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Enhancing Quality of Argumentation in a Co-located Collaborative Environment through a Tabletop System

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Abstract—This study validates the potential of a tabletop system to enhance students' quality and intensity of argumentation when engaging in co-located collaborative design activities. Twenty-four undergraduate students participated in a between-subjects design where one group used the proposed system and the other group used a paper-based approach. Overall students using the tabletop system over exceeded their peers in relation to their quality and intensity of argumentation. Further studies should increase the number of students to be able to generalize our findings.

I. INTRODUCTION

The ability to successfully engage in argumentation is an essential component of professional success; professionals must be ready to interact with each other, to assess other people's points of view, and to present their own position using well-grounded and adequate arguments [1]. Argumentation skills are particularly relevant for design-based disciplines, such as Computer Science (CS); software design is an inherently group-based and argumentative activity that demands designers to successfully present ideas to peers as well as to collaboratively refine these ideas through discussion [2]. However, recent industry reports on CS graduates' deficiencies in communication and critical thinking skills [3] reveal that CS education needs support to develop students argumentative abilities. In this paper, we argue that such support should also harness already existing opportunities for students to in high-quality collaborative argumentation, e.g. traditional face-to-face in-class software design group activities that demand students to find a solution for an authentic open-ended problem.

Previous research on educational argumentation reveals that Computer-Supported Collaborative Learning (CSCL) environments can provide that support; these environments can not only encourage peer interaction, but also guide groups of students into effective argumentative knowledge construction [4]. Nonetheless, due to CSCL traditional focus on the analysis of written-based asynchronous communication [5] [6], little is known about the impact of CSCL approaches on students' argumentative skills when engaging in face-to-face group interactions. Within this context, multi-touch tabletop displays become a promising technology; current work on the area suggests tabletops can encourage argumentation by bolstering exploration [7], increasing awareness of other actions [8] [9], providing a more fluid interaction [10], and promoting productive elaborations and justifications [9]. Nevertheless, little research on the support tabletops can provide to the construction of argumentative knowledge has focused on tasks relevant to college students. Moreover, the existing explorations on collaborative software design supported by interactive surfaces [11] [12] have not explored the specific needs of software design learners.

This study attempts to fill the existing gap by continuing the exploration of the initiative previously reported in [13] in which a tabletop system for augmenting collaborative argumentation in CS students was proposed based on the design principles of interdependence, stages, interference and awareness of others. To be more specific, this research evaluates the proposed system's potential to enhance the quality and intensity of argumentation of CS students when engaging in co-located collaborative database design. In order to do this, we set up an experiment with two groups of students; while one group used the proposed system to solve a database design problem, the other used the traditional paper-based approach. Students' interactions were video-recorded and further analyzed using the argumentation dimension of Weinberger's framework [14] for categorizing argumentative knowledge construction. Although this framework focuses on asynchronous discussions, we decided to use co-located interactions due to its proven efficacy for CSCL. Our findings show that the proposed tabletop system effectively enhances both the quality and intensity of students' collaborative argumentation, providing validity to the initially derived design principles. This paper is structured as follows: first, a related work section

is introduced, the proposed tabletop solution is described, and its implementation specifications are explained. Then, the research context, experiments and corresponding results are detailed. Finally, a discussion section including reflections about further research is presented.

II. CONCEPTUAL BACKGROUND AND PREVIOUS STUDIES

Argumentation theorists have a variety of definitions for the term [15]. For the purpose of this study, we will define argumentation skills as the ability to use data for constructing arguments, and to use those arguments to clarify, emphasize or demonstrate the reasonableness of a position. Understanding how to argue is an essential component of critical thinking and decision-making in every situation [16], specially in the crafting of scientific discourse [17]. Previous studies have proved that students' knowledge on argumentation can benefit from participating in high-quality argumentative discussions within learning environments based on interaction and debates [16]. Argumentative knowledge construction scenarios, where learners engage in collaborative argumentation and critical thinking with the goal of jointly constructing knowledge within a domain, provide these opportunities. Our study attempts to augment the quality and intensity of argumentation of CS students by harnessing the argumentative knowledge construction that takes place when they engage in co-located collaboration within the Database Design domain.

Researchers from different fields have developed several different approaches to analyze argumentative discourse [18] [4] [19]. One of the most used approach is Toulmin's model of argument structure, which assesses argumentation quality based on the identification of the absence or presence of argument features such as claims, data, warrants, backings, and rebuttals. Despite the influential role of Toulmin's model, it is not considered as dialogic. Therefore, it does not fully allows for capturing the inter-dependency among collaborators [20]. In turn, the learning sciences have introduced a variety of dialectical models of argumentation, each considering different scopes of argumentation as well as definitions of argumentative interaction [21]. Many of the concepts derived from these approaches have been transferred to enable argumentation knowledge construction analysis in CSCL environments [22] [14]. Of particular relevance to our study is the CSCL framework of Weinberger and Fischer [14] that proposed the analysis of four dimensions of argumentative knowledge construction (participation, epistemic, argumentative and social mode); due to its proven applicability in computer-supported environments and its emphasis on dialogical analysis, we propose the use of Weinberger's adapted version of Toulmin's model to assess students' collaborative argumentation.

As for the studies that report on CSCL efforts to guide learners in effective argumentative knowledge construction, most of the existing initiatives have focused on asynchronous written communication in online environments. For example, a sub-area of research has focused on the development of computer-supported argument visualization platforms that offer a visual representation of the logical structure of arguments during online collective deliberation [5] [23]. In addition, a large portion of research in the area has focused on the development of tools that scaffold learners' interactions: [24] [6] proposed tools to script collaboration, [25] provided means to reflect on one's social deliberative skills, [26] [27] presented representational tools that support interactive argumentation, and [28] focused on fostering consensus. Furthermore, computational argumentation research has also developed more formal logic and mathematical models with an interest in reasoning over the model in order to evaluate claims or prove properties automatically [29]. In sum, the existing research strongly suggests that CSCL environments can in fact facilitate the development of argumentative knowledge.

Despite the widespread recognition of CSCL potential benefits for argumentation, little is known of its impact on co-located, simultaneous collaborative argumentation. The few existing work on the support of computers on face-to-face collaborative learning has not really addressed the impact of technology in participant's argumentation skills. Instead, it has focused more on understanding how individual and group usage of technology can impact both students' participation and level of coordination when working in groups. For example, Dickey et al. [30], proposed ThoughtSwap, a stand-alone application that was designed to run on wirelessly connected notebook computers in a middle-school classroom environment. The purpose of the tool was to buttress the scope of students' participation while maintaining coordination during in-class discussion. In the same line, Harry et al. [31] presented Tin Can, a tablet-based system to collaboratively track discussion topics and ideas in a higher-education liberal arts classroom. The authors concluded that the struggles that some participants face with oral communication can be better addressed by also providing text-based stages. Another significant area of research on co-located CSCL has focused on enabling group participants to visualize measures of their real-time behavior in shared displays [32], [33], concluding that visualizations cause over-participating members' to decrease its level of participation. While these studies' findings do not specifically describe co-located CSCL's impact on collaborative argumentation, they are highly indicative of the CSCL approach's potential for supporting argumentative knowledge construction. We propose the study of multi-touch interactive tabletops as another valid technological approach for supporting co-located collaborative argumentation. Previous studies indicate that tabletop-supported collaborative interactions can help develop students' argumentation skills by encouraging externalization, reflection and higher-level thinking [7] [34]. In addition, tabletops' ability to generate more clashes can prompt interference, which in turn elicits curiosity, awareness of others' actions, and verbal negotiation [8] [10]. Similarly, these clashes can serve as a trigger for productive argumentation and collective knowledge construction [9] [8]. By focusing on higher-education audiences and considering the needs of software design learners, this work attempts to contribute to the existing research on tabletop's impact on collaborative learning.

III. System Design

Based on the design principles derived in [13], a tabletop system was implemented to support software design in higher-education. The system comprises a tabletop for group usage, as well as tablets and infrared pens for each group member. The design aims to enhance the quality and intensity of argumentation in co-located collaborative sessions through the reinforcement of four principles: interdependence, stages, interference and awareness of others. These principles are implemented as follows:

Enforcing structure of the task: Three **stages** are proposed to boost students' opportunities to better understand the problem. In the first stage, a short initial problem description is shown in each students' tablet. In each tablet, each student is able to highlight keywords related to the problem. A cooperative gesture [35] on the tabletop (check marks), that aims to augment students' **awareness** and **dependence** on each other, defines the end of the first stage and the start of the next one. On the second stage, the tabletop shows students a shared view of both the problem description and the coincidences and/or dissimilarities in the keywords they highlighted during the previous stage. This last feature is expected to enhance students' **awareness** of each other. A touch on a button on the tabletop leads to the last stage which corresponds to the modeling task.

Clue-based instructions: In contrast to the traditional approach of providing students with a long detailed description of the design problem from the beginning, the proposed system delivers the instructions in the following manner: during the first and second stage students are presented and can interact with a short initial problem description. During the third stage, further instructions become clues that each student can request through his/her tablet. Student access to a requested clue **depends** on the rest of the students' acceptance to the request. Once all students accept the request for a clue, the clue is displayed in each student's tablet. Clue-based instructions aim to enable **interdependence** among students, as well as **awareness of others**.

Shared reading and highlighting: Students are able to use their tablets to highlight keywords of the reviewed text during all stages of the process. Additionally, during the second and third stages the application provides a shared-view of all members' highlights. Colors allow to differentiate keywords' owners. The shared reading and highlighting feature aims to enhance students' **awareness of others'** contributions.

Puzzle-like modeling: To promote both a more flexible modeling process and students' participation, both entities and attributes within a database conceptual model are represented with cards. While colors allow to differentiate each card's creator, any student is able to manipulate and edit any card on the tabletop. Both, the level of granularity and the flexibility of edition and manipulation seeks to allow for members to more easily **interfere** in each other's work; this, in turn, is thought to enhance **awareness** and prompt argumentation.

Fig. 1. Students working with the Tabletop System

IV. Implementation

The hardware solution used in this study took as a reference the solutions proposed in [13] and [36]. Additionally, this version of the proposed system used Kinect V2 depth camera to improve the hand and finger tracking. The system is composed of the following devices: one infrared camera, one web camera, a Kinect V2 depth camera, a mini-projector, three infrared pens and three tablets. On the software side, the interface is supported by a client-server application. The server application was developed in Kivy, a Python framework; and a web application on the client side for the interactions with the tablets. More specific details of the implementation of the tabletop can be found in [36].

Infrared pens, multi-touch gestures and tablets allow participants to interact with the proposed tabletop device. Students use the tabletop to design a database conceptual model with the proposed system; infrared pens are used to created relations and cardinalities on the tabletop, whereas entities can be moved towards any direction using a multi-touch gestures. Tablets allow students both to create and edit entities and to send them to the tabletop.

V. Methodology

A. Participants

Twenty-four undergraduate students, enrolled in a Database System course of an engineering-oriented university, participated in an experiment during their regular classroom term. Students were assigned to specific groups based on their personality and life experience. According to [37] and [13], factors such as shyness or poor life experience interfere with argumentation initiatives in Collaborative Software Design (CSD) environments; e.g. a person with no experience, could, because of this factor, refrain from expressing her opinion and/or participate during the design activity. Therefore, each group was integrated with individuals that could balance the discussions and interactions during the design task.

The conformation of the groups was based on a pre-test consisting of two questionnaires. The first questionnaire determined the student's personality traits in five different dimensions: openness, conscientiousness, agreeableness, extroversion, and neuroticism; which according to [38] are necessary and sufficient for broadly describing personality. The second questionnaire measured the life experience of a

Fig. 2. Students working in the Paper-based condition

person, involving questions about travels, financial independence, literature and news. Eight homogeneous groups of three students were formed using the results obtained from applying both questionnaires.

B. Experimental Setup

To determine the potential of the proposed system to enhance the quality and intensity of argumentation of CS students during collaborative learning tasks, we carried out two observation sessions. In both sessions, students were asked to solve a database design problem collaboratively. As a result, students were expected to generate a database diagram. Each session lasted approximately 20 minutes. The first session was used to help students get acquainted with each other as well as get used to working together. Students' interactions were recorded during both sessions; nevertheless, for the purpose of this study, only the observations and measurements from the second session were analyzed.

Following a between-subjects design, four groups were assigned in any of the two conditions: (1) experimental condition: using the proposed tabletop system to solve the task (See Figure 1); and (2) control condition: using the traditional paper based approach to do the design task (See Figure 2).

C. Measurements

To measure the quality and intensity of argumentation in collaborative tasks, we used Weinberger and Fischer's [14] analytic framework. While this framework is intended for the analysis of online text-based interactions, we used it to analyze the participant's verbal interactions in a face-to-face co-located environment. More specifically, we used the categories of the argument dimension of Weinberger, which refers to the participant's ability to construct and balance arguments and counterarguments to prove a possible answer to a problem. On this dimension, the discussion can be analyzed in two levels: 1) The *construction of single arguments*, categorized hierarchically according to the quality of an argument as *simple claims, qualified claims, ground with warrant claims and grounded and qualified claims*; and 2) The *construction of sequence of arguments*, which is the arrangement of single arguments in a line of argumentation. These sequences of arguments consist of *arguments, counterarguments and replies*, and help learners balance multiple perspectives of a

problem solution, prompting them to defend their position in the discourse.

Thus, the **construction of single arguments** level allows us to measure the quality of the argumentation through hierarchical levels from *simple claim* (lowest) to *grounded and qualified claim* (highest) as follows: **Simple claim (Level 1):** Statement that advances a position without justification or limitation of its validity; **Qualified claim (Level 2):** Claim without justification, but with limitation of its validity (with qualifier); **Grounded with warrants claim (Level 3):** Claim with provision of grounds that warrant the claim; **Grounded and Qualified claim (Level 4):** Claim with grounds that warrant the claim and limitation of its validity.

As for the intensity of argumentation, we used the construction of sequence of arguments. For this purpose, each student's interaction was categorized as one of the following sequences of arguments:

- **Argument:** Statement in favor of a specific proposition.
- **Counter-argument:** An argument in opposition of a preceding argument.
- **Reply to Argument or Counter-argument (Integration):** Statement advancing a preceding argument or counterargument.

D. Coding

Two different raters observed and analyzed videos of each groups sessions, using The Observer XT [39]. Each participant's verbal contribution to the discussion was classified according to the two levels mentioned above. Raters were trained to code the group's sessions. After finishing two training sessions, consisting on coding 10 minutes of one group's session, the raters started to code all the group's sessions. The raters reached a reasonable inter-rater reliability Cohen's k = 0.79, for the coding task.

VI. RESULTS

After the observation and analysis of videos, a total of 682 verbal contributions were obtained from the discussions. The overall coding of the intensity of argumentation for both group conditions is presented in Table I. It is evident from this coding that students using the proposed tabletop system proportionally differ from those using the paper-based approach. Students in the experimental condition show more counter-arguments and replies to argument or counter-arguments than those in the paper-based approach. Note, however that for the latter coding (i.e. reply to A/CA) students generated more arguments. Figure 3 portrays in a more explicit way this difference. We carried out a hypothesis testing to validate, statistically, this apparent difference. The Chi-Squared test indicated a significance dependence between the experimental conditions and the proportions observed in each condition ($\chi^2(2)$=9.83, p=0.007). The level of intensity in the discussion among the two conditions are statistically different. Moreover, a Mann-Whitney U test was used to confirm this difference (U =50772, p=0.001)

TABLE I
PROPORTIONS OF DISCUSSION INTENSITY PER EXPERIMENTAL
CONDITION

Intensity level	Tabletop (%)	Paper-based (%)
Argument	41.4	53.1
Counter-argument	20.4	18.0
Reply to A/CA	38.2	28.9
Total	**100.0**	**100.0**

TABLE II
PROPORTIONS OF QUALITY OF ARGUMENTATION PER EXPERIMENTAL
CONDITION

Quality level	Tabletop (%)	Paper-based (%)
Level 1	67.2	81.4
Level 2	1.8	0.3
Level 3	24.9	16.2
Level 4	6.1	2.1
Total	**100.0**	**100.0**

Fig. 3. Intensity of Argumentation per Experimental Condition

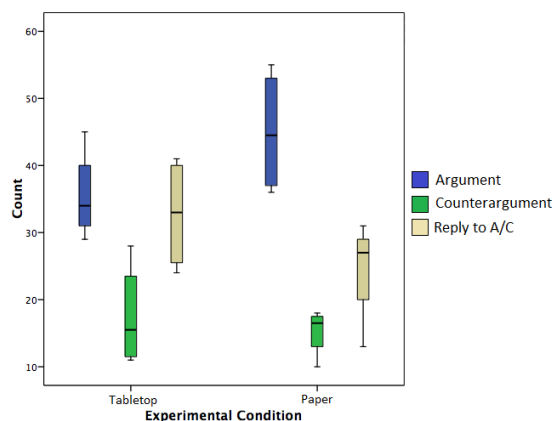Fig. 4. Quality of Argumentation per Experimental Condition

As for the category of quality of argumentation, table II summarizes the different levels associated with this category in each experimental condition. Students using the traditional approach reached higher proportions of level 1, whereas students using the tabletop system engaged in higher levels of argumentation, such as level 3 and level 4. Level 2 in both conditions had marginal occurrences. Figure 4 evidences the dissimilarities in the proportions. A Chi-Squared test was carried out to test a dependence between the group conditions and the proportions in quality of argumentation. The results show a significant dependence $(\chi^2(3)=21.94,$ p$<$0.001) between variables. The proportions in the different levels of the quality of argumentation among the two conditions are statistically dissimilar. Again, a Mann-Whitney U test was used to test whether there is a difference among the levels of quality reached by students under the conditions. This test confirmed the previous statement (U=49611, p$<$0.001). Students using the tabletop system reached higher levels of quality in their argumentation during the co-located collaborative sessions.
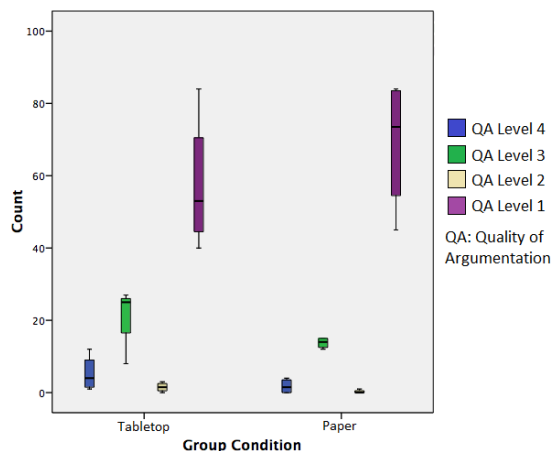
VII. DISCUSSION AND FURTHER WORK

The aim of this study was to explore how a set of design principles (See section III) implemented in a tabletop system could enhance the quality and intensity of argumentation of CS students when they engage in co-located collaborative database design. The descriptive and inferential results show a positive impact of the proposed system over the quality and intensity of the students' arguments in comparison to those shown by their peers, using the traditional paper-based approach. These results have proven that relying only on oral communication could generate good quality of argumentation. This goes in opposition to the claims of [31] that were in favor of supporting a hybrid oral and text-based approach to gain good levels of argumentation. Additionally, as stated by [40], generating counter-arguments instead of exclusively arguments places a particularly important role in student' revising and updating knowledge. Therefore, the fact that students in the experimental condition showed higher levels of counter-arguments proves the potential to positively influence the quality of argumentation. Despite the positive outcomes of this study other factors should be consider to further generalize our results. First, more students should be involved in similar experiments where design activities take place. Second, the discourse and actions that emerge during the design sessions should be studied deeper and with a more qualitative approach as stated by [9], to try to find the direct impact of the proposed design principles in students' argumentation. Third, in this study we decided to focus only in the argumentation dimension of Weinberger's framework; nevertheless, we recognize the relevance of the other dimensions of the framework. Further studies should address all the previously mentioned factors.

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