Tablet Math Application for Supporting Independent Simultaneous Interaction of Colocated Users

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***Abstract**. This paper presents an Android application for tablets that allows multiple students to solve mathematical assignments simultaneously while using a single device. To facilitate this, the tablet's screen can be split into two, three, or four sections, enabling individual interaction. Still, a single student can use the device without applying the split screen feature. Following the process from the idea to the final realization, this paper provides insight into the technology and techniques used to implement the split screen feature. In addition, the application was evaluated with first-grade primary school pupils in Croatia. Pupils interacted with the application under two different conditions: individually and in pairs or a group of three. The results indicate that even though pupils liked working in both settings, a higher number preferred working alone rather than sharing a device in pairs.*

Keywords. Mobile learning, primary education, tablet sharing, Android application development, split screen

1 Introduction

Education and the approaches to teaching students constantly evolve. The introduction of mobile technology in schools (Quinn, 2001) offered students a new tool to engage with educational content dynamically and seamlessly (Wong & Looi, 2011). Throughout the last two decades, various initiatives promoted the 1:1 (one device-per-one student) learning (Balanskat et al., 2013; Richardson et al., 2013). However, many schools worldwide still do not have enough resources to meet this device distribution (European Commission, 2019; Heinrich et al., 2020; Tamim et al., 2015). Under these circumstances, educational activities can be organized in a way that students share a device. Yet educational applications are rarely designed and modeled to support the interaction of multiple students sharing a device. Examples of supporting interactions among multiple users on a single device can be observed in the single display groupware (SDG) domain (Stewart et al., 1999), which focuses on developing systems that allow people physically located next to each other to interact simultaneously with one common output interface. However, the SDG model has been used mostly in activities on personal computers and shared large displays (Kumar, 2008; Nussbaum et al., 2008).

This paper presents an educational application (Komljenović, 2023) developed to support multiple colocated users' simultaneous use of a single tablet by dividing the screen into multiple independent segments. The application is designed to help users practice and learn basic mathematical operations (addition, subtraction, multiplication, and division).

A similar application was previously developed for iPads and evaluated with pupils attending the first four grades of primary education in Croatia (Čarapina & Pap, 2023). In their study, the authors explored differences in students' performance and perceived satisfaction completing similar mathematical tasks on paper, tablet in 1:1 (one-per-one), and tablet in 1:m (one-per-many) settings. The results showed a statistically significant difference in task performance between the paper and tablet conditions in favor of paper treatment. However, the study suggested that this might be attributed to the students' unfamiliarity with the application and their limited experience with using tablets in the classroom. Still, no significant differences were found between the 1:1 and the 1:m conditions. In addition, no difference was found between the three evaluated 1:m settings (i.e., 1:2, 1:3, and 1:4). Moreover, the students' perceived satisfaction was significantly higher while working with tablets than during the paper condition. Still, the results showed no significant difference between the 1:1 and the 1:m conditions. Since one of the highlighted limitations of the study in question was combining the different 1:m settings (1:2, 1:3, and 1:4) altogether, in this study, the authors aimed to explore in more detail the perceived satisfaction of students while working alone on a tablet compared to working in pairs, i.e., 1:2 settings.

2 Tablet Split Screen Design and Implementation

Android OS supports multiple ways to simultaneously use and display two applications (*Multi-Window Support*, 2023). One way is to use a split screen mode to view two applications side by side. However, there is no possibility to display more than two applications at the same time. Other ways include using picture-in-picture mode, in which one application is opened in a smaller element and displayed over the main application that is in focus. This mode is mainly used for playing videos. Some applications support the floating display feature, allowing them to be used in a floating window on top of other applications. These features supported in native Android development did not cater to our specific needs. Since we wanted to support more than two students using a single application simultaneously on a single tablet, we looked for other solutions, and a new application was developed using Android's fragments.

The tablet math application's development started in Figma, where a split screen prototype was designed to support up to four users on independent segments (Franković et al., 2023). Several things were considered, such as students taking control of the device or the layout orientation and rotation of graphical elements if students sit one across from the other. Each segment was visually distinguished, with different backgrounds, buttons, and font colors.

The application was developed natively using the Kotlin programming language and Android Studio IDE to support learning and practicing basic math operations. Besides using it in split screen mode, a single user can also interact with the application (Fig. 1). The split screen feature was implemented by using fragments, which allowed the division of the screen into several segments that function independently, as shown in Fig. 2, Fig. 3., and Fig. 4. A fragment represents a part of the application interface that can be used multiple times. It has its appearance and lifetime and can process the events that occur due to input. They cannot exist alone but must be triggered by another activity or fragment.

In addition, in the developed application, each fragment can be rotated and adjusted in orientation before and during the activity. Fragments retain their orientation through activity changes by saving the rotation button's unique identifier. Each time the rotate button is clicked, the fragment undergoes a 90-degree rotation, altering the orientation of the content container accordingly. This method ensures that the content inside the container remains intact and properly aligned with each 90-degree rotation. By preserving the layout and integrity of the content, users can seamlessly rotate the fragment without encountering any disruptions.

Figure 1. Single user mode

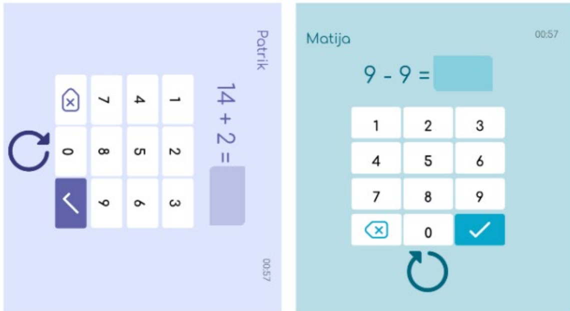

Figure 2. Two fragments of the math activity

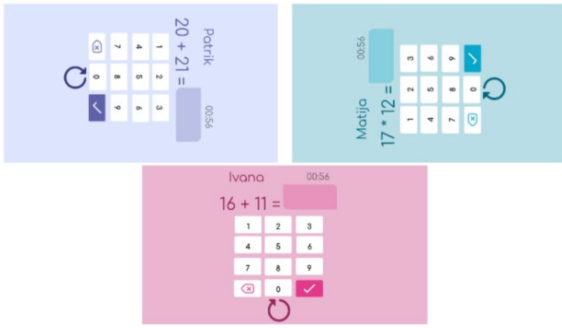

Figure 3. Three fragments of the math activity

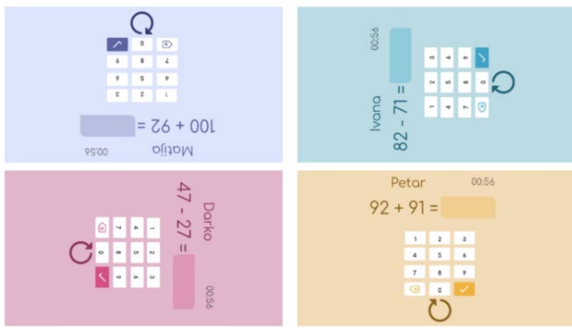

Figure 4. Four fragments of the math activity

3 Application's Workflow

When the application starts, the students see a welcome screen (Fig. 5) that allows them to start the math activity or select a button that opens the settings screen (Fig. 6). In addition, the currently selected settings for the math activity are displayed in the bottom right corner of the welcome screen. In the application's settings, users can change the lower and upper limits of the numbers to be generated, modify the countdown timer, increase the number of users, and enable or disable available operators.

Figure 5. Welcome screen

Figure 6. Settings screen

The application's personalization screen depicted in Fig. 7 looks different depending on the number of players selected. It displays text fields where students enter their names, enabling the personalization of the segments.

Figure 7. Personalization screen for students' name inputs (this example is for splitting the screen into four segments)

After the activity starts, the students' names are displayed on each segment, and instructions for the task are given. The math activity starts after each student confirms he or she is ready to solve the tasks. The math activity displays the student's name in each segment, the countdown timer, and in the middle, the generated math task that the student has to solve by entering a number using the numpad keyboard (Fig. 1). Submitting an answer automatically generates another math task until the time runs out. After the time runs out, a student is presented with the results (Fig. 8). On the showcase, they can see the number of correct answers and scroll through them.

Figure 8. Results screen

4 Application Evaluation

The application was evaluated in school settings to determine the next steps for improving the application's design and to explore students' perceived satisfaction when sharing a tablet with a split screen feature in pairs compared to working alone.

4.1 Research Methodology and Participants

During a 45-minute school hour in May 2024, 15 first-grade pupils (7 to 8 years of age) from one primary public school in Zagreb, Croatia, solved a similar set of generated mathematical tasks (addition of numbers from 5 to 15) during two different 5-minute conditions. During the intervention, a class teacher was present but did not interfere with the students in the classroom. It should be noted that pupils who participated in this study are not used to tablets as part of the in-school assignments, and this was the first time they had used the developed math application. In one condition, they were using a tablet alone, and in another condition, they shared a tablet with another pupil (i.e., they worked in pairs). However, one group was formed out of three students due to the odd number of present students in the classroom.

Since the pupils in the classroom were distributed across two rows of tables, during the first 5 minutes the first row was assigned to a single-use condition and the second row was grouped in pairs (Fig. 9). In the following 5 minutes, the conditions were switched, and the second-row pupils solved the assignment using a tablet alone, and pupils in the first row shared a tablet in pairs and one group of three (Fig. 10).

Figure 9. Research settings during the first condition where the first row used tablets in 1:1 distribution and the second-row students worked in pairs

Figure 10. A group of three students sharing a tablet

After completing the assignments, they were asked to complete an anonymous questionnaire with three questions (Fig. 11). The content was read aloud to ensure that everyone clearly understood the questions that needed to be answered.

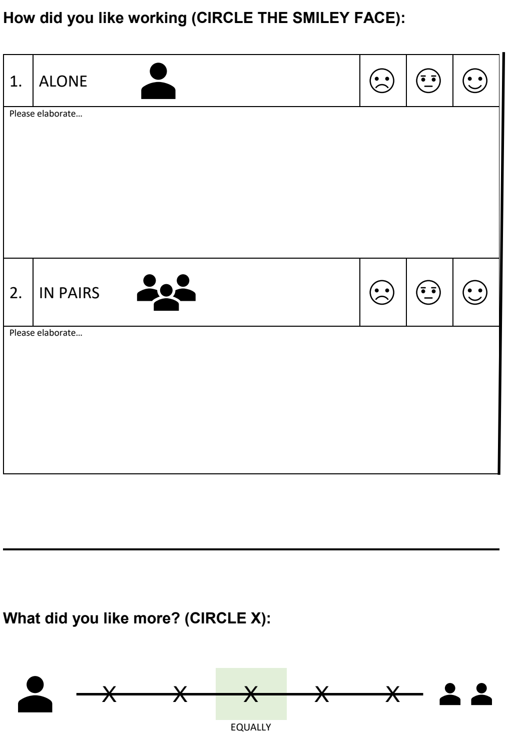

Figure 11. Questionnaire

The first two questions were a simple Likert-type three-point scale with smiley faces (sad, neutral, and happy) and open-ended questions to rate their experience working alone and sharing a tablet. In the third question, they were asked to rate their overall preference between working alone and in a group sharing a tablet on a Likert-type five-point scale, where 1 indicated they preferred working alone over sharing a tablet, 3 indicated they liked both settings the same, and 5 indicated they preferred sharing a tablet over working alone.

4.2 Results and Discussion

Seven pairs and one group of three students participated in the study. The following sections present the satisfaction questionnaire results and overall observations regarding the application's usability and performance.

4.2.1 Questionnaire Analysis

As each questionnaire was filled out correctly, the responses of all 15 students were included in the analysis. Table 1 presents a descriptive statistic of the results.

Table 1. Descriptive statistics of the questionnaire responses

	Mean	Std. Deviation
Working alone	2.53	0.834
Sharing a tablet	2.33	0.617
Preference	2.47	1.598

The answers regarding satisfaction of working alone and sharing a tablet show overall positive attitudes. Still, the responses indicate that the rate of positive responses was higher for the individual activity (Fig. 12) than for the shared tablet activity (Fig. 13). However, the rate of negative responses (i.e., sad smiley face) was also higher for the individual activity (20%) compared to sharing a tablet (6.67%).

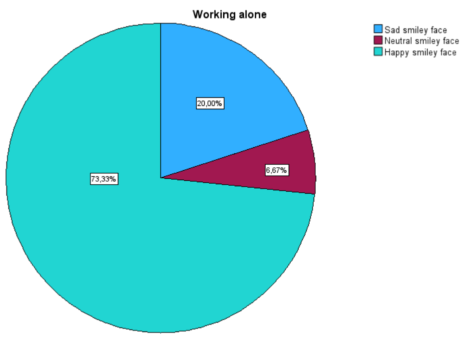

Figure 12. Ratings for the single-user activity

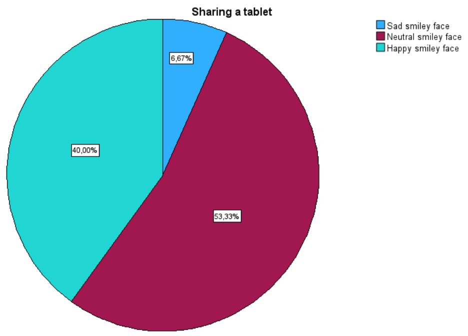

Figure 13. Ratings for the shared tablet activity

Since the pupils wrote no descriptive comments to elaborate on reasons for their responses, this should be explored in more detail. Additional interviews are recommended because most pupils of that age are still not fluent in reading and writing.

However, it was observed that some students were physically dominant over the shared device during the paired activity, which could have influenced the satisfaction of both parties (Fig. 14).

Figure 14. An example of a dominant student (on the right) in a pair

In the third question, on the preference scale, pupils responded by circling 1, indicating they preferred working alone over sharing; 3, indicating they liked both settings equally; or 5, indicating they preferred sharing over working alone. No one circled the in-between values of 2 and 4. The average result on the preference scale was 2.47, showing that a higher percentage of pupils preferred working alone (46.67%) compared to those who preferred sharing a tablet (20%). This can be observed in the rating percentage depicted in Fig. 15. Yet, 33.33% of pupils preferred both conditions equally.

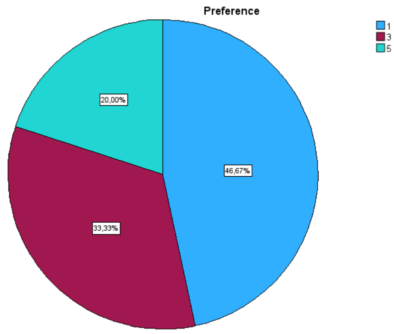

Figure 15. Settings preference analysis

4.2.2 Application Usability and Performance

Regarding the application's usability, a group of three had problems understanding what order to enter their names when prompted (Fig. 3). Enabling the application to inverse the prompt positions for three students to enter their names would help students align the application's layout to their seating position.

Moreover, since we wanted to evaluate the application in a regular classroom setting, we observed some limitations in the application's setting page regarding the feature of setting up the range of numbers to be used. To be more precise, the minimum and maximum values for each operand could be adjusted, yet the range for the result cannot be set, which turned out to be as important as the previous two.

In addition, it was observed that the timer resets after the application is closed (intentionally or unintentionally). Since there were a few cases of pupils unintentionally putting out the application, making the activity timer run even when the user leaves the application would solve the timer reset that happens if a user refreshes the activity. This would provide more adaptability for various learning stages and activities.

4.3 Research Limitations

The current application allows four students to solve math problems simultaneously. However, some limitations should be addressed. The evaluation was conducted with only 15 first-grade students, limiting the findings' generalizability. A larger and more diverse sample would provide a more comprehensive understanding of the application's effectiveness and user satisfaction.

Moreover, the evaluation was conducted over a 45-minute session, which may not be sufficient to fully understand the long-term impact of using the application on students' learning outcomes and preferences. Participants were not accustomed to using tablets for educational activities, which could influence their responses and overall experience with the application. This novelty effect might not reflect the typical classroom setting where students are more familiar with the technology.

Using anonymous questionnaires limits the ability to follow up on individual responses to understand the reasons behind certain preferences or dissatisfaction.

Additionally, the questionnaire did not capture detailed qualitative feedback due to the participants' young age and limited writing skills.

It should also be highlighted that the study included one group of three students due to the odd number of participants, which introduces variability that may have affected the results. The differences in dynamics between pairs and groups of three were not separately analyzed, potentially confounding the results.

5 Conclusion and Future Work

This paper presents an Android mobile application for generating math tasks. The application supports the shared use of a single tablet among colocated users. This is enabled with the implemented split screen feature, which divides the tablet's display into two, three, or four segments. Each segment can be adjusted in rotation and display an independent math activity. Fragments are the basis of this application, and their implementation supports splitting the screen on mobile devices into more than two parts. This enabled a parallel display of independent math activities.

The application was evaluated with first-grade pupils to gain insights into possible improvements and pupils' attitudes while interacting with it in shared mode. The questionnaire results indicate that most pupils preferred working alone over sharing a device in pairs.

Future improvements to the application include redesigning the interaction for the group of three to be more position-independent, adding more math activity adjustment options on the settings page, and improving the application's general performance. The application currently focuses on basic mathematical operations (addition, subtraction, multiplication, and division). This narrow scope might limit its applicability across different educational stages and subjects. In addition, adding features such as progress tracking or adaptive learning algorithms that analyze areas where the student struggles could improve the learning experience.

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