Supporting Argumentative Knowledge Construction in Face-to-Face Settings: From ArgueTable to ArgueWall

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Abstract: Research on computer-supported collaboration scripts has so far widely neglected human-computer-interaction (HCI) aspects. This paper presents a set of case studies on the user interface of a computer application that smoothly fits into the practice of argumentative knowledge construction in co-located collaborative learning. During an iterative design process different user interface designs were evaluated regarding their effects on the knowledge construction process. Starting from a tabletop application ('ArgueTable') the design process led to an alternative display environment ('ArgueWall'), which uses laptops together with a shared wall display. The results show that HCI aspects can have strong effects on the scripted learning processes. Due to the inherent interaction of humans and computers, HCI should be an integral part of research on computer-supported collaborative learning (CSCL).

The Need for Computer Support in Argumentative Knowledge Construction

While high quality of argumentation has shown to be beneficial for learning, it is rarely found in unsupported collaboration (cf. Kollar, Fischer & Slotta, 2007). Learners usually do not provide grounds and qualifications for their claims. In addition, learners rarely raise socio-cognitive conflicts through counter argumentations. A possible solution is to provide instructional means that focus on the quality of argumentation to enhance collaborative learning. Computer-supported collaboration scripts have been successfully implemented to facilitate collaborative knowledge construction by increasing the quality of argumentation during discussions (e.g. Stegmann et al., 2007).

However, research on collaboration scripts has widely neglected an important aspect that plays a role in computer-supported collaborative learning: variations of the user interface as studied in HCI. Collaboration scripts are often implemented using typical desktop user interface elements, such as textboxes, buttons and drop-down menus. Such interfaces often do not reach the goal of providing an intuitive interface, which guides learners naturally through the process. Instead, text-based instructions are commonly used, leading to a waste of time and a misplaced emphasis on the task of operating the computer.

This paper presents studies on the user interface design of a computer application for argumentative knowledge construction in face-to-face collaborative learning. The user interfaces was developed using an iterative design process as proposed by Nielson (1993). The studies show that the design of the user interface - in particular the choice of displays - can have strong effects on script-based learning processes.

HCI in the Design of Applications for Collaborative Learning

In the field of HCI a number of studies have shown that the type of display environment can affect co-located collaborative processes. Some of the display characteristics that play a role are the number, orientation, size and privacy of a display as well as the seating arrangement and the users' proximity to the display (Mandryk, Scott & Inkpen, 2002).

Several of these aspects also play an important role in collaborative *learning* scenarios. First, depending on the number, size and orientation of displays, they can offer *private* workspaces or be visible to the whole group, which increases the *awareness* of the learning partner's activities (Mandryk, Scott & Inkpen, 2002). An increased awareness could have positive effects (e.g. efficient task coordination) as well as negative effects (e.g. distraction from the primary task). Second, the *balance of participation and role distribution* within the team can be affected. For instance, Rogers and Lindley (2004) found collaboration to be more balanced on horizontal displays compared to vertical ones. Furthermore, empirical studies indicate that combinations of shared *and private* workspaces can support a more equal participation in face-to-face collaborations (Looi et al., 2008). Third, there are ergonomic aspects such as arm fatigue or limited elbowroom (Inkpen et al. 2005). The result of such factors combined is that different types of displays are used for different purposes (cf. Everitt et al., 2006) and thus have different *affordances*.

Computer-Support for Argumentation

Scheuer and colleagues (2010) have done an extensive literature review on systems that support argumentation. They identified different types of argument representations that have been used in such systems: linear, threaded, graph-based, container and matrix. Empirical studies show that the type of argument representation can affect collaboration. Suthers and colleagues (2008) conducted a study in which they found that knowledge maps better facilitate collaboration as compared to threaded discussions. Furthermore, Lund and colleagues (2007) compared different ways of using argumentation diagrams: as a means for debate or as representation of the debate. In their study, instructions on how to use the argumentation diagram had a significant effect on the argumentation itself. A further important aspect is the concrete task at hand, for instance whether to focus on the individual or group performance (cf. Pfister and Oehl, 2009).

Iterative Design Process

Against this background, our goal was to create an application, which guides learners during the creation of arguments. According to Toulmin (1958) these arguments should consist of claim, grounds and qualification. Furthermore, we aimed at facilitating argument sequencing (cf. Leitão, 2000).

To develop an optimized user interface, we followed an iterative design process as proposed by Nielsen (1993). During this design process the user interface is iteratively tested by users (in our case learners) and then refined according to their feedback. That way, usability problems can be identified early in the design process and the user interface is gradually improved.

Paper Prototype Study

Due to the findings in the field of HCI discussed above, we chose a tabletop displays for our learning scenario. In particular, we were interested in two characteristics that tabletop displays facilitate: (1) they foster balanced participation rates (Rogers and Lindley, 2004) and (2) they enable natural face-to-face communication, e.g. in terms of eye contact (Inkpen et al., 2005). In the beginning of our iterative design process, we therefore created a paper prototype of a tabletop system, in which learners are seated on opposite sides of a table.

We started with the question how argument representations should look like in order to be comprehensible and at the same time support learners in creating arguments. To examine this question, different stacks of cardboards were provided to the participants. Each cardboard represented an argument. There were different types of argument representations: (1) A triangular design with the captions ‘claim’, ‘grounds’ and ‘qualification’, (2) a linear design with the clause openers ‘I think that’, ‘because’ and ‘unless’ and (3) an empty cardboard that allowed learners to create own designs for argument representations. The cardboards were placed on a table, which was covered with a table-sized piece of paper. Arguments could be sequenced by drawing lines on the paper background. In addition, flexible wires could be attached to cardboards.

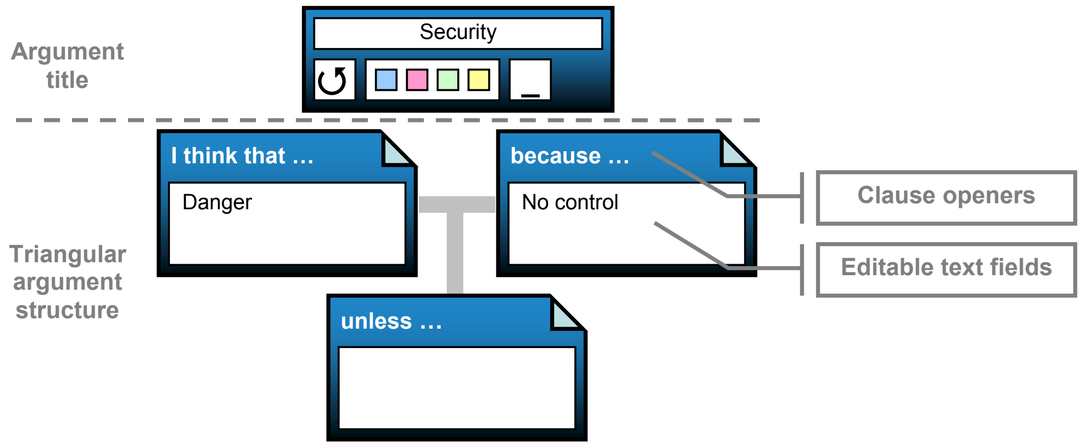

Figure 1. Redesign of Argument Representations after the Paper Prototype Study.

Overall, N=12 learners in groups of two or three participated in the paper prototype study. 58% were female. Four of them were graduate students, the remaining eight were doctoral students. Participants were asked to imagine they took a course called “Learning how to argue”. In the beginning a short introduction was given, in which the structure of arguments was explained. Learners were instructed to create arguments consisting of claim, grounds and qualification, to provide pros and cons, to build argument sequences by relating their arguments to their learning partner’s arguments, and finally to draw a conclusion. The participants were told that in the end the content of the table should represent the course of discussion. There was no time limit to ensure that all groups would be able to reach a conclusion. After the groups had finished their argumentation there was an open discussion, which the experimenter started by asking why the according design alternatives were chosen. Later, more general feedback was collected and finally the participants were asked to modify or create their own designs. The feedback of the participants led us to a redesign of the interface for the construction of single arguments (see Figure 1). Furthermore, we identified argument sequencing as difficult task, which is rarely done by learners even when instructed to do so.

Comparing Two Display Environments: ArgueTable or ArgueWall?

Based on the lessons learned in the paper prototype study, a functional tabletop prototype was implemented and gradually refined. For this purpose several case studies were conducted, using the same task and proceeding as in the paper prototype study described above. While several issues were improved, the deficient argument sequencing remained despite several measures (e.g. specific metaphors that indicate which arguments should be linked). Across all studies, we observed that learners mainly interacted with the application in the first phase when argument representations were built. During the subsequent discussion, in which the task was to build argument sequences, there was little interaction with the application. These observations led us to the hypothesis that using separate displays for the two phases could emphasize that there is still further interaction needed in the second phase. We therefore started to think about separate physical workspaces for the two learning phases. This made us question the reasons for choosing a tabletop scenario in the first place.

Thus, we conducted a final study in which the tabletop application ('ArgueTable') was compared to a distributed application consisting of laptops and an interactive wall ('ArgueWall'). We decided to use a wall-mounted display instead of a tabletop display as shared workspace, because the combination of laptops and a tabletop display did not seem feasible. For instance, as occlusion has to be avoided, it would not be clear where the laptops should be placed. Hinrichs et al. (2007) describe how even much smaller devices such as hardware keyboards can create a barrier between user and tabletop or make interaction clumsy if the keyboard is removed and retrieved when needed.

Research Questions

Against this background, we examined two research questions:

RQ1: To what extent does the display setting (ArgueTable vs. ArgueWall) affect processes during argument preparation? We expected the awareness of the learning partner's activities to be higher on the ArgueTable compared to the ArgueWall condition (where the individual work takes place in private workspaces). At the same time, we expected the individual work to be less disturbed in the ArgueWall condition, because there is less distraction by the learning partner's activities.

RQ2: To what extent does the display setting (ArgueTable vs. ArgueWall) affect collaborative argumentation? We expected more argument sequences in the ArgueWall condition. Furthermore, we were aware of the possibility that only one of the two learners stands up and interacts with the wall display. This could lead to unwanted role distributions, such as thinker and writer.

Methods

Participants and Design. Ten dyads (N=20) participated in our study. 45% participants were female. Their age ranged from 20 to 31 (M=24.85, SD=3.63). We varied the type of display setting using a within-subject design. Therefore, all participants used both types of display setting in a counterbalanced order.

In the ArgueTable condition a tabletop display was used for both, the individual and collaborative phase. During the individual phase, the workspace was graphically divided into two personal workspaces. During the collaborative phase, the same tabletop display served as shared workspace.

The ArgueWall condition was realized using two laptops during the individual phase. Participants created their argument representations next to each other using laptops, but without direct sight on the learning partner's display. During the collaborative phase a wall mounted display was used. The individually created arguments could be transferred to the shared display using the Gateway interaction technique (cf. Guinard et al, 2007). To create argument sequences, users had to stand up and move and/or connect their arguments on the wall-mounted display using direct touch.

Learning Task and Procedure. At the beginning, the functionalities of the applications were demonstrated by creating exemplary arguments on the topic 'ban on smoking in restaurants'. The functionalities of both applications during the individual and collaborative phase were identical: By dragging notes from a stack, new argument representations can be created, each consisting of the three components claim, grounds and qualification (on laptops or on the tabletop display). In the collaborative phase, argument representations can be freely arranged using direct touch dragging gestures on the shared, interactive (wall-mounted or tabletop) display. Furthermore, argument notes can be linked in order to build argument sequences. It is also possible to minimize single arguments as well as entire argument sequences. After the introduction, participants were asked to discuss two different topics: 'pro/con tuition fees' and 'pro/con speed limits on highways'. For each topic learners should first prepare three important arguments that support their position (pro or con) before discussing the topic.

Data sources and Dependent variables. After each discussion a questionnaire with items regarding the previous discussion was administered. The subjective awareness of the learning partner's progress, the subjective distraction from the learning task and the subjective confrontation during the collaborative argumentation were measured with a self-report questionnaire. All items had to be answered on a 5-point Likert scale from 1 ('completely disagree') to 5 ('completely agree'). *Awareness* was measured with the item 'It was easy to detect when my partner was finished with preparing arguments'. *Distraction* was measured with the item 'I could prepare my arguments undisturbed'. *Confrontation* was measured with the item 'In the discussion I perceived my learning partner as opponent'. Furthermore, the number of argument sequences was used as indicator for the *quality of argument discourse* (cf. Stegmann et al., 2007). In order to examine the *role distribution* within the dyad, the participants were not instructed regarding different roles during the discussion.

Statistical tests. All inference statistical tests were performed against a 5% error level. Paired-sample t-tests were performed according to the type of dependent variable at hand.

Results

RQ1: Effects of display setting (ArgueTable vs. ArgueWall) on processes during argument preparation:

Awareness. Regarding the perceived awareness, the mean answer was higher for the ArgueTable (M = 3.85, SD = 1.23) than for the ArgueWall condition (M = 2.85, SD = 1.57). A paired-sample t-test showed a significant effect, $t(19) = 2.30$, $p = .03$, two- tailed, $r = .47$, $d = .72$. However, the questionnaire results also indicate that the awareness was not considered to be an important factor for the choice of display environment.

Distraction. To assess the subjective distraction, the answers of the item 'I could prepare my arguments undisturbed' were reversed. Using the ArgueTable participants felt more distracted (M = 1.35, SD = 0.93) than in the ArgueWall condition (M = 2.05, SD = 1.19). A paired-sample t-test showed a significant effect, $t(19) = -2.33$, $p = .03$, two- tailed, $r = .47$, $d = -.66$.

RQ2: Effects of display setting (ArgueTable vs. ArgueWall) on collaborative argumentation:

Argumentative discourse quality. The mean number of argument sequences built on the ArgueTable was lower (M = 2.41, SD = 1.51) compared to the ArgueWall (M = 4.20, SD = 2.25). A paired-sample t-test showed a significant effect, $t(9) = -2.59$, $p = .029$, two- tailed, $r = .65$, $d = -.96$.

Confrontation. Regarding the item 'In the discussion I perceived my learning partner as opponent', the mean answer was M = 3.35 (SD = 1.39) for the ArgueTable and M = 3.90 (SD = 0.91) for the ArgueWall condition. A paired-sample t-test showed a significant effect, $t(19) = -2.34$, $p = .030$, two- tailed, $r = .47$, $d = -.48$. Thus, the partner was perceived more as opponent in the ArgueWall condition and less so in the ArgueTable condition.

Role distribution. In the ArgueWall condition, both learners stood up at the beginning of the collaborative phase and engaged in the discussion across all dyads. Therefore, an unwanted role distribution (such as one person being responsible for the interaction with the application, the other one for contributions with regards to content) was not observed.

Discussion

The need to switch displays between individual and collaborative phases (as in the ArgueWall setting) seemed to increase the concentration on the discussion phase and its associated tasks. Regarding the question of confrontation, the answers showed that the learning partner was less perceived as opponent in the tabletop condition, i.e. when sitting face-to-face. Previous studies, which compared face-to-face and side-by-side seating arrangements (cf. Sommer, 1967), suggested the opposite. A possible explanation for this discrepancy was found in informal interviews conducted at the end of the user study. According to participants' statements, working on separate displays during the individual phase triggers the notion of self-dependency. It seems whether one is working on a shared or separate displays has a larger effect on the subjective confrontation than the seating arrangement. Finally, a role distribution within the dyad could not be detected. In all groups both learners went to the wall-mounted display and interacted with the application. Their part in the discussion was fairly balanced. These observations were confirmed by questionnaire results, which pointed out that the participants had the feeling of an equal distribution of work. Again, this finding differs from related work, which found collaboration to be less balanced around wall displays (cf. Rogers & Lindley, 2004). Our assumption is that in our study both learners felt equally responsible for the interaction on the wall display, as they both created part of the content in the prior individual phase.

In summary, the final study revealed clear advantages of an explicit private workspace for individual phases in collaborative learning scenarios. This aspect was considered more important than the awareness of the learning partner's progress. Moreover, the number of argument sequences was much higher on the ArgueWall, which can be ascribed to both a more clearly arranged workspace and increased concentration due to the display switch between the individual and collaborative phase.

Conclusion

When developing computer applications to support collaborative learning scenarios, the design of the user interface plays an important role. In co-located settings a major factor is the choice of display environment for individual as well as collaborative tasks. Several studies have shown that different types of displays have various assets and drawbacks (e.g. Inkpen et al., 2005). However, it is hard to foresee how important the individual pros and cons of a certain display environment are in a specific collaborative scenario, which makes the choice very difficult. In our case, the iterative design process led to a display environment that looked very different from our first vision, which was derived from findings in related work (ArgueTable). The final display setting, consisting of laptops and an interactive wall display (ArgueWall), showed to have significant positive effects on the collaborative learning process. We therefore recommend that for new collaboration-supporting systems the design process starts from the basis of relevant related work, but also takes into account a broad range of possible hardware configurations and includes low-cost comparative evaluations. Small case-studies with low- and high-fidelity prototypes appear to be superior to *only* applying rather general guidelines from the literature when it comes to finding adequate designs.

Our findings underline that research on the user interface should be an integral part of CSCL. Our studies showed that HCI aspects can have strong effects on script-based learning processes. These effects may interact positively or negatively with scaffolds like collaboration scripts. Our recommendation is to develop scaffolds for CSCL in an iterative design process, before studying effects of these scaffolds on collaborative learning in traditional experiments.

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