td><td>9</td><td>26</td><td>33</td><td>68</td></tr>
<tr><td>3</td><td>11</td><td>37</td><td>115</td><td>163</td></tr>
<tr><td>4</td><td>3</td><td>41</td><td>57</td><td>101</td></tr>
<tr><td rowspan="4">online</td><td>5</td><td>12</td><td>13</td><td>30</td><td>55</td></tr>
<tr><td>6</td><td>0</td><td>0</td><td>6</td><td>6</td></tr>
<tr><td>7</td><td>0</td><td>16</td><td>15</td><td>31</td></tr>
<tr><td>8</td><td>2</td><td>17</td><td>31</td><td>50</td></tr>
<tr><td colspan="2">F2F average (SD)</td><td>6.25 (4.43)</td><td>28 (14.76)</td><td>57.75 (40.41)</td><td>92 (54.26)</td></tr>
<tr><td colspan="2">Online average (SD)</td><td>3.5 (5.74)</td><td>11.5 (7.85)</td><td>20.5 (12.12)</td><td>35.5 (22.22)</td></tr>
<tr><td colspan="2">% difference =(f2f-online)/f2f</td><td>44%</td><td>58.9%</td><td>64.5%</td><td>61.4%</td></tr>
</table>

In order to examine the students' learning performance, their models were rated by one of the authors. In addition, a pre-test and a post-test activity presenting a similar problem was given to the students. One student from the f2f groups and one from the online groups did not participate in the pre-test and the post-test questionnaire, thus they were excluded from the study. The results are summarized in Table 6.

Table 6. Students' performance.

Averages	Model assessment (SD)	Pre-test (SD)	Post-test (SD)	Difference
Face-to-face	4,62/5 (0.41)	10,57/20 (3.81)	13.00/20 (5.09)	2,43 (4.62)
Online	4/5 (1.00)	8.86/20 (2.59)	12.86/20 (4.32)	4 (3.16)
Total	4.31/5	9.71/20	12.93/20	3,21

	(0.88)	(3.50)	(4.91)	(4.19)

The students who collaborated in an online manner had lower initial performance. In addition their models found to be slightly worse compared to the models presented by the students who collaborated in f2f manner. However, the learning gain of the former groups was higher. Moreover, a significant learning difference was found only for the students who collaborated online (Wilcoxon matched-pairs signed-ranks test, W=-25, p=0.03<0.05). No significant difference for the students who collaborated f2f was derived (Wilcoxon matched-pairs signed-ranks test, W=-15, p=0.21, ns). In addition, the former students' post-test score was highly correlated with their model assessment (r=0.82) whereas for the students who collaborated f2f no correlation between post-test and their model assessment was derived (r=-0.10). This finding suggests that the quality of the model constructed using the ModellingSpace software was an accurate learning predictor only for the students who collaborated online. This could be attributed to the teachers' intervention, or to unbalanced contributions in the f2f collaboration.

4. Discussion and conclusion

In this paper, the differences imposed by two different collaboration approaches were examined. Sixteen 9th grade students participated in the study, who worked in groups of two. Half groups worked f2f whereas the rest collaborated online, using the ModellingSpace collaboration software.

Regarding the first research question, the obtained results suggest that the online dyads focused extensively on the analysis and synthesis actions. Their interaction was mainly expressed through the entities' manipulation. Moreover, they needed less support. The finding that the online dyads were better focused on the problem solving activity confirms similar findings presented by Jonassen and Kwon (2001). The point that the online students replaced verbal interactions with entities involvement agrees with similar results of study Suthers et al. (2003). In contrast with the findings of Michinov and Michinov (2008), the students who worked online presented more task-focused interactions and the students' participation didn't differ significantly compared to the f2f collaborated students.

As far as the second question is concerned, the f2f dyads asked more frequently for the colleague's or the teacher's help. Moreover, the f2f dyads exchanged their roles faster. This finding is in line with the more active role engagement depicted by the f2f partners reported by Meyer (2003). In contrast, online dyads utilized more the software and the chat in order to focus on the process and they were not distracted by social interactions. Both groups emphasized on the exploratory talk, while their disagreements were infrequent. In both conditions, the students demonstrated balanced contributions as well as disputational talk, cumulative talk and exploratory talk are concerned.

According to the third question, Tutty and Klein (2008) observed that the online dyads performed better, while in the present study their model obtained lower scores. Lack of teacher's support and encouragement might have contributed to this. However, students who collaborated online demonstrated a higher learning gain between pre-test and post-test (2.43 and 4 for f2f and online accordingly, see Table 6). A possible explanation is that the gradual shift of control and responsibility of the learning process to the learners seems to positively influence their learning effectiveness. In concordance to the study of Sins et al. (2011), a similarity on the emphasis the online dyads gave on the entities of the problem emerges. Sins et al. (2011) report that the students' who collaborated online, spent less time on surface reasoning, a finding which was also replicated in our study.

According to the reported findings, it is suggested that well organized modeling activities could be effectively carried out by the students without the teacher's intervention. However, since few disagreements were observed, a role assessment could be applied in order to evoke richer interactions and not only agreement (Collier and Yoder, 2002). Also, given that the students who collaborated online showed comparable post-test performance with that of students who worked f2f, another possible suggestion might be the application of a mixed collaboration's type according to the learning goals. In particular, f2f collaboration could be implemented when focus should be given in social interactions. Subsequently, when students have to emphasize on more demanding modeling activities, an online collaboration context could be applied.

A notable contribution of the presented work is the effective combination of both qualitative and quantitative approaches, the adoption of two complementary coding schemes to better investigate the peers' interactions, as well as the effect of f2f versus online collaboration in the context of quantitative modeling. However, the study presented in this paper is not without limitations. More studies should be conducted using a variety of problems in order to better anticipate the influence of the nature of the activity on the students' behavior in both contexts (f2f and online). It is expected that more abstract problems would provide richer opportunities for collaboration and greater variation in terms of proposed solutions. In addition, findings from studies related to how learners form their goals (Tselios & Avouris, 2003), which strategies they follow, what criteria they use to evaluate information and how they adapt to any given learning environment (Katsanos, Tselios, & Avouris, 2010, Tselios, Avouris & Komis, 2008, Tselios, Daskalakis & Papadopoulou, 2011), can update existing design practices and consequently differentiate to an extent the students' collaborative behavior. Moreover, the teacher's influence on online collaboration should be further examined. Another suggestion for future research would be the application of different coding schemes in order to better approach the differences between the two environments. The aforementioned limitations constitute future research goals.

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