Cooperative Face-to-Face Learning with Connected Mobile Devices: The Future of Classroom Learning?

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Abstract Communication and collaboration among peers influence learning outcomes in a positive way. Therefore, our research work focuses on enhancing face-to-face group learning with the usage of mobile devices by developing a learning game for iPhone/iPad devices called MatheBingo. The app allows up to four learners to connect to each other through their mobile devices and learn together in a face-to-face setting. An initial evaluation in this field of research indicates the usefulness of such activities and how they uniquely motivate children to learn. It can be summarized that the connection of mobile devices is an important step toward the future of face-to-face classroom learning.

Keywords Collaboration · Math · Mobile learning · iOS development · Field study

Abbreviation list

ADS	Apple Definition Statement
HCI	Human computer interface
HY	Hypothesis
IICM	Institute for Information Systems and Computer Media
iOS	internet Operating System

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Mathe Bingo	Math Bingo
mLearning	Mobile learning
TEL	Technology Enhanced Learning
TU Graz	Graz University of Technology
Wi-Fi	Wireless Fidelity

1 Introduction

The field of Technology Enhanced Learning (TEL) is a rapid emerging one. Just 10 years ago, TEL researchers introduced Web 2.0 [1] and called it e-Learning 2.0 [2, 3]. Since then Wikis [4, 5], Weblogs [6, 7], and Podcasts [8, 9] have become an essential part of today's classrooms. With the invention of smartphones mobile learning comes more and more attractive and nowadays we are thinking even about the usage of wearable devices for teaching and learning [10].

Nevertheless, with the rapid development of network communication technologies there has been an increase in the quantity of research on applying mobile technologies to learning. In terms of educational application, mobile technologies can be regarded as services that electronically deliver general and educational content to learners regardless of location and time [11]. Researchers have argued that mobile technologies have created many new and exciting opportunities for learning [12]. They provide instant learning feedback and guidance and use new interfaces for diverse learning approaches [13].

Within this chapter we present a new learning game for iPhone and iPads called "Mathe Bingo" ("Math Bingo") using an innovative collaborative learning setting for young learners (6–7 years of age) within classrooms. Additionally, we show and reflect upon results of a first trial within an Austrian so-called "iPad class" from both the observers' and the children's perspectives. First of all, we will start with the theoretical background and experiences with cooperative learning with mobile devices and the experiences with iPhone/iPad app development at Graz University of Technology (TU Graz), especially concerning apps for young learners.

Our chapter is organized as following: First of all, we describe the theoretical background and give insight to current studies about cooperative learning with a special eye on mobile devices. Afterwards the goal of our study, the research questions as well as the research method are presented. Section 5 points out the concept and design of our app-prototype. In addition we tested the app for the first time in classroom and carried our experiences. Finally, the discussion section describes our findings and the conclusion summarizes the research work and gives an outlook for future work.

2 Theoretical Background and Studies on Cooperative Learning with Mobile Devices in Classrooms

In this section we like to give a short introduction to cooperative and collaborative learning, how mobile devices can be used in classroom, and how games can facilitate cooperative and mobile learning. Finally, we point out our first experiences with iPhone development at TU Graz.

2.1 Cooperative Peer Learning in the Classroom

Cooperative and collaborative peer learning has been frequently seen as a stimulus for cognitive development, through its capacity to stimulate social interaction and learning among the members of a group. The goal of collaborative learning is to facilitate teaching through a coordinated and shared activity, by means of social interactions among the group members [14]. These social interactions are essential to achieve the desired learning, as a result of a continuous attempt to construct and sustain a shared and open point of view of the activity [15].

As collaboration is commonly a feature of the work environment, it must also be reflected in the design of learning activities. Johnson and Johnson [16] suggested five important key guidelines for successful collaborative learning: shortly positive interdependences, face-to-face promotion of interactions, individual accountabilities/personal responsibilities, interpersonal/small-group skills, and group processing.

In contrast cooperative learning is considered more structured, more prescriptive for teachers about classroom techniques, more directive to students about how to work together in groups, and more targeted to the public school [17]. Oxford [18] pointed out six principles for cooperative learning, which are very similar to those of Johnson and Johnson for collaborative learning [16]: positive interdependence, accountability, team formation, team size, cognitive development, social development.

Due to positive effect of collaborative and cooperative effects as stated by [19] the goal is to develop a first application that can support both. It should be usable for teachers through a structured classroom setting as well as for learners in an open and informal scenario. Because our field study took place in a classroom this chapter concentrates more on cooperative learning.

2.2 Usage of Mobile Devices in Classrooms

For an effective integration of mobile learning into a digital classroom environment, it is important for all students to have their own device equipped with wireless

communication capability to conduct learning tasks [13, 20]. Various mobile devices have been used in mobile learning, such as wrist-worn devices, mobile phones, handheld computers, tablets, stylus tablet computers, and laptop computers [21]. The development of these handheld devices and wireless networking has made possible numerous new approaches to individual work and learning.

As learning becomes personal, mobile students are able to participate in collaborative learning activities when and where they want to [22]. Thus, handheld devices have been utilized to support learning, create rich learning scenarios in such technology-enriched classrooms, encourage social interaction, and support collaborative learning [23–25].

One important feature of social collaboration is intimacy, which depends mainly upon nonverbal cues such as eye contact, miming, and smiling. A mutual gaze moderates interpersonal distance and the sense of intimacy. In addition, gesticulated interaction frequently takes place along with verbal utterances in meaningful processes, resulting in meaning creation.

Scott analyzed the nonverbal interpersonal interactions of group members during discussion, to assess whether the current collaborative learning environment setting is beneficial to discussion or not. Usefulness interaction is a critical factor for success of collaborative learning [16].

Collaborative activities have gained significant attention among educators for improving student learning [25]. Instead of passively receiving knowledge from teachers alone, students can engage in collaborative activities and knowledge construction activities during peer discussion and interaction. Therefore, it seems from high interest to bring students together by connecting their devices.

2.3 Games Facilitating Cooperative and Mobile Learning

Games are often seen as a good promoter of learning activities or the other way round; the benefits of learning through games are numerous [26]. According to Malone [27, 28] three characteristics are essential for games: challenge, curiosity, and fantasy. A game must have a clear, achievable goal, and feedback must be appropriate for the users. Furthermore, the game has to be challenging and not predictable. Based on this gaming theory, several learning games have been developed [29].

The main idea of introducing games for learning is that learning happens indirectly, as a kind of side effect of playing the game. Even the learning effect might be much higher because learners are in an emotional and motivated situation [30–32]. Therefore, it can be assumed that a game design will have a positive influence to the learning behavior of the school children.

Nowadays, there are many multiplayer games with connecting mobile devices available [25], but we are not able to find a single learning game among them; at least not within the German iTunes Store (10/2012) or related research on this certain topic [33].

2.4 Cooperative Mobile Learning Within Classrooms

Building on the trend that more and more mobile devices are available in classroom and on the attractiveness and importance of cooperative and collaborative peer learning, cooperative mobile learning within classrooms comes strongly to the fore: Thus, the collaboration of students with their peers through different technological devices, and the influence of these devices on interaction among students, become important research issues.

Studies have validated experiments which help students to collaborate and exchange information through handheld devices as well as providing opportunities to interact with each other using these devices for supporting learning, thus facilitating cooperative learning, e.g., students engaged in collaborative learning through face-to-face communication on a social network with the support of handheld devices by a wireless network [24].

Nevertheless, the idea of a cooperative learning app for connected mobile devices for young learners is a new one. As pointed out before, there are no known other applications in the German iTunes Store supporting learning through connected devices.

Similar ideas are carried out in different research studies: First, children should draw together one sketch [34] or second find predefined words by collecting letters cooperatively [35].

2.5 Lessons Learned from iPhone/iPads Learning Apps Development at TU Graz

TU Graz has an established tradition of research and development of mobile applications. The first lecture on iPhone development took place in 2010 with more than 100 participants. Since then, more than 100 iPhone/iPad apps have been uploaded to the iTunes Store and offered for free by TU Graz. Therefore, a number of workshops have been given on app design and how to achieve user satisfaction [36].

At the same time the Department of Social Learning as well as the Institute for Information Systems and Computer Media (IICM) at the TU Graz started a mLearning initiative with the goal of developing educational apps and finding out how these apps change the way we learn. Each of the apps developed addresses a specific learning goal as described in the Apple Definition Statement (ADS): According to ADS, every app has to claim three major requirements (description of unique selling point, audience, and solution).

All developed educational apps are available at the website http://app.tugraz.at. It is worth noting that the target audience of these applications is a range from preschool-aged children toward students at universities.

The following is an example of one of these apps and the research on its use within higher education: Ebner and Billicsich [37] gave a first impression on how smartphones can change the traditional lecturing through digital documentation of teaching and learning events. Similar to today's well-known application "Evernote," students are able to collect photos, notes, hyperlinks, or videos of a lecture and store them online to augment the learning process.

Field research is often undertaken to evaluate an app, including its usage and effects, under the guidance of the Department of Social Learning. For example, a class of 9-year-old school children was observed to find out how they approach their iPad usage, as well as to look on the outcome of their usage within the classes.

In her study, Huber [38] pointed out how iPads can enhance the traditional classroom. According to her data, apps facilitating creativity were used more intensely [38]. Follow-up research showed how iPads help to individualize education with a special focus on language teaching [39] or how tablet computers change the way we teach—in music classrooms, for example [40].

These studies have shown that applications designed for children have certain special requirements. For example, the rotation feature must be used carefully, and the concept of file handling should be simplified as well, as children must be aware of hierarchy, position, and auxiliary views such as bars in order not to get lost. Huber and Ebner [41] published a list of such requirements for mobile learning apps aimed at children. From our point of view, the two main omissions among iPad apps used in the classroom are:

- Lack of feedback for teachers: When school children work and learn with different apps the face-to-face education is individualized. But the teacher needs to know how the child performed, how many exercises done or learning goals have been achieved. Yet mobile applications are stand-alone programs and can be done on their own, without a feedback channel for a supervisor or teacher. There is no way for the teacher to get an overview of the current performance of an individual, or of the whole class. Therefore, a central web-based infrastructure is necessary as well as a user and class management. Furthermore, an automated analysis of the outcomes is needed. Our attempts show the great potential of such learning analytics and central feedback applications [42].
- Lack of collaboration: Current mobile applications are able to enhance individualization and personal learning, as children are enabled to learn according to their particular needs and at their own pace. Developers of mobile learning apps take no specific note of cooperation and collaboration issues. This stands in contrast to the development of gaming apps, where cooperation features and connections of multiple devices are trendy and common.

In our research study we would like to particularly address the issue of lack of cooperation and collaboration by designing a cooperative/collaborative learning app running on multiple mobile devices of the learners with a special focus to math, respectively, STEM education [43].

3 Goal of the Study and Research Question

In our work we want to build on these insights and plan to develop and test a learning app for young learners, with special attention to cooperative peer learning, aspects of the games, and usage of the personal device. Additionally, we aim to bring cooperative learning with connected mobile devices into the classroom setting.

In other words, one must consider whether the connection of students' mobile devices impacts a specific learning goal. Therefore, the overall research question addressed in this work is: How can collaborative learning can be advanced in classrooms using the mobile devices of the school children?

In particular our main goal is to develop a first math app for school children that bring learners together through their connected devices. Therefore, following hypotheses (HY) have been carefully worded:

- HY1: The developed app is able to assist cooperation between learners.
- HY2: The developed app motivates learners to play the game again.
- HY3: The developed app is easy to use for learners.

4 Research Design

As there are no existing collaborative learning games, as mentioned in the first part of this paper, our research design is twofold:

- In the first place, an appropriate app has to be developed, following the principles of a cooperative classroom setting. Therefore, we describe the design and development of the app "MatheBingo". We strongly follow the approach of *prototyping* as described by [44, 45]: identifying basic requirements, development of a working prototype, implementation, usage, and revision.
- Second, an initial evaluation of the app was needed to get insights into its usage. For this, we used a *participatory observation* in a real classroom setting in an Austrian iPad class (first grade in a primary school). After a short introduction into the idea and rules of the app, the children were randomly separated into groups of four. Because of technical problems, the groups took turns playing the game. The children used the app for about 60 min on their own, assisted by the teacher and a research assistant as well as watched (and commented on) by their peers. The two participating observers were asked to make notes of their observations during that phase. Afterwards, the observers wrote a report about their observations, focusing on cooperative usage and technological aspects of the app's usage. After the math lesson, a short feedback from the children was gathered to understand their views on the application.

5 Concept and Design of the iPhone/iPad App "Mathebingo"

In the following paragraphs we describe the concept, technological considerations, the user interfaces, the rules of the game, and its expected usage. The main goal is to get an idea about the game play and how the app is working. Technical details will not be carried out.

5.1 General Concept

The general idea (ADS of the application) of "MatheBingo" was to develop a learning game in the field of math (ADS: solution) for school children in the age of 6–8 (ADS: audience) with a special focus on collaboration (ADS: differentiator). So the application should allow children to connect with each other and to work together on a learning goal [46]. The game design should help to motivate the learners to use the learning applications again and again.

The idea of the game, called MatheBingo, is rather simple. Everyone knows about how to play Bingo: Each player gets a card with randomized numbers and crosses a number out when the game leader calls it. The first player with crossed out numbers all in a row wins the game. Our application follows these rules, but in our case the cards are inputted on each individual device (in our particular case on iPads) and the leader of the game is the game table on an iPad.

Instead of just calling out a number, it requires a simple calculation appropriate to the knowledge level of the pupils. So the game table asks for simple summations or subtractions, which must be calculated by the children and afterward the result can be marked on their devices, if the appropriate number is available.

5.2 Technical Framework

Building on the specialized know-how of the sector of iPhone/iPad development, it was decided to program a so-called universal app running on both devices. ObjC is used for the programming language. The app must operate with at least iOS 5 and higher. In addition to the official iPad Human Interface Guidelines [47], the extended guidelines mentioned above considering the mLearning focus [41] must also be taken into account.

The fact that children do not have any concept of how Wi-Fi or Bluetooth works is one of the major challenges of this application. With other words necessary technologies have to work in the background without needing additional information from the learner.

5.3 Rules of the Game and Expected Usage

In accordance with the Bingo game concept, "Mathebingo" is a competitive app where the player who has the first complete row wins. Therefore, this concept does not fulfill the common idea of a "group learning goal" or "common goal", but nevertheless, this concept has an important feature of cooperative learning: Within the so-called "unlimited" option, all players have as much time as they need to find the right number on their device. This feature resulted in more children supporting one another, especially those who needed more time, due to the fact that children in this age group played the game mostly "open" by presenting their devices (or Bingo cards) to their classmates.

A very common goal for peer learning activities is that more advanced students support the others: Proficiency in math and excitement for the game should lead to students advising others for in order to be able to go on with the game. Nevertheless, aptitude in math is not the only factor needed to win, as the winner also depends on luck for the winning arrangement of numbers on his or her bingo card. Given this factor of chance, each player is potentially able to win a game.

Figure 1 shows a typical setup for a game. In the middle the game table is placed and up to four additional devices are the bingo cards. It does not matter if the devices are iPads or iPhones, respectively, it is possible to mix them (for example, iPad is used to act as game table and up to four iPhones are the bingo cards).

5.4 The Main Interfaces of the Applications and Their Features

The learning game includes five different screens: the splash screen, the preference screen, the search screen, the game table, and the bingo card. Each screen is

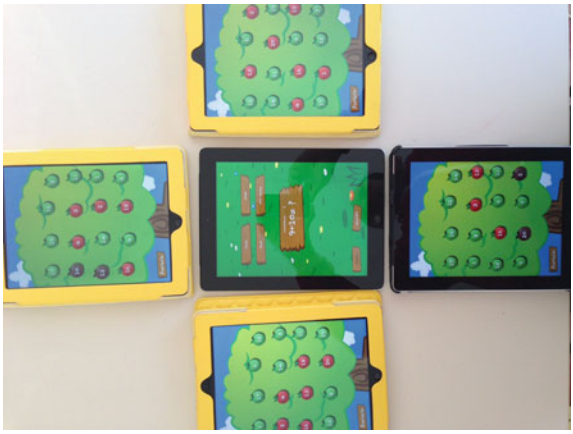

Fig. 1 MathBingo with one game table (*middle*) and four playing devices (*bingo cards*)

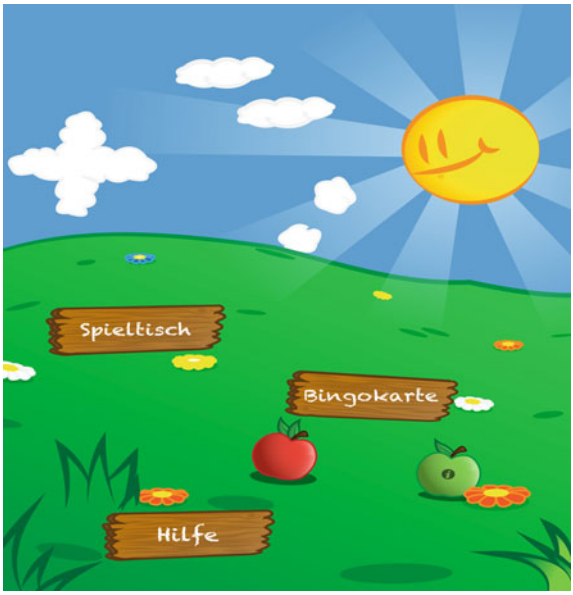

Fig. 2 Start screen

designed by a professional designer to be appropriate for school children. The splash screen (Fig. 2) is the start screen and there are three simple buttons on it.

The user taps one of the first two buttons to indicate whether the device should act as the game table or as a bingo card. Our intention is that, if available, an iPad takes the role of the game table, but this can also be done by an iPhone. Second, there is a help button, with additional instructions and guidance regarding the app's usage.

When a user chooses to act as game table, the preference screen will open. On the top the devices connected to the table are shown. Below them a snail is pictured, representing the option of changing the amount of time provided to the learner for marking the correct solution on their card. Finally, users are able to choose two additional options: the skill level (which manages the range of the required calculations) and the background music.

When the "start" button is pushed the game table is shown. The game table screen (Fig. 3) is rather simple: in the middle of the screen a calculation is provided. For example, Fig. 3 challenges the children to add 8 + 6.

If the bingo card is chosen on the splash screen (Fig. 2), the device is noted as a bingo card and the search screen is provided. This screen tells the child that his/her device is looking for a game table. If such a table is found, the device is automatically connected to it. The only requirement for a successful connection is that the devices be on the same Wi-Fi network.

The last screen is the bingo card (Fig. 4) itself. If the device has found a game table, a bingo card with 16 randomized numbers (within the defined range) placed on apples is provided. The learner can choose only one number, via a touch gesture,

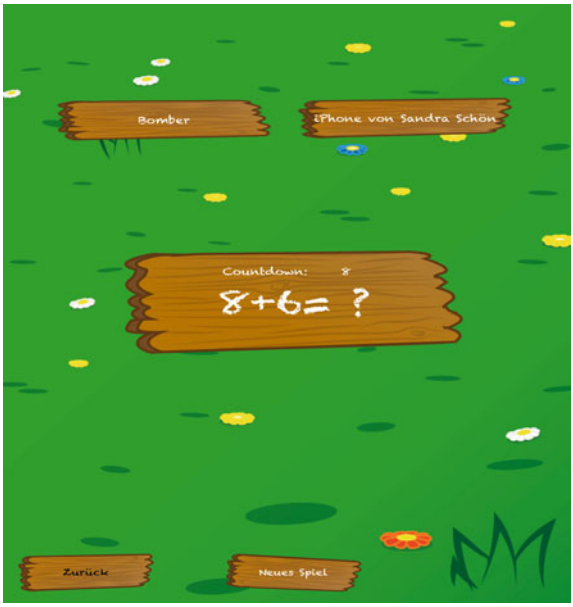

Fig. 3 Game table screen

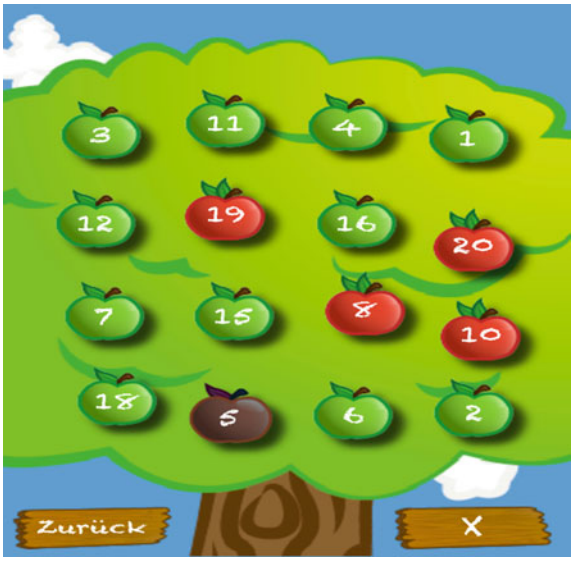

Fig. 4 Bingo card

within the given time. If he/she has solved all of the calculations in a single row (represented by red marked apples) the game is won, as signified by a big Bingo sign (Fig. 5).

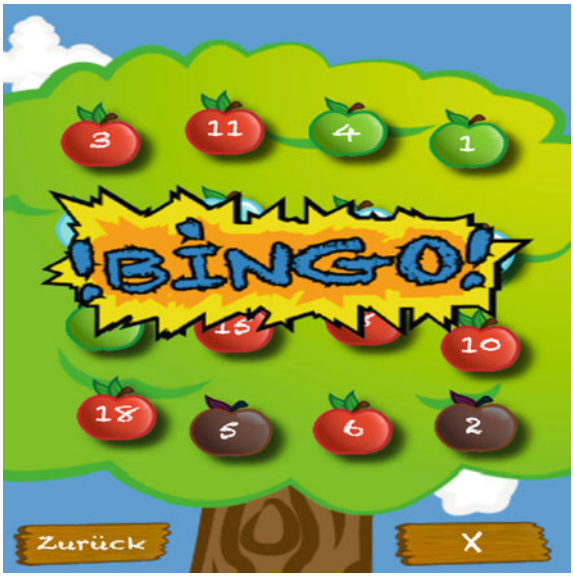

Fig. 5 BINGO—end of the game

6 Using the App in the Field: Results

As described in the section "research design", a participatory observation and a plenum discussion with the children were carried out as part of our field research. In the following section, we describe the results, starting with some notes regarding the setting. Afterwards, the outcomes of the field study are clustered into three parts. First, the observations of the research assistant as well as those of the teacher are presented. Second, the feedback of children is listed, and third, technical challenges are addressed.

It must be noted that the participatory observation aims to determine whether the developed prototype works in general (technical perspective) and whether collaborative learning in general occurs (didactical perspective). The following chapters describe the general setting of the field study and the outcomes in terms of cooperation and technical issues.

6.1 The Setting of the Field Research

The research study in the field took place in an elementary school located in Vienna in late spring 2013. 22 school children between 6 and 7 years of age participated. This class is so-called "iPad-class". This means that all children get their own iPad when starting school.

Due to the fact that all of the children had been using the devices at least for more than half a year, they were comfortable using their devices. Nevertheless, the installation of the Mathe Bingo app was done beforehand to save time.

The teacher was very experienced in using iPads in the classroom. She has already implemented different applications for different purposes. Furthermore the class owns its personal blog, where the use of the tablet is documented for especially the parents and other interested people.

Finally, the technical equipment of the school was rather bad. Wi-Fi was up but tablets lost connections regularly and also the bandwidth was very low. Nevertheless, the situation is no unusual for Austrian schools especially for elementary schools.

6.2 *Outcomes Related to Cooperation While Using the App*

The main idea of the app was to initiate and foster cooperation and support among the children while playing the game. As sketched previously, our hope was that support would be offered by pupils who were better at math or faster at finding the right number on the device.

The following observations illustrate the cooperative aspects of the usage according to the models of Johnson and Johnson [16] and Oxford [18]:

- Face-to-face promotion of interactions: The devices lay in front of the children, so each child was able to see the bingo card of each fellow. This provided a basis for cooperation.
- Group processing: Additionally, no child played on his/her own during the observation phase. As cooperation is related to communication, it is also remarkable that there was steady communication in every group during the observation phase.
- Interpersonal/small-group skills: Another important fact was that the children helped each other a number of times—in some cases with every new assignment.
- Positive interdependences: As mentioned in the report, the observers also repeatedly describe individual children looking at the game of another group and helping them finding correct solutions. This occurred especially frequently when the child had a visiting, nonplaying role.
- Individual accountabilities/personal responsibilities: Last, but not least, the observers mentioned that even children with lower level mathematical skills were motivated to play the game and engage with topic. The observers see the fact that their chances of winning are equal to those of the high-performing children as a reason for this.
- Another valuable insight builds on a mistake: Some assignments within the app were too difficult for the pupils' level of knowledge. Surprisingly, the pupils tried to solve the challenging assignments on their own, discussed their solutions

and managed to find the correct answers. This should be taken into account as a future didactical strategy in offering some challenging calculations to the learners.

To sum up these results concerning the cooperation, the concept and goals of providing such an app for cooperation were realized. Additionally, the observers reported that the children in general seemed to enjoy finding the right answer on their cards and expressed their enthusiasm the moment the color of an apple changed to red (for the correct solution).

The children even invented a special bingo result: Sometimes a child ended up with a red apple that completed two rows at once. This phenomenon was affectionately called "double bingo".

Feedback of the children: Children mentioned positively that they "love to win the game" as well as ending up with a double bingo. They showed general enthusiasm for this kind of game and said that they would use the app in the future due to its motivating character. On the negative side, the children reported technical problems, as will be described in the next paragraph.

Building on this problem, they said that they could not play as often as they wanted. One child mentioned that the apple was not changing the color to red even though it was touched correctly. Some children were annoyed by the loud victory celebrations.

6.3 Summary of Technical and Other Challenges

As the app is also a technical innovation, technical aspects are important. In our case our field research unfortunately showed technical problems that we had not found in our prior tests: Sometimes the searching devices did not find the game table and sometimes the connection simply got lost.

The children had serious problems finding and connecting the devices within their five groups. Recognizing this, the teacher had to decide to let each group play one at a time, which then worked well. Concerning the application itself, the predefined knowledge levels did not match the usual proven method suggested from the school literature (especially regarding subtractions from 1 to 30). Finally, sometimes the touch screen did not react in time, especially when children tried to mark the right solution.

7 Discussion

In this section the methodology and findings of the observation are discussed. As is typical for this kind of development and initial field research, our methodology allows for general inferences and concrete feedback for the future development of

the app and usage within classroom. Deeper insight into learning outcomes will require additional and more-experimental settings (which are currently very difficult to obtain). Such general findings concerning this learning app are. Nevertheless, we like to try to answer our HY:

- HY1: *The developed app is able to assist cooperation between learners*. The field study showed that the application enhances communication and cooperation between the children. In particular the teacher mentioned that the children solved math problems they had not yet learned about during playing the game mainly through conversation.
- HY2: *The developed app motivates learners to play the game again.* The even chances of winning the learning game seems to be a key success factor of this app, as it does not favor pupils with better math competence and motivates even children who are poor at math. This seems to be the basis for the facilitation of such a highly communicative dynamic and the children's motivation to play the learning app again: The researchers observed that this leads to a long-lasting motivation doing the game again and again. In other words, the gaming factor increases the reuse of the app dramatically as opposed to pure learning apps.
- HY3: *The developed app is easy to use for learners*. The technical solution still needs enhancements: Sometimes it takes a very long time (180 s) to get connected, and sometimes the connection simply breaks down. The observation also pointed out that children were not able to connect to each other by themselves and that assistance was necessary. Bearing in mind that they have no understanding of Wi-Fi and other similar technologies, there is some additional training necessary during the process. But all these technical issues are solvable. In general the app works and children have no further problems during playing Mathe Bingo.

Last, but not least, future work, including additional field studies and experiments, should be arranged to gain deeper insights into both the communication of the children and the learning outcomes of the game. Future research should be undertaken concerning the individual and the group learning outcomes, as well as different possible settings (e.g., rotating groups), and apps on other topics.

8 Conclusion

Communication and cooperation are key factors in successful learning. Nowadays, we have the chance to use mobile technologies within classroom and to connect them on a network. Nevertheless, there have been only few research studies done concerning this issue, mainly because there are some technical restrictions.

Within this publication a trailblazing collaborative learning app for mobile devices (iPhone/iPad) has been developed using Wi-Fi connections among several different devices. The follow-up field experiment indicates that children are highly motivated to use these kinds of applications. Quite obviously, the game's setting

and its fostering of communication seem to equip it to motivate even poorer mathematicians in the class to engage with math and to learn. The application addresses all of the guidelines set out by Johnson and Johnson [16], as we have discussed, and the children clearly enjoy playing with it.

In summary, the gaming environment and communication about the problem at hand, as well as collaboration through mobile devices, is a very powerful combination. From our perspective, this first trial is very promising, and if the app is developed according to the technical capabilities of new mobile operating systems (in our case iOS7), usability and HCI guidelines with a special focus on children, as well as a theoretical pedagogical approach such as that of Johnson & Johnson tablets can enhance the quality of education in today's classrooms.

Mobile technologies have the capacity to change the landscape of our classrooms due to the fact that individualized, personalized, and collaborative learning settings can supported by appropriate applications. At the same time, it must be clearly stated that further research will be necessary to obtain more in-depth insights into how children benefit from such activities and how learning can be improved by such collaborative tools.

In conclusion, we hope to inspire others to devise and share classroom observations and experiments, or to develop similar apps. Bearing in mind that also wearable devices hit now the market it will become more and more necessary to enhance our research studies in order to guarantee that appropriate didactical scenarios are available. Learning with and through technologies is able to improve education, therefore we have to take a close look in which way.

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