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Adaptive vs. Fixed Domain Support in the Context of Scripted Collaborative Learning

Anastasios Karakostas* **and Stavros Demetriadis**
Department of Informatics, Aristotle University of Thessaloniki, Greece // akarakos@csd.auth.gr // sdemetri@csd.auth.gr
*Corresponding author

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ABSTRACT

This study focuses on how to adaptively support small groups of students during a scripted collaborative activity. Forty (40) students collaborated remotely in dyads (in lab conditions) on a task structured by a collaboration script in the domain of multimedia learning. Half of the dyads (treatment group) were supported by a domain-specific adaptive intervention in the form of reminding prompts, while the rest of the dyads (control group) were supported by an informationally equivalent fixed form of support. Our main hypothesis was that the adaptive intervention would lead to better individual and group learning outcomes compared to the fixed one. Qualitative and quantitative analyses showed that (a) students in the treatment group outperformed those in the control group in domain knowledge acquisition, (b) dyads in the treatment group accomplished tasks more efficiently than the control dyads, and (c) dyads in the treatment group enacted more solution-convergent interactions than the control dyads. Overall, this study provides evidence that by implementing techniques of adaptive domain-specific support during a collaborative activity, instructors can substantially improve learning outcomes.

KEYWORDS

Adaptive student support, Computer supported collaborative learning, Collaboration scripts

Introduction

Although collaborative learning has been proved significant for students both for social and cognitive reasons (Slavin, 1996), collaborating students usually fail to engage in productive learning interactions when left without teachers' consistent support and scaffolding (e.g., Hewitt, 2005). Currently, issues regarding the adaptive operation of CSCL (computer-supported collaborative learning) systems attract the increasingly intense efforts of various research groups (e.g., Walker et al., 2009). These efforts advance the tradition of Adaptive Hypermedia Environments toward CSCL and expand the perspective of the field while setting innovative research agendas. In general, adaptive collaboration support techniques aim to model the major aspects of the collaborative activity and activate learner/group support interventions when needed and in the form it is needed (Soller et al., 2005). Although, there have been reported some encouraging first results (e.g., Kumar et al., 2007), there are also implementations that do not prove that such type of interventions lead to enhanced learning outcomes (e.g., Baghaei et al., 2007). Moreover, most of these systems are research prototypes that demonstrate possible system architectures or have been used to showcase their beneficial learning impact but are not widely available outside the research laboratory.

Based on the above drawbacks, we investigate if the integration of adaptive domain-specific support in a scripted collaborative activity would lead to better learning outcomes compared to a fixed support mechanism. In the following, we present (a) the theoretical background of our research, (b) the study design and results, and (c) a discussion analyzing the learning impact of the collaboration support method.

Theoretical background

Support collaboration using collaboration scripts

Collaborative learning has been proved important for students for social, cognitive and meta-cognitive reasons (Slavin, 1996). However, when students are engaged in collaborative learning they need significant support and guidance since they are rarely engaged in productive interactions such as asking each other questions or reflecting upon their knowledge (Hewitt, 2005; Liu & Tsai, 2008).

A first step toward providing the kind of student support necessary in collaborative processes has been to script the activity (Fischer et al., 2007). Scripts structure the collaborative process by defining sequences of activities, by creating roles within groups and by constraining the mode of interaction among peers or between groups (Dillenbourg & Tchounikine, 2007). Implementing CSCL scripts has been reported to result in improved learning outcomes (Fischer et al., 2007; Hernández-Leo et al., 2006). However, CSCL scripting has been criticized for its loss of flexibility (Dillenbourg & Tchounikine, 2007), and also the danger of "over-scripting" collaborative activity (Dillenbourg, 2002).

Supporting collaborative learning through adaptive/intelligent interventions

Current CSCL efforts have focused on supporting groupwork through the use of adaptive and/or intelligent systems. Adaptive and intelligent interventions tailor the collaborative learning process to the needs of the individual students or groups. The target of the adaptive/intelligent interventions varies and can be classified into 2 main categories: 1) peer interaction support (i.e., help peers to "learn to collaborate"), 2) domain knowledge support (i.e., help peers to deepen their domain understanding) (Magnisalis et al., 2011).

Peer interaction support refers to the actions taken by the system in order to help learners improve their interaction and develop domain-general knowledge and skill (Soller et al., 2005). For the purpose of this study, we focus on the second category of support. *Domain-specific support* refers to the actions taken by the system in order to help learners understand the domain better. This kind of support concerns the aspects of users and groups (and their activities) that have to be modeled and can be inferred or observed in system/user interaction in order to support group learning (Ayala & Yano, 1998). As domain-specific support focuses on problem-solving modeling, it involves systems that are strongly related to specific domain (Baghaei et al., 2007; Walker et al., 2009).

Four major issues emerge from the adaptive and intelligent collaboration support area: (1) systems are in an early stage of development and evaluation and relevant studies most often do not report clear learning benefits (2) the systems are strongly related to the target domain, (3) modeling students' domain knowledge is almost always concerned with the individual, and (4) there is a lack of coherence in assessing the learning impact, since no common benchmarks have been agreed upon, making almost impossible to compare the efficiency of using different methods for supporting the same target of intervention.

Research motivation

In order to support the group learning we focus on: (a) the enhancement of student interaction and (b) the enrichment of the users' knowledge pool. Collaboration scripts have proved to be a suitable mechanism to structure and guide student interactions. Additionally, to avoid misunderstandings, it is vital to give feedback of one's understanding and use the partner as a source for clarifications. However, the domain knowledge understanding of the group members is not always in the adequate level to foster the grounding process. In other words, even if we support students on how they should interact, we cannot be sure that they would collaborate efficiently on the specific domain. Furthermore, this lack of domain understanding may lead to the failure of collaborating partners to pool their unshared knowledge resources (Rummel & Spada, 2005). This could be fatal in a situation where the group members are mutually depending on one another's knowledge to successfully complete the group task. In order to enrich the users' knowledge pool we could apply adaptive domain-specific collaboration techniques. Therefore, main questions emerge: can we offer adaptive support to a group of collaborating learners and is it possible for this adaptive support to be lastly cognitively beneficial for learners? Finally, will the adaptive support provide significantly enhanced learning outcomes than an informationally equivalent fixed supportive technique?

Consequently, in this study we explore whether a simple adaptive form of supportive intervention is indeed more beneficial as compared to fixed form of support. To this end, we used the "Learning Activity Management System" (LAMS) tool to implement (a) an adaptive and (b) a fixed intervention to help teammates recall important aspects of the learning material.

Method

Research objectives

The main goal of this study is to explore whether a simple adaptive form of supportive intervention is more beneficial as compared to an informationally equivalent fixed form of support when they are both provided during a scripted collaborative activity.

Experimental design

We conducted an experimental lab study comparing the two conditions: (a) students who were supported by a fixed method (control condition), and (b) students who were supported also by the adaptive prompting method (treatment condition). Furthermore, a peer-tutoring collaboration script also supported both conditions.

Instructional domain

The instructional domain of the activity was "Multimedia Learning". This particular subdomain was part of the course "Learning theories and educational software" that the participants followed during the semester. More specifically, the domain concerned the Cognitive model of multimedia learning theory based on the Dual Coding Theory as presented in (Mayer, 2003).

Collaboration support system

The computer-based system that supported the collaboration was LAMS (Learning Activity Management System) (LAMS, 2010). LAMS is an open source licensed under GPL2 and it is basically a web-based tool for designing, managing and deploying collaborating learning activities.

The script

A two phases collaboration script orchestrated the whole activity and provided fixed form of support to the learners by guiding their collaboration. The assigned task for each phase was to provide answers to an open-ended domain questions (LAMS chat tool). These were essentially "learning questions" that provided the opportunity for structured peer interaction. However before answering each learning question, dyads were asked to discuss and agree on theory keywords that are relevant to the subject under investigation.

Overall, each one of the two phases comprised one keyword question (KQ) and one learning question (LQ). It is important to notice that students were not informed that the KQs were related with the LQs. The script also provided guidance on the roles (author and reviewer) that the students had to follow during the two LQs. One of the students was assigned the author role (responsible for introducing an initial answer) and the other one the role of reviewer (to review and propose improvements for the suggested answer). Students were then encouraged to further discuss their common answer freely, improve it, if necessary, and submit it. Afterwards, the dyad worked in a similar manner on the second phase of the script. In the second LQ peers they exchanged their roles (author, reviewer) (see Figure 1).

Treatment condition

Apart from the collaboration script, students in the treatment group were supported by one complementary method: an adaptive prompting mechanism. Dyads in the treatment mode were prompted after each keyword question (KQ) during the collaboration phase. The system was monitoring the keywords that the students provided and compared them to teacher's keyword-based domain model (that is, seven keywords that we had pre-declared as the most important for the subject under discussion). In case some keywords were missing from the students' dialogue, the system responded with a relevant prompt that included information about the missing keywords. It is important to notice that the prompts were presented one by one after students had completed their discussion.

For example, a reminding prompt for the question “Think of major keywords relevant to Dual Coding Theory.
Use the chat tool below to discuss and submit your list of keywords” was: “VISUAL MODEL: It seems that you have not included “Visual model” as a keyword. The theory suggests that learners organize a mental “visual model” based on perceived pictorial information”

The goal of the adaptive domain prompting mechanism is first to identify missing domain conceptual knowledge (as documented by analyzing the peer dialogue) and second to provide the needed information and help peers develop a more accurate, shared, individual, mental representation. In general, adaptive collaboration support techniques aim to model the major aspects of the collaborative activity (such as domain, activity structure, student/group profile, peer interactions, etc.) and activate learner/group support interventions when needed and in the form it is needed. Moreover, each statement in a group dialogue and eventually the whole group dialogue is a process of sharing the individual mental representations in order to reach common understating. Based on this perspective, we believe that the group dialogue reflects (at least) a part of the group knowledge model based on which the adaptive support is provided. The proposed adaptive mechanism is based on each group’s domain conceptual knowledge and provides the missed and needed information. Consequently this would help group members to collaborate more efficiently (for example, during the next discussion). The triggering of the prompting technique depended on peer interaction and also the objective of the intervention was to help partners in their next task.

Control condition

In the control condition, after each KQ the system presented to the students the list of all keywords (seven in total) with their extended definitions that had been pre-defined by the instructor. This list of keywords is considered as a fixed support mechanism, informationally equivalent to the adaptive support mechanism, since it included all the prompts possibly presented to students in the treatment condition. Students could read the keyword definitions and then continue with the next task. In Figure 1 we present the collaborative activity and the differences of the two conditions.

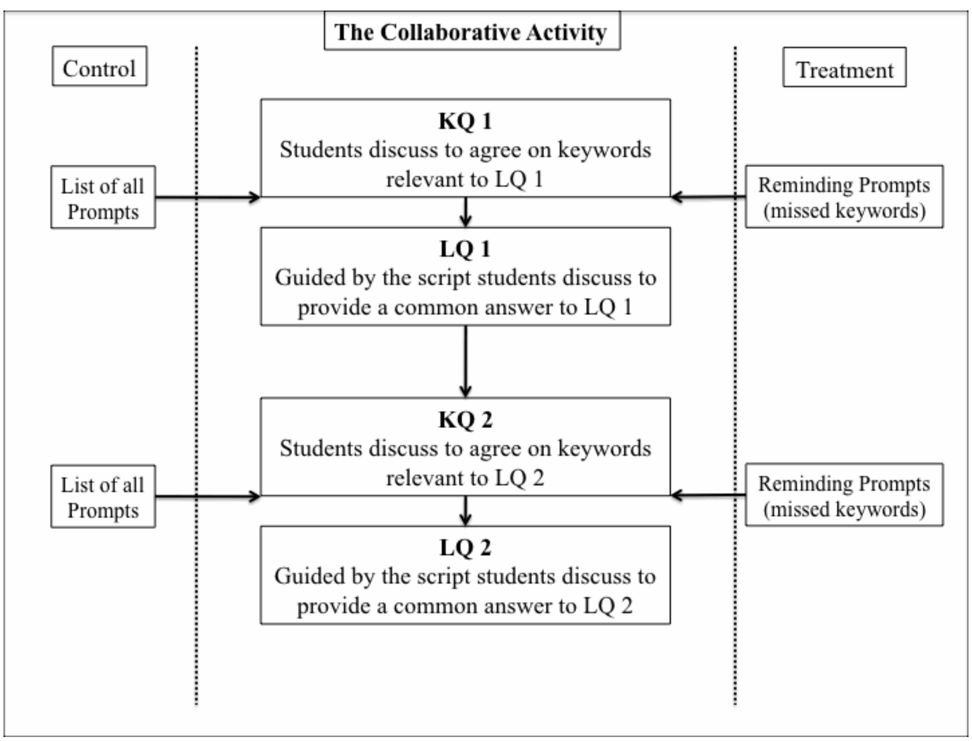

Figure 1. The collaborative activity

Participants

The study employed 40 undergraduate informatics students (19 females) in their 3rd (out of 4) year of studies. The collaborative activity presented in this study was a required task for this course and students who successfully completed the whole procedure were awarded a bonus grade. All students were domain novices and they had never been engaged in online collaborative learning activity before.

Students were assigned to one of the two conditions (treatment and control) in the following way: we conducted a prior domain knowledge questionnaire, which included a set of eight closed-type and two open-ended question items. With this instrument, we identified the student's basic domain knowledge (pre-test). The test was administered on a paper. Two independent raters were the raters of the test. Inter-rater reliability for the open-ended questions was high (ICC = .91).

Based on their answers, we classified students as: novice, intermediate and advanced. The next step was to assign students to dyads. Based on students' profile, we formed 20 mildly heterogeneous dyads. In other words, all dyads consisted of students belonging in adjacent competency classes (for example, novice-intermediate or intermediate-advanced) avoiding the formation of "novice-advanced" dyads. There is evidence on the available literature indicating that mildly heterogeneous groups (regarding students' domain knowledge) are more likely to outperform homogeneous groups at accomplishing specific goals (Wang et al. 2007). Finally, the dyads were distributed in the two conditions (treatment and control) stratified by their domain knowledge. In other words we had the same "novice-intermediate" and "intermediate-advanced" number of groups (10) in both conditions.

Procedure

The study lasted two weeks. Students first attended an introductory lecture on Monday of the first week. Then, all students were given to study the same 20 pages text-based learning material. On Monday of the second week, students were given the 30-minute prior domain knowledge pretest. The collaborative activity took place on Wednesday. There were two collaboration sessions that lasted 2 hours. The treatment group worked in the first session, and the control group in the second.

Each dyad partner was placed in different laboratories. The students in the two conditions were not informed that they would be treated differently. As the collaboration phase ended, the students individually completed the post-test in 30 minutes followed by an opinion questionnaire regarding the learning experiences. The next day, we interviewed the students from each group to record in detail their attitudes and relevant comments on the activity.

Measures

Learning outcomes

Measure 1 (individual domain learning): In order to measure the individual domain learning we conducted a post-test comprising two parts: (a) the first part included the same closed-type questions as the pre-test questionnaire. This part focused on assessing students' acquisition on basic domain knowledge (first level of Blooms' taxonomy) (in the following "Measure 1-A"). (b) The second part of the questionnaire included three open-ended questions, which referred to sections of the learning material that students individually studied and collaboratively worked on. This part focused on assessing the students' understanding of the domain (second level of Blooms' taxonomy) (in the following "Measure 1-B").

The post-test questionnaire was developed by the authors as domain experts. The questions were additionally verified and validated by one more domain expert who was not involved in the experiment. Some ambiguous or unsuitable questions were modified, removed, altered, or arranged in a proper order. The reliability of the closed-type questionnaire was sufficiently high (Cronbach's alpha = .842).

Measure 2 (in-task group learning): In order to measure the dyad domain learning during the task, we assessed the dyad answers to the two LQs. This is considered as "in-task group learning", since the answers were jointly formulated by the two partners. We transferred all the dyad answers from the log files to paper sheets. The dyad answers were assessed by two independent raters (see further below).

To avoid any biases, dyads' and students' paper sheets were mixed and assessed blindly by two raters, who used a 0-10 scale and followed predefined instructions on how to assess the LQs and each part of the post-test. Each student received 2 scores: (a) a score for the closed-type part of the post-test, and (b) a score for the three open-ended questions of the post-test. The mean of these two scores was used as dependent measure for individual learning. The two raters rated also each dyad answers paper sheets. The mean and the sum of these two scores was used as dependent measure for in-task group learning. As a measure of inter-rater reliability, we calculated the intraclass correlation coefficient (ICC) for the two scores (both for the LQs and the post-test). For all statistical analyses a level of significance at .05 was chosen.

Dialogue analysis

The dialogue analysis was conducted for both KQ discussions and LQ discussions. In relation to the KQ dialogues, we tried to identify for both conditions (control and treatment) the keywords that the groups had missed. For the treatment condition the missed keywords for each KQ, could be easily identified because missing keywords triggered the presentation of the relevant reminding prompt. For the control condition the missed keywords were identified through dialogue analysis, which compared the provided keywords by groups to the predefined keywords by the instructor. This analysis was conducted by the two authors and the results were the same.

Regarding the LQ dialogues, we analyzed the dialogues in order to identify the keywords that groups from both conditions missed in the KQ but included in a correct and adequate manner when formulating the respective LQ answer. To achieve that we analyzed the dialogues based on the "domain-related analysis" model proposed by Rummel and Spada (2005). This model focuses on "topics" arising within a dialogue. By "topics", is meant short, identifiable thematic segments within a dialogue. In our study, by topics we refer to the needed keywords that a group should include in an LQ answer. Based on the model, we analyzed each topic with regard to its general relevance to the answer, the adequacy of the way in which it was discussed, the correctness of the statements and the depth of the discussion. Two coders, as before, independently coded the chat dialogues (Cohen's kappa = .89). Disagreements were resolved through discussion. Thus, we identified the keywords that partners (in both conditions) missed in the KQ but used efficiently in their LQ answers.

Student's opinion questionnaire

In our study the opinion questionnaire aimed to identify students' opinions for the leaning procedure in four main dimensions: (a) the adaptive prompting (domain-specific support), (b) the fixed support mechanism, (c) the main guidelines that the students had to follow in the script, (d) the whole learning experience and (e) the online collaboration environment. Naturally the first part of the questionnaire addressed only the students in the treatment mode and the second part only the students in the control group. The rest of the questionnaire was common for all the participants.

The questionnaire validity was tested through a small pilot study with 8 students who did not eventually participate in the final experiment. We administered the opinion questionnaire and conducted also short interviews after the students had worked in the environment. Based on the feedback received from the students we constructed the final form of the questionnaire. Finally, the opinion questionnaire reflects a good reliability (Cronbach alpha = .88). We statistically analyzed the students' answers in the opinion questionnaire by calculating the mean (M) and the standard deviation (SD) for each question in each condition. Furthermore we conducted a t-test analysis to examine if the differences between the conditions are significant.

Interviews

Interviews were conducted in order to record details of how students of the different groups worked and perceived the whole activity. The interviews lasted about 15 minutes each and they were semi-structured. They focused on students' opinions about: (a) the activity as a whole (likes/dislikes), (b) the role of prompting (students were asked to comment on how helpful, necessary, relevant, annoying, and time consuming considered the prompts to be), (b) the role of fixed support (students were asked to comment on how helpful, necessary, relevant, annoying, and time consuming considered the fixed support to be and (c) evaluation of the learning environment in terms of usability, efficiency and workload. Students were randomly and individually interviewed.

All of the individual interviews were audio-recorded and fully transcribed for further analysis. The coding scheme analysis included four main categories and the relevant subcategories. In Table 1 we present the coding scheme.

Table 1. Interview analysis coding scheme

Category	Subcategories	Description
Impact of the collaborative activity	-group interaction -group answers	Students' statements about the benefits and shortcomings of the activity
Impact of prompting	-acts after the prompting -thoughts about prompts	Statements referring to the adaptive prompting mechanism
Impact of fixed support	-acts after fixed support -thoughts about fixed support	Statements referring to the fixed support mechanism
Impact of the script	-script tasks -roles	Statements referring to the collaboration script
The learning environment	-usability -efficiency	Statements referring to LAMS

The interview transcripts analysis classified students' statements according to (a) relevance (the coding scheme categories/subcategories the statement was relevant to) and (b) attitude (the opinions or judgment expressed by students). For example, the student statement "prompts were helpful for our discussion regarding the open-ended questions" was classified as relevant to "impact of prompting" (subcategory: "acts after prompting") and expressing the opinion of "helpful".

In order to validate the above scheme, two independent field experts, who were not involved in any other aspect of the study, were asked to read through three transcripts (from both conditions) and to identify a category system. The generated categories were compared to the initial categories. The differences were discussed and a consensus was reached regarding the final form of the scheme. Finally two coders individually coded the interview transcripts following the above scheme. The intra-coder reliability was satisfactory (Cohen's kappa = .90).

Results

Learning outcomes statistical analysis

We proceeded to apply parametric statistics to our data as the normality and the homogeneity of variance criteria were satisfied. T-test control was applied to students' pre-test data and analysis of covariate (ANCOVA) to the other measures with the pre-test as covariate. The pre-test did not show any significant differences between the two group scores in either of the two questionnaire parts (part1: close type questions, part2: open ended questions) (Table 2).

Table 2. Pre-test analysis

		Control (n=20)	Treatment (n=20)	t-test
1	Part1 closed-type questions	M = 4.80 SD = 1.18	M = 5.00 SD = 1.43	t = .48 **n.s.** (p = .631)
2	Part2 open-ended questions	M= 3.25 SD = 2.09	M = 3.5 SD = 1.72	t = .68 **n.s.** (p = .68)

Inter-rater reliability for the second part of the post-test was high (ICC = .94). The treatment group outperformed the control group in both measures of domain basic knowledge (close type questions) and domain understanding (open ended questions). ANCOVA indicated that the difference was statistically significant (Table 3, item 1 and item 2).

Table 3. Post test analysis

		Control (n=20)	Treatment (n=20)	ANCOVA
1	Measure 1-A (domain basic knowledge)	*M* = 5.80 *SD* = 2.42	*M* = 7.30 *SD* = 1.49	*F*(1, 5.49), ***p* < .05**
2	Measure 1-B (domain understanding)	*M* = 3.19 *SD* = 2.61	*M* = 5.00 *SD* = 2.43	*F*(1, 4.92), ***p* < .05**

Inter-rater reliability for the two LQs was also high (ICC = .905). Referring to the sum of the two LQs, ANCOVA indicated that the groups in the treatment condition outperformed the dyads in the control condition (Table 4, item 1). However, as we proceeded to interaction analysis (see below), we identified that the students' need for support was different in the two KQs. For this reason, we further statistically analyzed the two LQs separately. In the first LQ, groups in the treatment condition achieved better scores than the groups in the control condition. This result is also statistically significant (Table 4, item 2). However, although the groups in the treatment condition answered better in the second LQ than the controlled groups, the result is not significant (Table 4, item 3).

Table 4. In-task group learning analysis

	In-task group learning	Control (n=10)	Treatment (n=10)	ANCOVA
1	Measure 2 (both LQ1 and LQ2)	*M* = 7.88 *SD* = 1.96	*M* = 9.38 *SD* = .88	*F*(1, 6.88), ***p* < .05**
2	Measure 2-1 (only LQ1)	*M* = 7.75 *SD* = 2.19	*M* = 9.5 *SD* = 1.05	*F*(1, 5.48), ***p* < .05**
3	Measure 2-2 (only LQ2)	*M* = 8.00 *SD* = 1.97	*M* = 9.25 *SD* = 1.69	*F*(1, 4.34), **n.s.** (***p* = .053**)

Dialogue analysis

The analysis of the group dialogue showed that in the first KQ the treatment groups missed 18 keywords totally (same as the number of the prompts that appeared after the KQ1). Based on the analysis model, we identified that from these 18 prompts, the students used correctly and with adequacy 15 keywords in LQ1. By contrast, dyads in the control condition missed 17 prompts, but they used efficiently only 3 of them in LQ1.

Concerning the second KQ, results showed that the treatment 7 dyads missed 1 keyword each (7 keywords totally). All the dyads used that key concept efficiently during the second LQ. On the other hand, 5 control dyads missed from one keyword (5 totally) and 3 of them used it during the LQ2. In table 4 we present the results of the dialogue analysis.

Table 5. Dialogue analysis

		Treatment Dyads (adaptive support)	**Control Dyads (fixed support)**
		Phase 1	
1	**KQ1** *cases of missing keywords*	**18**	**17**
2	**LQ1** *cases of including key concepts in group answers after support*	**15** (out of 18)	**3** (out of 17)
		Phase 2	
3	**KQ2** *cases of missing keywords*	**7**	**5**
4	**LQ2** *cases of including key concepts in group answers after support*	**7** (out of 7)	**3** (out of 5)

Moreover, the dialogue analysis in LQ1 showed that the majority of the treatment dyads (8 out of 10) were focused on the subject meaning that their interactions were more solution-convergent that the dyads in the treatment group. In contrast, the controlled dyads had the opposite behavior. The majority of the (8 out of 10) used domain aspects that were needless or irrelevant to the LQ1 solution. Finally, the interaction analysis showed no similarity with the above difference during the LQ2.

Student's opinion questionnaire analysis

The opinion questionnaire included 9 items: (a) 3 items different for each condition concerned the support (adaptive or fixed), (b) 2 items referred to the script, (c) 2 items to the whole learning activity and (d) 2 items to the collaboration environment. In table 6 we present the results concerning the supportive mechanisms.

Table 6. Students' answers regarding the subjectively perceived impact of the supportive mechanisms

	Questions	**Answers** (Likert scale 1-7)
	Adaptive support (*n*= 20)	
1a	The prompts helped me to recall the relevant key concepts	*M*= 5.50, *SD*= 1.395
2a	The prompts help me to be more efficient when discussing the respective learning question (LQ)	*M*= 5.70, *SD*= 1.559
3a	The prompts were clear and precise	*M*= 6.10, *SD*= 1.119
	Fixed support (*n*= 20)	
1b	I chose to see the support (keywords list) and it helped me to recall the relevant keywords	*M*= 4.15, *SD*= 1.69
2b	The keywords-list help me to be more efficient during the next collaborative activities	*M*= 4.60, *SD*= 1.85
3b	The keywords-list was clear and precise	*M*= 5.30, *SD*= 1.750

In table 7 we present the items concerning the script, the whole learning procedure and the collaboration environment. T-test results showed that there are significant differences in students' answers in items 6 and 7 concerning the benefits of the activity.

Table 7. Students' answers in items of the opinion questionnaire

	Questions	**Answers** (Likert scale 1-7)		
		Treatment (*n*= 20)	**Control (*n*= 20)**	**t-test**
4	The system guidelines for the peer roles (author, reviewer) were clear and easily understandable	*M*= 6.35 *SD*= .875	*M*= 5.70 *SD*= 1.08	t = 2.090 p > .05
5	I believe that I responded decent at my role	*M*= 5.95 *SD*= .887	*M*= 5.85 *SD*= 1.09	t = .327 p > .05
6	The collaborative activity enhanced my domain knowledge	*M*= 5.85 *SD*= 1.424	*M*= 4.80 *SD*= 1.196	t = 2.524 **p < .05**
7	The collaborative activity was beneficial for me (regardless of any improvement in my domain knowledge)	*M*= 6.10 *SD*= .967	*M*= 5.35 *SD*= 1.182	t = 2.195 **p < .05**
8	The chat tool helped me to express easily my thoughts	*M*= 5.70 *SD*= .865	*M*= 6.25 *SD*= .967	t = -1.897 p > .05
9	LAMS is a usable and pleasant environment	*M*= 6.20 *SD*= .768	*M*= 6.60 *SD*= .598	t = -1.838 p > .05

Interview analysis

Students in the treatment mode were rather positive about the adaptive prompting. All of them declared that the prompts were clear, precise and understandable. They also mentioned that the prompts appeared on time. A student said: "…the prompts appeared when I could focus on them. They were short, precise with just the information that I needed in order to recall some crucial parts…" Three of the students mentioned that although they had already studied the prompted notions, the prompts made them realize the connection between the notions and the relevant question. A student said "I was familiar with the presented information by the prompt, but I was not sure that it concerned that question until the prompt appeared…"

On the other hand, students on the control condition did not respond the same about the fixed support mechanism. 8 of them mentioned that they only checked what they had missed without further study. 5 of them studied further the keywords that they had missed and only 1 student mentioned that he/she studied all the keywords from the support. Moreover, 12 of them said that the supportive keyword list made them anxious. Some of the students mentioned that the keyword list was not interesting to them: "it was just a list with keywords and explanations… it was difficult to follow during the activity". Another one said: "I rather prefer to task and discuss than to read a list of keywords…"

Regarding the entire activity, students from both conditions expressed a common positive view. They mentioned that it was very interesting and intriguing to discuss with a partner remotely trying to find a solution to a common problem in real time. Moreover, the strong majority of the students (n = 38) mentioned that the script roles helped them to structure and organize their discussions.

Discussion

It is a fact that few intelligent and adaptive collaborative support systems have been implemented and even less evaluated (Walker et al., 2009). A great deal of them is research prototypes and it is difficult not only to evaluate and determine the effect of these systems on students' collaboration and learning, but also to deploy them in every day classroom conditions (Kumar et al., 2007). Besides, several systems are strongly domain-specific and cannot be widely used in any desired domain. Finally, there is no large-scale evidence available that proves the effectiveness of the adaptive collaboration support techniques regarding domain-specific learning outcomes (Baghaei et al., 2007).

Against the above, in this study we investigated the extent to which it is possible to effectively implement a domain-specific collaboration support strategy of dynamic format during a scripted collaborative activity. More specifically, in this study we focused on and eventually compared two kinds of support: (a) an adaptive intervention by identifying missing domain keywords in the peer discussion log file and presenting reminding prompts to partners accordingly and (b) a fixed support by giving the students the option to see all the domain keywords of a question afterwards. The adaptive method indeed resulted in improved individual and group-learning outcomes as indicated by the statistical analysis of the post-test and the LQ results respectively.

Concerning the individual learning, the first section of the post-test showed that students in the treatment mode outperformed the students in the control mode in recalling conceptual knowledge (learning at "basic" level of Bloom's taxonomy) (table 3, item 1). Additionally, results from the second section of the post-test indicated that the treatment students used much more efficiently the conceptual domain knowledge to a new problem situation than the students in the control mode ("understanding" and "application" levels of Bloom's taxonomy) (table 3, item 2). Also the opinion questionnaire revealed that students in the treatment mode found prompts very helpful to refresh their domain knowledge (table 6, item 1a) and believed that the prompting mechanism helped them to be more efficient during the next collaborative activities (table 6, item 2a). Finally they stated that the prompts were clear and precise enough to be understood /to be perceived (table 6, item 3a).

We also argue that the adaptive support proved more beneficial to in-task group learning compared to fixed support. Statistical analysis of the sum of the dyads scores in LQ1 and LQ2, showed that the treatment dyads achieved greater scores than the control dyads (table 4, item 1). However, although treatment dyads outperformed both in the two LQ, the results are statistically different only for the first question (table 4, item 2). This can be explained by the results of the dialogue analysis. These results showed that the main impact of the adaptive support was evident during the first phase of the script (KQ1 – LQ1) (table5, item 1 and item 2). In that phase both treatment and controlled dyads missed a large number of keywords, and as result they needed support. The assessment of dyads answers to LQ1 proved that the adaptive prompting helped the groups to answer the LQ better. On the contrary, the dyads in the second KQ missed a small number of keywords. As a result they needed less support. The statistical analysis of the dyads answers in LQ2 showed that although the treatment dyads outperformed the control dyads, the results are not significant (although it is very close to level of statistical significance) (table 4, item 3). In our opinion this can be explained by the low need for support during the second phase of the script. Moreover, interaction analysis also revealed that the adaptive prompting helped dyads were more solution-convergent during their LQ1 discussion than the control groups. However, the two groups worked the same during the LQ2.

We believe that the improved outcomes of the treatment group can be explained by considering that the students are exposed to remedial domain-specific information right after they discuss the relevant domain issues. The adaptive mode of presentation enabled students to easily integrate missing information in the domain model they constructed by activating three key cognitive processes: “selection” (focus on relevant information), “organization” (organize new information in a coherent model) and “integration” (link it to their previous domain knowledge) (Mayer, 2003). Based also on students’ interviews we argue that one of the reasons the prompts proved beneficial is that they appeared “at the right moment”, right after the keyword discussion, simulating a human teacher intervention assessing what had been discussed. This had a positive impact on students making them feel as if they were engaged in human-to-human conversation and eventually more willing to focus on prompt information.

By contrast students in the control condition did not achieve comparable performance level as students in the treatment group. This means that the additional prompt-based support offered to treatment students was necessary for achieving the higher performance and had greater impact than the fixed support mechanism. The opinion questionnaire revealed that students in the control condition found the fixed support less helpful to refresh their domain knowledge (table 6, item 1b) and to improve the next collaborative activities (table 6, item 2b) than the treatment students (table 6, items 1b and 2b respectively). The same occurred in the (table 6, item 2a). Furthermore, the interview analysis revealed 3 major behaviours concerning the fixed support: (a) students did not give any attention at all to the support, (b) students just checked what they had missed without further study and (c) students studied only what they had missed. In contrast with the friendly tone advices of the reminding prompts in the treatment condition, the fixed support did not appeared attractive or useful to the controlled students.

Overall, we believe that the result of this study highlights an important perspective in computer-supported collaborative learning. Even when peer interactions are triggered by collaboration scripts and supported by a fixed domain-specific support, the individual domain models of the partners might not be as rich as necessary to result to an elaborated common domain model for learners. In this case, adaptive supportive mechanism (dynamic form of support) that help students “repair” their incomplete domain models can result to significantly improved learning outcomes. This perspective of collaborative learning is in line with the paradigm of sharing individual mental representations (Stahl & Hesse, 2009). The two collaborators aim to establish shared knowledge by exchanging ideas based on their internal mental representations. However, when these representations fail to meet certain criteria then the computer-based partner intervenes to the dialogue externalizing its own representations and contributing to the shared knowledge. This study shows clearly that the remedial information provided by the adaptive system can improve students’ domain models and lead to better performance in problem solving.

Conclusion

The limitations of this study include: (a) sample size: we acknowledge the fact that a replication study with larger sample is needed to corroborate the outcomes presented here and (b) limitations of the evaluation methods: Although the study evaluation methods showed positive learning outcomes, it needs to be further examined which part of the adaptive mechanism affected this positive impact.

We believe, also, that our study provides incentive to further explore interesting relevant questions, such as: (a) how to further automate and otherwise improve the presented method for adaptive domain-specific support by analyzing peer dialogue and (b) explore which adaptation components affect the quality of collaboration (for example using layered and decomposition evaluation frameworks (Paramythis et al., 2010)).

This study provides encouraging evidence that dynamic forms of support (as opposed to fixed forms) can be implemented during a collaborative activity and result in improved collaborative learning outcomes. The main goal of this study is to investigate specific (and simple) types of adaptive collaboration support in more detail in order to increase our knowledge of when and why adaptive collaboration support is (or not) effective. In other words, this work provides the basis for exploring the impact of more complex and thoughtful adaptive support mechanisms in the context of collaborative learning.

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