# A Tabletop System to Promote Argumentation in Computer Science Students

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## Abstract
This study explores the design of a tabletop system that seeks to bolster the argumentative skills of Computer Science students. A set of four design guidelines - positive interdependence, stages, interference, and awareness - were derived from user research and used for designing and prototyping a multi-display tabletop application. Four students evaluated a video prototype; the overall results showed that the application's features have great potential to support the design guidelines. Moreover, students' impressions about the prototype's enforcement of positive interdependence indicate possibilities for augmenting argumentation opportunities. Steps for future work are presented.

## Author Keywords
Software Design; Tabletops; Computer Science Education; User-Centered Design; Argumentation

## ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.

## Introduction
Software design is an inherently collaborative and argumentative activity that demands designers to successfully present ideas to peers as well as to

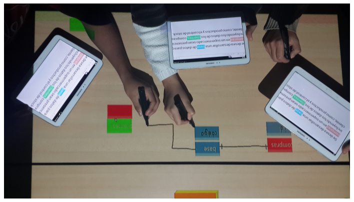

**Figure 1:** Proposed multi-display tabletop application

collaboratively refine these ideas through discussion [17]. Nonetheless, employers' accounts on the struggles recent graduates face when communicating [15] strongly suggest Computer Science (CS) education requires support in this area. Within this context, multi-touch tabletop displays become a promising technology for supporting the development of argumentative skills. Previous research on tabletops indicates such technology has the potential to enhance collaborative learning (CL) [16, 8, 5] by fostering a more enjoyable, playful environment that promotes exploration [19] and equity of participation [18]. Furthermore, former studies suggest tabletop applications can encourage argumentation [6, 5]. Nevertheless, little research on the area has focused on tasks relevant for college students [14]. Moreover, the existing explorations on collaborative software design (CSD) supported by interactive surfaces [1, 12, 2] have not explored the specific needs of software design learners. In this study, an iterative user-centered design approach was used to develop the prototype of a multi-display tabletop application for collaborative database design learning (Figure 1). The application aims to augment the possibilities for argumentation among participants. In what follows, a set of design principles derived from user research is presented, the prototype of the proposed solution is described, and the results of a first exploratory evaluation are discussed.

## Related Work

Several studies have explored the potential of tabletops for CL [16, 8, 5, 14]. Kharrufa et al.[8] found that tabletop applications that support externalization and reflection can encourage higher-level thinking and elicit effective learning. Schneider et al. [16] concluded that engagement can act as mediator for productive collaboration. Additionally, Wallace et al.[18] found that tabletops can support equitable participation in learning situations. On the realm of tabletop support for group argumentation and discussion, previous research concluded that by prompting interference, multi-touch tabletop applications can elicit curiosity, raise awareness of others' actions and encourage verbal negotiation[5] [6]. Some of the different mechanisms explored to afford interference are: allowing lack of territorial constraints [19], enabling participants to intrude at each other's work [6] and supporting high-level physical interactions [5] [14]. Nonetheless, few studies have explored tabletops' support for argumentation in groups of college students, addressing tasks directly related to their interest[14]. Finally, in spite of the existing explorations of CSD supported by interactive surfaces[1, 12, 2, 3, 7], to our knowledge only [11] focused on CSD learning. After studying college students' use of a tablet application for software design [12] over an academic term, [11] reported that the proposed application enabled students to work effectively in teams as well as to quickly develop, refine, and evaluate their designs. In contrast, the present study seeks to explore the design of a tabletop application considering the needs of collaborative software design learners.

## User Research

In order to better understand the struggles software design learners experience when engaging in collaborative argumentation, we carried out two user research activities. The activities took place in the Ecuadorian setting of an engineering-oriented university, Escuela Superior Politecnica del Litoral (ESPOL), and involved the participation of twenty-two undergraduate students, enrolled in a Database System course of a CS program. The first activity consisted of two observation sessions; in each session, students were handled a paper-based description of a typical database design problem and

**Figure 2:** Tabletop system used for user research

**Figure 3:** Second iteration of the paper-based prototype

asked to solve the problem in groups of 3 to 4 members. To contrast the variety of needs that different types of interaction elicit, half of the groups were observed performing the activity using a tabletop application for CSD [7] (Figure 2) while the other half worked in a paper-based environment, using black markers and a large paper sheet. The second user research activity was a diary study of students' reflections on their immediately previous group work experience.

## Design Guidelines

Our user research's findings on the factors that hinder argumentation initiatives in a CSD class are consistent with [9] findings: a) academic unpreparedness, b) group dynamics, c) mix levels of experience, d) shyness, and e) poor listening skills. To address these issues while augmenting opportunities for argumentation during CSD, this research proposes the following design guidelines for a tabletop application:

**Positive Interdependence (PI):** In a collaborative setting, it refers to group members relying on one another in order to succeed [10]. A tabletop application for CSD learning could prompt PI by ensuring each group member owns a piece of information necessary to complete a problem description. In this way, students with a lower lever of academic preparation are empowered to participate (issue a). Furthermore, this can buttress effective group dynamics (issue b) by augmenting the need for members to verbally interact in order to achieve full understanding of a problem.

**Stages:** Mix levels of experience (issue c) among group members cause some of them to move faster through a problem while others fall behind. Furthermore, shyness(issue d) can hinder a member's ability to let the group know that he or she is falling behind. To enable equal opportunities for each member to engage in argumentation, a tabletop application for CSD learning should enforce the division of a software design assignment in stages. In such scenario, a group would only be able to advance to a new stage once the previous has been declared as finished.

**Interference:** Although it can be seen as something negative, interference can prompt discussion [5] [6], forcing members to overcome shyness (issue d) and to listen to others (issue e). A tabletop application for a CSD learning environment could trigger interference by introducing unexpected behaviors, such as misleading design clues.

**Awareness of others:** Similarly to the impact of interference, a tabletop application that enables each member to know other people's contributions, not only allows individuals to be aware of what is happening in the design process, but creates opportunities for them to argue about others' decisions (issue d, e)[4].

## System Design

The proposed prototype evolved through a design process that consisted of three iterations. The goal of the first trial was to explore the potential impact of the design guidelines. For that purpose, the designers engaged in a bodystorming session with a paper-based prototype. The second trial was conducted with two groups of CS students of 3 and 4 members each. Groups where asked to design a database solution using the second iteration of the paper-based prototype (Figure 3). The goal was to analyze the quality of students' argumentation while interacting with the prototype. As a result, the third and final iteration proposes the design of a multi-display

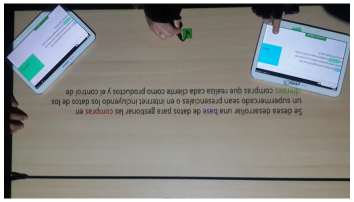

**Figure 4:** First stage of the design task: shared reading and collaborative gestures

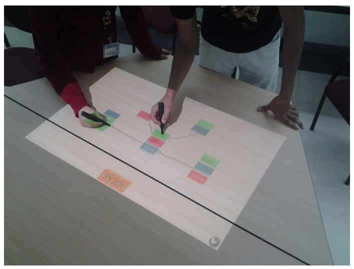

**Figure 5:** Second stage of the design task: Deck of clues and puzzle-like modeling

approach (tabletop and tablets); its main features can be summarized as follows:

**Enforcing structure of the task:** Previous iterations showed that students have better opportunities to achieve homogeneous understanding of the description of a design problem if the task is divided into two stages. The first stage is related to reading and understanding the problem description; and, the second focuses on modeling. A cooperative gesture[13] on the tabletop (check marks) defines the end of one phase and the start of the next one (Figure 4).

**Clue-based instructions:** Contrary to the traditional approach of providing a whole set of instructions from the beginning, the proposed system delivers the instructions in the following manner: during the first stage, a short general instruction is presented on the tabletop as well as on the tablet of each student (Figure 4); during the second stage, specific instructions become clues within a deck of cards on top of the tabletop (Figure 5). Clues can be either useful or misleading. Each student can draw clues from the deck to his/her tablet (Figure 6). Availability of a clue is limited to one student at a time; however, a student can transfer his or her clue to another student's tablet. This new approach promotes interdependence and fosters equal participation in discussion. Additionally, misleading clues introduce interference, triggering further argumentation opportunities.

**Shared reading and highlighting:** Students are able to highlight keywords of the reviewed text at both stages of the process. Additionally, the application provides students the following opportunities to see others' highlights: during the first stage, the tabletop provides a joint view of all members' highlights (Figure 4); at the second stage, a clue owner can use its tablet to see both his or her highlights and the highlights of all the clue's previous owners (Figure 6). Colors allow to differentiate highlights' owners. These visual cues of others' activities enable awareness of other people's actions, and boost argumentation of key components of the design.

**Demonopolizing deck use:** In previous iterations, students showed a tendency to assign the task of drawing and reading clues to only one member. This behavior hinders equal participation in the modeling activity. The system addresses this by exhibiting an erratic behavior: when a student attempts to make consecutive excessive use of the clues, the application sends the new clue to the tablet of another randomly selected student.

**Puzzle-like modeling:** To promote a more flexible modeling process and participation, both entities and attributes within a database conceptual model are represented with cards (Figure 5). The color assigned to each card represents its creator. This level of granularity allows members to more easily interfere in each other's work, enhancing awareness and prompting argumentation.

## Implementation

The current application is a horizontal prototype of the solution. It offers limited functionality, emulated by a variety of techniques. It runs under a portable projector camera system that works with two PS3Eye cameras and a mini projector. The interaction with the tabletop is through infrared pens. On the software side, a client-server application supports the user interface. On the side of the server, the application was developed in Python and Kivy Framework and on the side of the client a web application enables student to interact with a tablet.

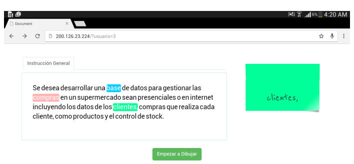


**Figure 6:** Tablet view of instructions

## Evaluation

Before moving to a full implementation, we aimed to evaluate the impressions and reactions of users when observing some key features of the proposed prototype. Moreover, the displacement of users' zone of comfort was sought. For that purpose, a three-minute video prototype of the main features of the system was presented to a group of four students from a CS program who were enrolled in a Database Systems course. These students had previously used a multi-touch tabletop application for database modeling[7]. They were not informed about the ultimate goal of the system, nor were they asked to evaluate the achievement of this goal. Students reacted positively to having the design task divided in stages as well as to features that raise awareness of others' work. For instance, they found that the colored cards were useful to identify the contribution of others and were eager to see their peers' highlights during the shared reading stage. However, their impressions on the interdependence enforced by the clue-based approach were negative. They mentioned they did not like to depend on somebody else and contended they would rather have the whole instructions given to them from the beginning. Additionally, they suggested to have access to the highlights of other users in their tablets, instead of having it only available at the tabletop. Despite the fact that students were not enthusiastic to use pens to write on the tabletop, they welcomed its use when drawing relationships among entities.

## Conclusions and Future Work

Overall, our analyses of users' perceptions lead us to conclude that the prototype's features have great potential to accomplish the derived design guidelines. The discomfort caused by the prototype's features that force participants to depend on others, suggests possibilities for creating equal opportunities for argumentation. An elaborated version of this prototype will be developed and the effectiveness of the design guidelines' achievement will be evaluated in a real classroom setting. Our work contributes to the research in this area by proposing: 1) Specific design guidelines for collaborative software design learning, drawn from user research sessions; 2) A horizontal prototype of a tabletop application that seeks to augment argumentation among CS students.

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