Exploring On-time Automated Assessment in a Co-located Collaborative System

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***Abstract*—This research explores the effects of providing on-time automated assessment in a co-located collaborative system for Entity-Relationship design. In addition, students' perceptions about the validity and usefulness of this automated assessment, and its potential for reflection were analyzed. Thirty undergraduate students from computer science participated in the study, a quasi-experimental pre-post test design was conducted. Short quizzes for measuring students' learning performance were used and the perceptions of students were gathered by means of questionnaires. Results showed that on-time assessment positively affected students' learning performance in the study. Finally, students perceived that the system assessment is valid and useful and has the potential to generate mechanisms for reflecting about individual learning and group performance. The study concludes with steps for further research.**

I. Introduction

Professionals of the Twenty-first Century are required to demonstrate collaborative skills and software designers are not the exception. Moreover, researchers such as [1] have recently pointed out that Computer Science graduates need to strengthen their communication and critical thinking skills. Therefore, higher education institutions are urged to support their students in the development of both collaborative and communicational abilities. In this context, co-located collaborative environments provide ideal scenarios to nurture these abilities ([2], [3]). Regarding the actions or the process that emerge when designing, students commonly require feedback from their tutors or peers. As stated by Poulos and Mahony [4], feedback needs to be effective, i.e., it has to be appropriate and timely. Besides, other researchers (e.g. [5]) have highlighted that the purpose of feedback is to reduce discrepancies between what it is currently understood, the current performance and the final goal of a task. Therefore, providing feedback both during and at the end of a task can provide enhanced opportunities of learning.

The present study is built upon a previous study [6] in which four design guidelines (positive interdependence, stages, interference, and awareness of others) were used to design and deploy a collaborative tabletop prototype, resulting in promising outcomes. Moreover, these design guidelines were used in a recent research that validated the potential of a tabletop system to enhance students' quality and intensity of argumentation [7], also with positive outcomes. Furthermore, this second study suggested that these design guidelines could have the potential to improve learning performances on students. This paper aims to fill the gap and go beyond the two previous studies described above by measuring the impact of a proposed system that supports collaboration and on-time assessment, on the learning performance. More specifically this study seeks to address the following research questions: (1) Do the fostering of collaboration and on-time assessment, provided by a tabletop system can improve the academic performance of students? and (2) What are the students' perceptions about the validity, usefulness and potential for reflection of the automated assessment generated in a co-located collaborative system?

II. Conceptual background and previous studies

Effective feedback has been defined as the information provided to increase performance which can be given or received by an individual or groups [8]. Moreover, feedback needs to be appropriate (in the context) and timely, in order to be effective [4]. According to Hattie and Timperley [5], feedback operates in four different levels: task, process, self-regulation and self level. A general form of feedback is assessment that is specifically intended to generate feedback on performance to improve and accelerate learning [9].

Several studies on Computer Supported Collaborative Learning (CSCL) to support reflection in groupwork spaces have focused on the development of tools for asynchronous written communication mostly in online environments ([10], [8]), suggesting that reflection tools can enhance group interactions, group-process satisfaction and social performance.

In the context of assessment in a co-located collaborative environment supported by tabletop systems, most studies have focused on qualitative aspects of collaboration (e.g. [11] [12]

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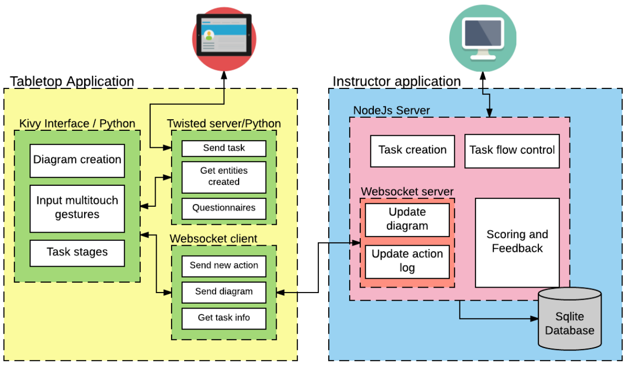

Fig. 1. Software components of the proposed tabletop system

[13]) or on group interaction (e.g. [14] [15]). No other work has previously focused on providing automated feedback about the quality of the task.

As for automated assessment in the database design context, most of the existing initiatives have explored the use of intelligent tutor systems in online or desktop applications (e.g [16] [17]), reporting only reactions from teacher and students (i.e. acceptance, usefulness). In addition, most of the feedback during the database design is done during the activity (i.e. messages, alerts) [18]. Furthermore, in [19], the authors developed a web-based coach collaborative learning environment to leverage learning opportunities through the discussion of beliefs before constructing a shared design solution, reporting usability and perception on students.

In summary, previous research has not explored so far the effect of automated assessment on learning performance in co-located collaborative design environments. This study attempts to fill this gap utilizing an environment that supports collaboration in a co-located environment, and that includes visualizations of the assessment and spaces for reflecting about the feedback provided.

III. The Co-located Collaborative System

The proposed system has hardware and software components. The hardware component consists of a multi-touch interactive tabletop (Coffee Table by Ideum) and three tablets. The tabletop can respond to touch-based gestures to move, delete and combine elements on the interactive surface, while the tablets are used by students to create and edit elements. In addition, the co-located collaborative system uses Kinect V1's depth camera to differentiate the interaction of the participants with the surface; and a Kinect V2 to record the audio and to determine the identity of the speaker, based on the angle of the audio source.

The software component of the system consists of the following: a tabletop client-server application, which is used by the students to do ER design activities, and a web application, which is composed of the student's tabletop application and instructor's application. Figure 1 shows the structure of the software components in more detail.

A. *Student's tabletop application*

The proposed system implemented the design guidelines derived from the study by Wong-Villacres et al. [6]. These design guidelines prescribe that an effective tabletop-based database design application should facilitate: (i) positive interdependence, (ii) task stages, (iii) interference and awareness of others.

The system deploys a web application that is displayed on the tablets and tabletop. The web application allows the students to login into the system, read the task description, create notes which can be sent to the tabletop, and the tabletop can send the notes (i.e. entities, attributes) back to the tablet to be edited. The tabletop can respond to different gestures to interact with the notes: drawing a circle with several notes inside join the notes together to create a combined element; drawing a line on top of one entity separates it from its group; drawing a line that links one note with another creates a relation between them; and dragging four different notes to assign cardinalities to the relations.

Each student is assigned a color (red, blue or yellow), depending on the place they are seated around the table. For user's identity recognition [20], the overhead kinect sensor records user's actions while interacting with the objects on the tabletop (e.g moving a note, drawing relationships, etc).

In relation to the task, **four stages** were predefined before starting the activity. In the **first stage**, students are presented with a ER design problem on their tablets, which is a short description presented as text. During the stage, they can underline important words and think about how to solve the ER design in a general perspective. The **second stage** presents all the underlined words in a shared view on the tabletop. During this stage, students discuss about shared words and a possible solution for the ER design. In the **third stage**, start creating entities and relationships by using notes generated from the tablets. During this stage, students can ask for more clues related to the design task. Nonetheless, if one student ask for a clue, all other students should accept the request sent to its tablets. The **four stage** was considered for giving and receiving written peer-feedback to leverage discussion about the activity and promote a reflection space (i.e. how am I going?).

B. *Instructor's application*

Instructor's application allows to create ER design activities, to setup the flow of the experiment and to visualize running activities in the tabletop system. The application enables the instructor to set the instructions, duration of stages, number of students, and the proposed solution of the task. The instructor has access to a list of created tasks and can assign them to any active tabletop session, allowing students to begin solving the task. During the execution of a session, the web application provides the instructor with a real-time view of the students' interaction in the tabletop with several charts reporting group interaction and the amount of participation per student. Additionally, the instructor can see the progress of each session by visualizing the ER model that is being created by the students. The elements of the ER model (entities, relationships

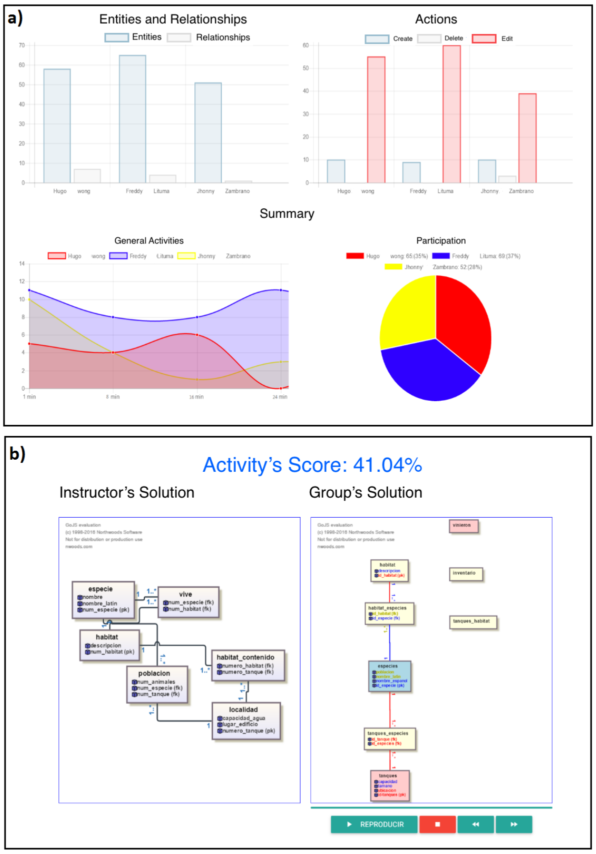

Fig. 2. Feedback visualization and score of a student's task. a) Statistics about the participation of each student. b) Diagrams of the instructor's proposed solution and the solution made by the students, with the corresponding score generated by the system.

and cardinalities) are colored depending on the color of the student that create them. When the tabletop session ends or the instructor stops its execution, the application compares the students' final solution with the proposed solution registered by the professor, and generates a detailed score based on the degree of similarity of both solutions. Both, the solution proposed by the students and the one included by the instructor are presented in a report which is sent by the system to the students' email.

C. Students feedback

At the end of the session, the students are presented with a web interface, which shows the score achieved by the group, and stats about their individual participation. The score is calculated by comparing the entities and relations made by the students and a solution given by the instructor. The students can observe on which items they had mistakes and the elements that have been included in the solution by each member (See Figure 2). The co-located collaborative system enables the authorship of the elements in the final solution and is able to playback the creation process of such solution.

TABLE I
DESCRIPTIVES ABOUT USEFULNESS, VALIDITY AND POTENTIAL FOR REFLECTION OF THE AUTOMATED ASSESSMENT

Descriptive Statistics	Usefulness of Assessment	Validity of Assessment	Potentials for Reflection
Median	5.50	5.00	5.50
Minimum	2.50	2.00	3.50
Maximum	6.00	5.50	6.00
S.D.	0.96	0.94	0.69
Skewness	-1.11	-1.49	-0.98

IV. METHODOLOGY

A. Participants

Thirty undergraduate students of Computer Science, 6 females and 24 males ranging from 21 to 26 years old, enrolled in an introductory Database Systems course and participated in an experiment during their regular classes. Students conformed groups of three members based on their own affinity.

B. Experimental Setup

After attending a lecture about designing entity-relationship models, students were invited to participate in an experimental session to determine the potential of automated assessment, generated by the proposed system. The following activities were carried out during this session:

1) **Individual pre-test:** A test about entity-relationship modeling was applied to the students using Socrative, an online application for students' assessment.
2) **Collaborative activity:** Students working in groups were asked to solve collaboratively a database design problem. The activity had a duration of 20 minutes and as result of the activity, an entity-relationship model was generated.
3) **Visualization of results:** The results of each group's design were visualized in a centralized screen. (see fig. 2
4) **Feedback questionnaire:** A six-point Likert scale questionnaire with six questions was applied individually to measure usefulness, acceptance and potentials of reflection after being exposed to the visualization.
5) **Individual post-test:** A post-test was applied to the students with similar content as the one included in the pretest. Again, Socrative was used for this purpose.

V. RESULTS AND DISCUSSION

To answer the research question 1, a paired-sample T-test was carried out to find whether there were differences between the scores obtained by the students in the pretest and posttest. The results show that the students' scores in the posttest (M=51.82) differ significantly ($t(29)=12.48$, $p=0.01$) from the scores in the pretest (M=39.33). These results were expected, the proposed system: supports spaces for engaging in argumentation about the received feedback/on-time assessment; and, includes reflection slots for giving feedback to other members of the group. These spaces appear along the design task and at the end of it. In this sense, Nussbaum [21] identified that engaging in collaborative argumentation might have effects in consolidating learning gains and Noroozi et al. [22] claim that collaborative argumentation generates a "shared understanding" of a given problem and thus foster knowledge construction which ultimately can lead to better learning. Nevertheless, a current meta analysis [23] points that researchers should be clever about the evidence and real impact of argumentation in learning performance in computer-supported collaborative learning.

Next, descriptive statistics (see Table I) were used to answer research question 2. To measure the validity and usefulness of the automated assessment; and, the potential for reflection provided by the visualization of the assessment, we used Likert scales; therefore, Table I shows medians instead of means. Note, however, the overall positive results reported by students about the usefulness and potential for reflection provided by the automated assessment. Moreover, students perceived that the system's assessment is comparable in terms of validity to the one given by the professor (Highest skewness from the three measured variables). Nevertheless, the computer-generated scoring still has limitations. Some students indicated that the system could not correctly recognize answers because they used hyphens or special characters in the names given to some elements of the design. Therefore, these results should be carefully examined before generalizing the findings, as suggested by [24] who carried out a critical study about automated evaluation in writing. Finally, students identified that the automated assessment has potential for reflecting about their own learning performance and the group performance.

VI. Conclusions and Further Work

This study demonstrates that fostering collaboration and on-time assessment, can improve the academic performance of students. Moreover, students' overall perceptions about the usefulness and validity of such assessment were very positive. They acknowledged that the feedback received through the assessment has the potential to trigger reflection about their learning and group performance. However, we cannot generalize the findings. Students worked in a context related to Entity-Relationship design and the sample size of the experiment was small. Professors' scores should be contrasted with the automated scores generated by the proposed system. Further research should include other domains and larger sample sizes to attempt generalizing the current findings.

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