Implementing multi-touch tables into the classroom: In what ways are students engaged in an interactive mathematical activity 'around the table'?

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This exploratory study is about the design, development and evaluation of an interactive application on multi-touch table, in order to enhance students' learning of algebraic generalization in a collaborative learning environment. Multi-touch table technology allows users to work together on a task displayed on its screen, supporting rich forms of interaction amongst them. In order to investigate the context of the educational application, a paper prototype was designed and implemented into two classrooms of 26 students, aged 12-13, in an experimental school of Athens, Greece (pilot fieldwork). Data was analysed with the SOLO (Structure of Observed Learning Outcome) taxonomy. Outcomes obtained from fieldwork fed into the design requirements that the final interactive prototype must meet. Thereafter, the final prototype was evaluated in the laboratory by two focus groups of users. Results show that students engaged in verbal interactions, affecting the understanding of the subsequent algebraic concepts introduced, encouraging further research.

Keywords: multi-touch table; activity; algebraic generalization; generalizing patterns; paper prototyping

Introduction

Nowadays, ICT (Information and Communications Technology) is an integral part of classrooms and education. New types of interactions are introduced, supported by new technological tools such as multi-touch tables. This tool reinforces face-to-face interactions with direct, contemporary dialogs, gestures, postures and actions. All these constitute rich forms of interaction for teaching and learning (Evans, Ryon, Feenstra, & McNeill 2009).

Research has been conducted on collaborative learning in classrooms using multi-touch tables (Harris et al., 2009; Higgins, Mercier, Burd, & Hatch 2011; Mercier & Higgins 2013). They suggest that design features of large multi-touch surfaces and design of specific task environments can support collaborative interaction. Furthermore, students' initial strategies are built upon those interactive features and affect the way they arrived at solution of the task (Higgins et al., 2012). In Harris et al. (2009), multi-touch interaction influenced the nature of children's discussion to become more task-focused and verbal and physical equity was also present. In Mercier and Higgins (2013) a multi-touch table application was developed exploring whether collaborative engagement in mathematical practice can support the development of mathematical fluency and flexibility.

However, not much research has been done to investigate whether collaborative engagement with multi-touch tables and focused discussions affect students' understanding of more complex mathematical concepts, such as pattern generalization and algebra. Therefore, I was interested to look more closely at students' interactions on a multi-touch table when trying solve a common mathematical task: in what types of interactions students are engaged and if their engagement affects their understanding of the mathematical concepts introduced.

Theoretical background

According to Dillenbourg and Evans the nature of the multi-touch table as well as the forms of interaction provided to users convey a socio-constructivist approach in the sense that "they support small teams that solve problems by exploring multiple solutions" (2011 p .491). This can constitute a simple setting for a collaborative learning environment. Such environments arise in the classroom in the form of activities, where students are divided into groups to achieve a common goal, usually with the mediation of traditional or digital tools.

In the present exploratory research, the results of a small pilot study aimed to explore students' engagement in a mathematical group activity on patterns' generalization, are introduced. According to Radford (2008) one of the basic components of working with patterns is the ability to observe differences. Specifically, Radford (2010) in his theory of objectification, tries to describe the semiotic process of students' transition from the discrimination of a similarity to its expression as a more formal mathematical generalization through the use of signs (gestures, words, symbols). This process suggests potential students' exploration on growing patterns in the form of iconic variables. In the mathematical activity used here, iconic variables were designed and implemented primarily as crafts and finally as virtual manipulatives on the multi-touch table surface.

In Radford's objectification theory (2010) there are three levels of generalization performed by students that are characterized by semiotic means of objectification. At the first level, students make 'factual generalizations' based on finding the total number of the elements of a pattern for a specific number of repetitions, usually through verbal descriptions and gestures. The second level is 'contextual generalization', where the generalized elements are named but not symbolized and take form through pointing expressions that describe their spatial position e.g. "the next figure". At the third level of 'symbolic generalization', generalizations are expressed through the use of the alphanumeric semiotic algebraic system. These levels of generalization were decisive in forming the categorization of reasoning levels of the SOLO taxonomy scheme (Biggs & Collis, 1982) adapted for this research's pattern activity as well as for the activity sheets in the evaluation process.

Method

The activity is about putting tables into a floor plan. Should they be connected or separated? Each table arrangement has its own pattern.

Students acted as party planners and had to arrange the available tables properly so as to sit a specific number of guests, 38 in this case. They were divided in groups of 5 and given 6 floor plans (A3 size) as well as 16 specially designed tables of cardboard (the structural core of the pattern) (Figure 1, left) to put them into the floor plan in order to find the best arrangement. Thirty-eight was the chosen number to accord with the scale measurements made so that students can experiment on various table arrangements. The activity becomes challenging where different constraints are introduced into the task (Harris et al., 2009) e.g. available space to put the tables, how far from each other etc.

The sample consisted of 50 students in total, year 8 (12-13 years old) with non-existent or a fragmentary relationship with patterns. Students worked in their classroom for 45 minutes approximately. Their teacher participated in the pilot field study in the role of instructor, and the researcher in the role of participatory observer. Two more researchers assisted in the recording procedure. The recording methods used were a camera, 6 tape recorders and notes.

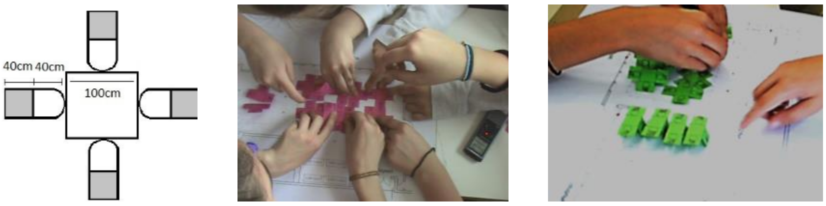

Figure 1: Cardboard table (left), Team arranges tables (middle), Inspiring arrangements (right)

Analysis

Transcripts from 6 groups were coded according to the SOLO taxonomy classification scheme. As stated in Higgins et al. "this taxonomy provides a hierarchical categorisation that identifies increasing complexity in reasoning" (2012, p. 1044). It also identifies relational complexity as a valuable feature of contributions (Moseley et al., 2005) between team's peers. This scheme was selected because the hierarchy of its levels follows a progressive pathway, indicating that the more reasoned the students' activity is (through claiming and arguing), the higher levels of reasoning are achieved. This matches the pathway that a student follows when 'doing mathematics'.

Statements	Definition	Example
Pre-structural	Perusing the floor plan and tables.	*"Should this be entered in the red frame? ...I guess."*
Uni-structural	Read the constraints in combination with the floor plan and review the problem requests.	*"must be 40cm off the wall ... We can measure by placing so to understand"*
Multi-structural	They are looking for different placements combining different capacity tables.	*"The tables can be joined ... Can we crease them? ... Count how much we 've put"*
Relational	They are using numerical operations to handle guests and tables.	*«We can do 38÷4? ...Could we merge 3 tables? ...But we 'll lose 3 guests?»*
Extended abstract	They try to give an explanation on how to fit more guests with connected tables, based on placements done so far and through mathematical operations.	*«9·4=36 ...we lose 2 guests ...chairs are leftover (...) since tables are connected. Yes! we fit more tables ...gaining space!»*

Figure 2: Table of the SOLO classification scheme adapted to the table activity

Therefore each student's statement was encoded according to the adapted SOLO scheme for this activity, characterized as Pre-structural, Uni-structural etc. (Figure 2), and then combined with the interaction that accompanied the statement, according to Thomas' interaction classification scheme (Thomas, 2002; Higgins et al., 2012). For example, a Uni-structural statement could be Quasi-interactive when attempting to draw others into the conversation about activity's demands, or Negotiating-interactive when putting forward an argument either in agreement or disagreement.

Results

Results show that students spent most of the time of the activity at the relational level with negotiating interactions, but were negotiating around the same topic. They kept counting the chairs one by one, although there were thoughts of how many tables were actually needed. Active participation was present (Figure 1, middle) and that might be due to the authenticity of the problem, the nature of the crafts, or both. Students' engagement was evident; all team members together were trying to find mechanisms to keep the tables connected, or were finding new ways of arranging the tables (Figure 1, right). Finally, table arrangements did not keep in line with the problem constraints, e.g. they did not keep the appropriate distances between 2 separated tables.

Design requirements

These issues required consideration of how to address them with interaction design elements in the final application. First, the allowable space needed to be visible and demarcated, as in the paper prototype, so that students could focus on that area as much as possible. The idea of a grid marked floor, indicating the allowable space, emerged from the notes some students made on the paper's prototype floor plan. The tables, which are now virtual manipulatives, alternate in green or red colour (Figure 3), depending on a right or wrong attempt to place them in the virtual floor plan, making the constraints inside the allowable space even more visible. A counter was put at the bottom of the floor plan, considering that this could indicate the increment in the number of tables and chairs so that students can assess which arrangement is best. This operation was designed in order to avoid loss of time by counting tables and chairs as in the prototype. Finally, 2 'table banks' were placed diametrically opposite on the tabletop surface, so that every member was able to reach the tables. Last but not least, in order to get an integrated image of how much the interaction influenced the observed pattern, activity sheets of 18 questions were designed and given to users of the evaluation process.

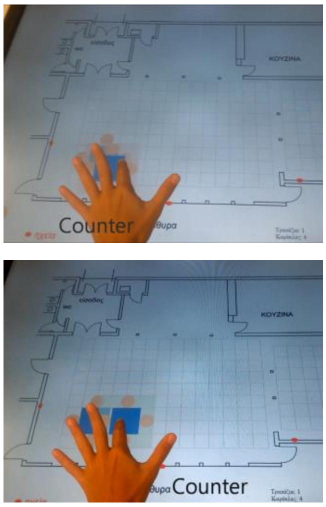

Figure 3: Color interactions

Evaluation

The evaluation took place in the interactive technology laboratory classroom in the University of Aegean, in Syros, Greece, by two focus groups of 7 users (2 teams) with the same age as the students in the pilot study, the same knowledge background on patterns and a satisfactory technological background. The laboratory took the dimensions of a typical classroom setting so that we could follow the classroom's procedures during the evaluation process (Figure 4).

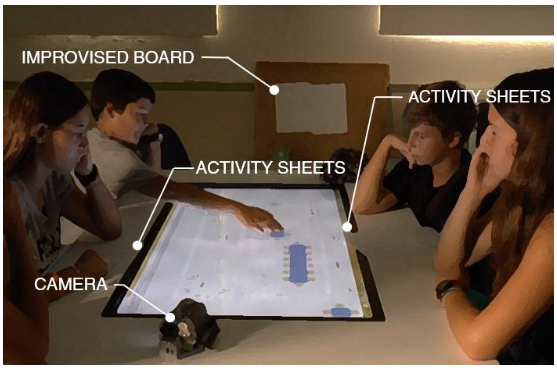

Figure 4: Evaluation process

At first, users were asked to interact with the multi-touch table in order to identify the basic interactive elements of its interface. Secondly, they were asked to do specific actions with the virtual manipulatives in order to evaluate the usability of the application. After finishing the interaction with the multi-touch table and having found the best table arrangement, we focused on the pattern generalization activity sheets. Users were free to exchange ideas and arguments, as in the paper prototype. The recording methods used were a steady camera and notes.

Results

Apart from the quantitative results of the usability evaluation process, the obtained qualitative results require a different approach to assess them. For example, the first team took more time to complete the activity and found the best arrangement, staying mostly at the relational level with elaborating interactions. The second team found quickly the best arrangement by testing different ways. Hence, they had more time to negotiate the pattern generalization process on the activity sheets and reached the extended abstract level. However, these results might be caused by the different organization interactions each team had. For instance, the first team's actions implied an informal 'turn' keeping for each member, even for oral interactions, while the second team's members interacted simultaneously on the multi-touch table.

The impact that the interactive application seemed to have on students' initial strategies towards finding the best table arrangement, can be summarized in two main outcomes. Firstly, due to technology's dynamic representations, users were able to test directly their hypothesis on a possible table arrangement and, simultaneously notice the changes made using the counter. Secondly, they were able to test multiple solutions in a short time. Furthermore, they used elements of the application when they were trying to describe to their peers what the pattern did.

For instance, they used the words "hides behind" or "gone" when referring to leaving chairs in the table-connected condition. Moreover, a user from the second team, being in the extended abstract level, opened the Windows' Painting on the tabletop surface in order to sketch his thinking of counting the elements of the growing pattern (Figure 5). He counted 2 chairs for every table (Figure 6, left), and having this picture in mind, he knew that he had to add 2 more chairs for each thereafter. Another interesting thought is the one presented in Figure 6, middle (counting in rows). Finally, no one expressed, unless under my exhaustive interventions as instructor, the counting thought on Figure 6, right.

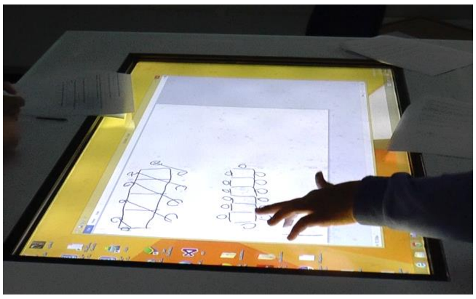

Figure 5: User sketches his thoughts

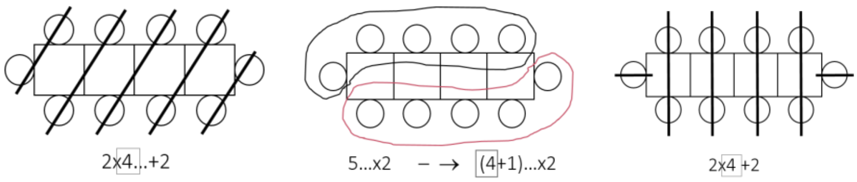

Figure 6: Counting thoughts

As expected, they got involved in verbal (words) and gestural (sketches) descriptions of the growing patterns (Radford, 2010). Although they seemed to manipulate tables as the main unknown variable, the vast majority had problems in generalizing the pattern in a symbolic way.

Conclusions

Comparing, partially, the paper with the interactive prototype, we notice students' engagement expressed in different ways. In the primary case, inspiration, active participation and teamwork were presented while in the second case, we had organizational interactions, negotiation that reached the extended abstract level and exhaustive use of every affordance provided by the technological tool as well as the future ability to update the software application with new, more complex activities, such as loading various table shapes (cyclic, polygonal etc.) or loading larger scale floor plans. However, this exploratory research has many limitations. Firstly, the limited sample makes it necessary that the evaluation process be repeated. Secondly, the reliability of the adapted SOLO scheme needs also to be verified with further research with a bigger sample.

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