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STUDENTS' BEHAVIOUR, PERCEPTIONS AND EMOTIONS WHEN LEARNING MATHEMATICS WITH CELLULAR PHONES

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Introduction

We have been experimenting with using cellular phones in teaching and learning mathematics for 5 years in several intermediate Arab schools in Israel. All of our experiments were in the framework of practical training of pre-service teachers in a teachers college. In the framework of the experiments, we developed appropriate activities for the learning of mathematical topics the cellular phones in a middle school. In some of our experiments, the middle school students themselves suggested activities to be carried out on real-life sites to investigate real-world phenomena with cellular phones.

Our pre-service and in-service teachers assisted us in carrying out the activities with the students and documenting the experiments. Some of the activities were carried out in the classroom or the schoolyard, while others were carried out elsewhere. The activities carried out in the classroom were formal (such as finding the relation between the parameters of a linear function and its graph), while the activities outside the classroom were informal (such as finding the relation of the perimeter of a tree trunk and the perimeter of its thickest branches). In doing these activities, the students investigated mathematical concepts and discovered mathematical relations. The activities included a discussion component that was held in the classroom or in forums; the students compared the results they attained and tried to justify them.

To collect our data regarding the mathematics learning and teaching that took place in the cellular phone environment, we used observations, took pictures, recorded videos and conducted interviews with the students, the pre-service teachers and the in-service teachers. We mainly used the constant comparison method and specifically the grounded theory to characterize the learning process and construct models of students' perceptions (Baya'a & Daher, 2009; Daher, 2009), emotions (Daher, 2011, 2012) and behaviour (Baya'a & Daher, 2010; Daher & Baya'a, 2012) while learning mathematical topics with cellular phones.

Literature and Theoretical Background

Recent studies that examined the use of cellular phones in mathematics learning among pre-service teachers (Botzer & Yerushalmy, 2007; Genossar, Botzer, & Yerushalmy, 2008) suggest that we are at the beginning of a new era for cellular phone integration in the mathematics classroom. We wanted to exploit cellular phone technology in the middle school mathematics classroom. At first, we carried out our experiments without relying on a theoretical framework, but those experiments taught us to adopt a view of learning mathematics as "the process of coming to know through continuous conversations across multiple contexts amongst people and interactive technologies" (Sharples, Taylor, & Vavoula, 2007, p. 224). Further, we agree with Sharples, Taylor, and Vavoula's (2007) argument that the agency for learning is not with the individual, nor with the technology, but in the democratic synergy between the different parts of the system with the aim to advance knowing. As described previously, we adopt this view of mathematics learning with mobile technologies, but we stress that special attention should be given to the mathematical activities with which students are engaged. These activities are an essential part of the learning context that is a central component in students' learning (see, for example, Tarasewich, 2003, and Uden, 2007). We think that a technological tool is a potential learning tool for a specific subject—in our case, mathematics. It will not become an actual learning tool until it is used with activities that fit its potential in the addressed content. This means that mathematics teachers should be familiar with technological pedagogical content knowledge (TPACK) to be able to write or choose appropriate activities for any new technological tool. We have suggested one TPACK model that fits mathematics teaching and learning in Daher and Baya'a (2010). This model describes teaching and learning mathematics based on mathematical phenomenon and three blended means: technological pedagogical models, representations of mathematical content and learning contexts. The model moves the student towards deep mathematical learning because of the rich mathematical representations and technological pedagogical tools. Students are motivated to learn mathematics because of the diverse contexts in which they learn (formal, authentic, historical and virtual) that add fun to mathematics learning.

Technology Used in the Case Study

The middle school students worked with cellular phone software (midlets) that support the learning of algebra and geometry. The midlets can be downloaded from the Math4Mobile site, which belongs to the Institute for Alternatives in Education that operates within the Faculty of Education at the University of

Haifa (Yerushalmy & Weizman, 2007). To perform the activities assigned to them, the students used the algebraic midlets and various tools and technologies embedded in their cellular phones. The students used the Fit2Go midlet when working outdoors. This midlet enables users to draw specified points and fit a linear or quadratic function to them. When a student needs the midlet to fit a linear or quadratic function to some points, the midlet provides the graph and algebraic rule of the function if such a function exists; if not, it displays the graph and algebraic rule of a function that passes through some of the points drawn. Figure 5.1 shows

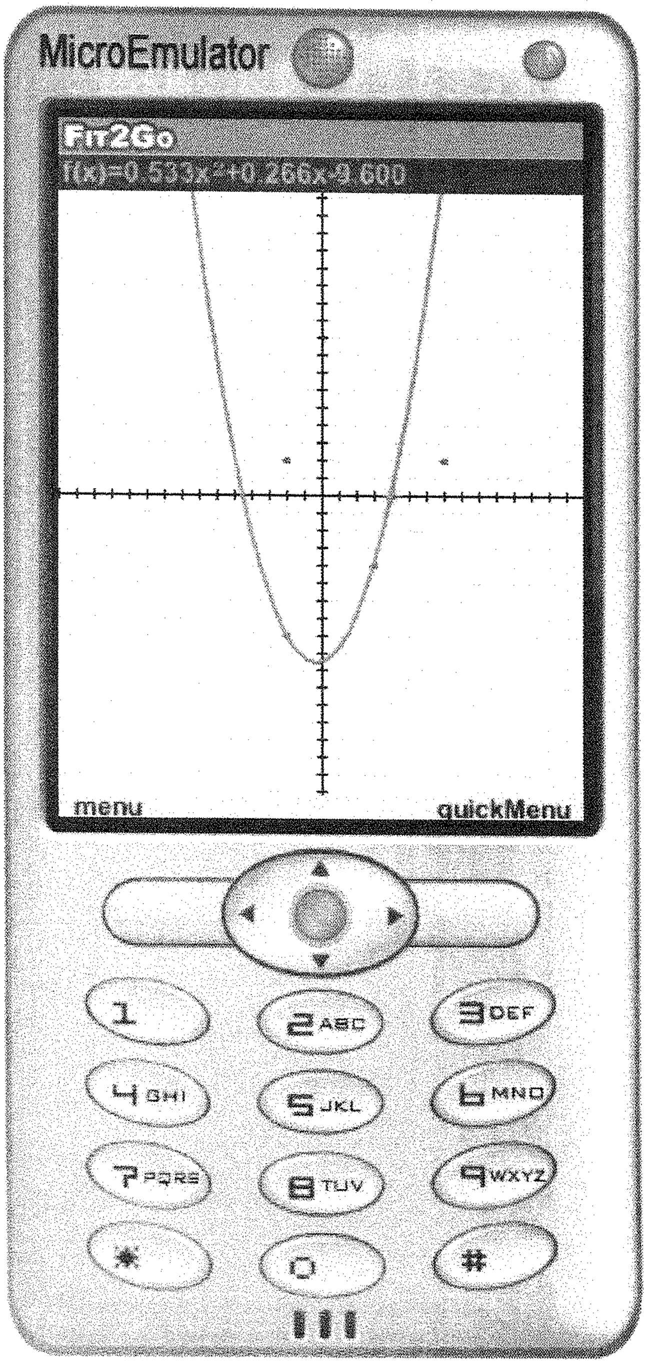

FIGURE 5.1 Quadratic function that fits three of five drawn points

a quadratic function that the Fit2Go midlet provided for five drawn points, where the function passes through three of the five points.

Working inside the classroom, the students used the Graph2Go midlet, which enables the drawing of a function given its algebraic rule. Figure 5.2 shows the function $f(x) = -x + 6$ drawn by manipulating the values of the parameters a and b in the function $f(x) = 2x + 3$ (the default function when choosing a function from the form $f(x) = Ax + B$).

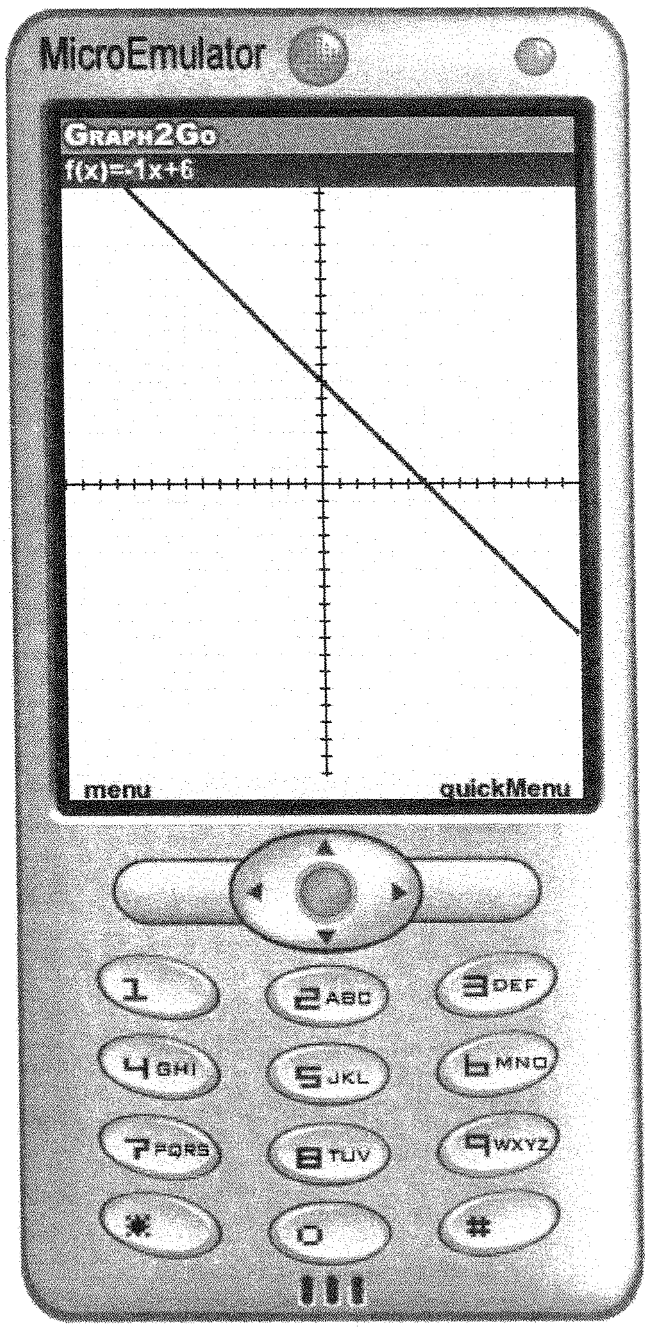

FIGURE 5.2 Graph of the linear function $f(x) = -x + 6$ of the form $f(x) = Ax + B$

The Case Study Context

This chapter draws on our research of almost 5 years. Our experiments in this period involved working with groups of students from four middle schools. These groups varied from a whole class (around 25 students) to small groups (around five students) and sometimes couples. Each year, we had around 50 students involved in our experiments. We conducted the experiments in the framework of practical training in our teachers college, guiding our pre-service teachers (around 15 each year) and their training in-service teachers (around three each year) to carry out activities that we prepared with them to investigate mathematical concepts in the field of functions with their students. These activities utilized various features of cellular phones (such as taking pictures, recording videos, measuring time) and mathematical applications suitable for cellular phones (midlets).

To create an image of the students' work in the cellular phone environment, we describe two activities that the students were involved with inside and outside the classroom. For more details on the activities that we prepared and carried out using cellular phones, refer to our articles that were previously mentioned in this chapter. This chapter will primarily describe and discuss students' learning of mathematics outside the classroom because this learning was enabled by the special features of cellular phones as learning tools. Nevertheless, this chapter will also touch on students' learning with cellular phones inside the classroom.

Classroom activity: The relationship between the parameters of a linear function and its graph.

Activity description: Through the activity, the students investigated a linear function of the form $y = Ax + B$ following the teacher's directions written on a worksheet. They were directed to fix the value of parameter A and change the value of parameter B to discover the relation between the value of parameter B and the graph of the linear function. Then, they were directed to fix the value of parameter B and change the value of parameter A to find the relation between the value of parameter A and the graph of the linear function. The students used the midlet Graph2Go to discover the relations required. They concluded that the intersection point of the graph/straight line with the y-axis is $(0, B)$ and that an increase in parameter B moves the straight line up. They also discovered how the value of parameter A affects the slope of the graph. Using cellular phones to investigate the relation between the parameters of a linear function and its graph, the students worked individually or in pairs; however, the results were discussed collaboratively with their teacher. The teacher allowed the students to choose how they wanted to work: individually, in pairs or in groups. One factor that influenced their choice was the possession of a suitable cellular phone that enabled working with midlets.

Students' mathematical activity with cellular phones inside the classroom also included other templates of linear functions such as $y = A(x - B)$ and tasks such as: Given the function $y = 2(x + 3)$, we want to change its parameters so that the graph of the function passes through the following point: (a) $(0, 4)$; (b) $(2, 2)$; (c) $(2, 3)$; (d) $(-1, 3)$.

Out-of-classroom activity: The relationship between the time since lighting a candle and its height: lighting a candle and measuring the height after different periods of time.

Activity description: The students lit candles in the schoolyard, but the wind extinguished them. Therefore, the students began to discuss where they should carry out the experiment. Some groups decided to do the experiment in one of the classrooms, where other groups gathered around the candle to keep it lit. The students in one group chose to measure the height of the candle every minute but found that the height of the candle did not change much during this time. Therefore, they decided to increase the time period in which they measured the height of the candle again to 5 minutes. Before each step in the experiment, the students discussed how they should perform it and what the possible outcomes of this step might be. Some groups worked faster than others due to coordination issues. The girls in one group put out the candle each time they wanted to measure its height. When asked why they did so, they justified this by not wanting to lose any part of the candle during the measurement. The boys in one group measured the height of the candle without putting it out. When asked why they did so, they justified this by not wanting to lose any heat so the results of the experiment would not be affected. During the measurement process, one of the students in each group recorded the results on a sheet of paper. The measurement was carried out by different students in the group; a different student performed the measurement each time. When the students completed the measurement and the list of the results, at least one of the students in the group began to assign points in the coordinate system of the midlet Fit2Go and tried to fit a linear or quadratic function to the assigned points. Further, during the experiment, one student in the group was responsible for taking pictures, while another student recorded important moments on video to document the experiment.

Upon completing the experiment, the students returned to the classroom and began comparing the functions that they obtained. They discussed the characteristics of these functions and tried to justify why the functions had specific characteristics.

Reflections on Our Case Study

We will discuss and reflect on our experiments working for almost 5 years with middle school students who utilized cellular phones to investigate mathematical problems and phenomena in the field of functions. In doing so, we will address each one of the three learning aspects that this chapter considers: students' learning behaviour with cellular phones, their perceptions of learning with cellular phones and their learning emotions in that environment.

Students' Learning Behaviour with Cellular Phones

We wrote two studies about students' behaviour in the cellular phone environment. The first examined middle students' behaviour when building their mathematical knowledge in the cellular phone environment (Daher, 2010), while the second examined the conditions and consequences of students' studying outdoors to investigate real-life phenomena mathematically (Baya'a & Daher, 2010).

The results of the first study (Daher, 2010) indicated that middle school students who learned mathematics outdoors with cellular phones behaved like mathematicians, especially during the second part of the experiment, when they suggested real-world phenomena to explore using a cellular phone. In particular, when discussing the experiments, the students presented supporting evidence about the results they obtained and described the nuances of the activities. This research points at the importance of using mobile devices outdoors to mathematically investigate real-life phenomena, especially because of the mobility of the tool, which makes it an effective tool for outdoor mathematical learning—learning that is not popular in the educational scene. Through these activities, students become active learners. Further, the use of cellular phones for outdoor mathematical investigations gives the students an opportunity to understand what it means to be a mathematician in general and a mathematician who works in applied mathematics in particular: locating an interesting phenomenon, planning to investigate this phenomenon, making decisions about the method of investigation (including deciding the role of the group's members), collecting data about the phenomenon, working with the data mathematically to translate it to mathematical relations, mathematically solving the equations/inequalities represented in the relations, discussing the solutions in the group and in the whole class and applying the solutions to the original phenomenon. It is expected that this experience will colour the students' future behaviour when working with mathematics, enabling them to make decisions regarding the mathematical investigation of real-life phenomena and regular mathematical problems. The group work outdoors makes the mathematics students highly value this collaborative kind of work and look forward to engaging in such work when investigating new mathematical problems or phenomena.

In the second study that involved observing mathematics students' behaviour when working inside and outside the classroom to investigate formal and informal mathematical phenomena, Baya'a and Daher (2010) took the various components of the grounded theory into consideration: conditions, actions and interactions and consequences. A conceptual framework was developed out of the relations among the various components. This framework showed that the factors influencing students' behaviour in the cellular phone environment were the principals' and coordinating teachers' involvement, cellular phone features and qualities, the activity themes and requirements, the learning modes (in class, out of class) and experiment phase (preparation, during activity, after activity). The framework also showed that the consequences of students' mathematical work with cellular phones included students' control over their learning and their connecting mathematics with real life.

The research results showed that the combination tool–activity is very effective for students' learning of mathematics. This implies a very important consequence: the centrality of the role of the teacher in appropriating the learning activity to the tool. This appropriation needs to be done in a supportive learning environment that consists of the school administration and the coordinating teacher.

Students' Perceptions of Learning with Cellular Phones

We conducted two studies that examined students' perceptions of mathematics learning using cellular phones. The first studied middle school students' perceptions of the cellular phone as a mathematics learning tool, while the second examined middle school students' perceptions of mathematics learning in the cellular phone environment.

In the first study, Daher (2009) found that middle school students were aware of different features of the two technological tools that they used to learn mathematics: cellular phones and web applets. These features were the availability of the tool, its collaborative features, its communication features, the size of the tool and the usability of the tool. These features influenced the participants' decisions of when, where and how to use each of the tools for the learning of mathematics. More participants preferred cellular phones over applets primarily for their small size, which makes portability and mobility easy, and its communication tools.

Our first study informed us that students highly value the portability and communicability of the tool, especially when they solve hard mathematical problems; mobile collaboration makes these solutions easier and more enjoyable. The results of the first study on mathematics students' perceptions made us aware that students are not afraid of new technological tools—whether they are midlets or applets—but they distinguish the various features and behave according to this perception.

In the second study, Baya'a and Daher (2009) found that the middle school students participating in the research perceived various qualities of the mathematics learning that were enabled by the use of cellular phones: (1) exploring mathematics independently; (2) learning mathematics through collaboration and teamwork, where the collaboration is on equal terms; (3) learning mathematics in a societal and humanistic environment; (4) learning mathematics in authentic real-life situations; (5) visualizing mathematics and investigating it dynamically; (6) carrying out diversified mathematical actions using new and advanced technologies; and (7) learning mathematics easily and efficiently.

Our second study confirmed our observation from the first study that, overall, the participating students were impressed by the potential and capabilities of cellular phones when used in mathematics learning. More importantly, students' perceptions of mathematics learning changed as a result of using cellular phones. Specifically, the students began to see the learning of mathematics as both an independent process and a collaborative process. Another important issue is the social environment that cellular phones enabled. The students perceived this environment as a humanistic and equitable environment. This happened because the cellular phone environment enabled carrying out activities outside the classroom, where the students worked collaboratively, deciding their roles and actions. Thus, portable and communicational tools enable carrying out mathematical activities outside the classroom, which causes the students to perceive mathematics learning as a process of exploring new mathematical relations, an independent process, and a more humanistic and equitable process.

Students' Emotions When Learning with Cellular Phones

Daher (2011) found that the cellular phone outdoor environment in which students work on everyday life activities was appropriate for cultivating mathematics students' positive emotions. The research findings indicated that students had different positive and negative emotions while performing different learning roles when learning with cellular phones to explore mathematical ideas. For example, they had positive or negative emotions depending on whether they obtained their desired roles in the group. Generally, the students had more positive emotions than negative ones. These emotions could be related directly or indirectly to the cellular phone environment. For example, students' positive emotions regarding the activity themes could be related directly to the cellular phone environment because these themes were possible owing to the mobility of the cellular phones and the technological tools in the cellular phones: the midlets, the stopwatch, etc. These tools and mobility enabled the performance of activities related to everyday life, outdoor phenomena, the students themselves or an issue or subject that the students liked. Students' positive and negative emotions regarding the outer environment conditions (hot, warm, cold, etc.) could be related indirectly to the cellular phone environment because the outer environment had become a mathematical learning environment due to the phones' mobility. This outdoor environment enables learning that is playful, collaborative and involved with real life, which contributes to students' positive emotions regarding their mathematics learning (Daher, 2012).

The research results made us aware of the importance of new technologies that enable having access to mathematical real-life phenomena. To do so, these technologies should enable mobility and communicability. Further, to have a positive emotional impact on students' learning, the mathematical activities that students carry out with these technologies should address phenomena related to students' lives and thus encourage their interest in mathematically discovering the phenomena. Moreover, these activities should facilitate various learning roles for the students, where the variability of the roles motivates the activity and interactivity of the students and their positive emotions towards learning mathematics.

After experiencing this novel use of cellular phones in mathematics learning in a longitudinal study over 5 years, we strongly believe that many opportunities and possibilities are yet to be realized. In spite of the disruption that these devices could cause in classrooms, we believe that banning them from schools is not the solution. We should keep studying the pedagogy behind the use of cellular phones in the actual educational environment, especially after the vast spread of modern intelligent cellular phones among youth. These modern devices contain many technological features that continue to expand on a daily basis and provide numerous sophisticated midlets in various mathematical fields. However, we need to develop appropriate activities that utilize these devices efficiently and profitably in the learning process.

References

Baya'a, N., & Daher, W. (2009). Learning mathematics in an authentic mobile environment: The perceptions of students. *International Journal of Interactive Mobile Technologies, 3*, 6–14.

Baya'a, N., & Daher, W. (2010). Middle school students' learning of mathematics using mobile phones: Conditions and consequences. *Journal of Interactive Learning Research, 21*(1), 5–25.

Botzer, G., & Yerushalmy, M. (2007). Mobile applications for mobile learning. In *Proceedings for Cognition & Exploratory Learning in Digital Age (CELDA)*. Algarve, Portugal.

Daher, W. (2009). Students' perceptions of learning mathematics with cellular phones and applets. *International Journal of Emerging Technologies in Learning, 4*(1), 23–28.

Daher, W. (2010). Building mathematical knowledge in an authentic mobile phone environment. *Australasian Journal of Educational Technology, 26*(1), 85–104.

Daher, W. (2011). Learning mathematics in the mobile phone environment: Students' emotions. *Journal of Interactive Learning Research, 22*(3), 357–378.

Daher, W. (2012). The influence of mathematical outdoor activities' characteristics on students' emotions. *The International Journal of Interactive Mobile Technologies, 6*(2), 4–12.

Daher, W., & Baya'a, N. (2010). A blended model for non-traditional teaching and learning of mathematics. In *Readings in Technology and Education: Proceedings of ICICTE 2010* (pp. 407–417). Corfu, Greece.

Daher, W., & Baya'a, N. (2012). Characteristics of middle school students learning actions in outdoor mathematical activities with the cellular phone. *Teaching Mathematics Applications, 31*(3), 133–152.

Genossar, S., Botzer, G., & Yerushalmy, M. (2008). Learning with mobile technology: A case study with students in mathematics education. In *Proceedings of the CHAIS Conference*. Open University (in Hebrew).

Sharples, M., Taylor, J., & Vavoula, G. (2007). A theory of learning for the mobile age. In R. Andrews and C. Haythornthwaite (Eds.), *The SAGE handbook of e-learning research* (pp. 221–247). London: SAGE.

Tarasewich, P. (2003). Designing mobile commerce applications. *Communications of the ACM, 46*, 57–60.

Uden, L. (2007). Activity theory for designing mobile learning. *International Journal of Mobile Learning and Organisation Archive, 1*(1), 81–102.

Yerushalmy, M., & Weizman, A. (2007). Math 4 mobile environment. The University of Haifa. http://www.math4mobile.com