# We Play We Learn: Exploring the Value of Digital Educational Games in Rural Egypt

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## ABSTRACT

The Egyptian education system faces urgent challenges. Proposed governmental reforms tend to focus on increasing access to physical and digital resources. There is insufficient understanding as to how the provided resources are currently used in rural areas. We explored the extent to which digital technology could motivate primary students to collaboratively learn a challenging topic in the National Mathematics Curriculum. We designed and researched a digital game to support memorizing multiplication facts. We used an incentive structure that encouraged individual learning with rewarding teamwork. The game was tested with mixed ability and gender groups of students using the Teams-Game-Tournament collaboration technique. A key outcome was that the students with educationally disadvantaged backgrounds benefited from using the game format. They devised their own play and study strategies. We discuss implications on future designs of the game, and considerations for its integration in Egyptian schools.

### Author Keywords
Edutainment; Play; Game-Based Learning; Games; Collaborative Learning; ICTD; ICT4D; HCI4D; Egypt

### ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces—*input devices and strategies*, interaction styles; K.3.1 Computer And Education: Computer Uses in Education—*collaborative learning*

## INTRODUCTION
The education system in Egypt faces urgent challenges. The curriculum focuses on learning for examination, and emphasizes memorizing rather than asking questions. There is little-to-no attention paid to lifelong and 21st century learning skills such as creativity, collaboration, and communication. Lack of teamwork skills is a frequent complaint from the labor market [13]. Lesson plans are centralized and rigid, which limits teachers' ability to try pedagogical approaches they see appropriate.


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Warschauer [24] identified four categories all necessary to enable using Information and Communication Technologies (ICT) for development: Physical resources (i.e., computers and Internet), digital resources (i.e., software and digital material), human resources (i.e., trained teachers), and social resources, which refer to community, institutional, and societal structures that support access to ICT. Recent governmental implementations of reform strategies are centered on increasing access to physical and digital resources through equipping schools with computer labs and broadband connections, and producing digital versions of the National Curriculum. There is significantly less attention paid to human and social resources in rural schools. Further, there is insufficient understanding as to how the provided physical and digital resources are currently used. The literature shows that introducing technologies in developing countries is not sufficient in itself to produce positive educational outcomes [23].

The presented research explores using educational games, as a part of a socio-technical learning environment designed to provide an improved learning experience in a rural school. We designed and researched a digital game to support memorizing multiplication facts for primary students. Our contributions are 1) We demonstrate how the students with educationally disadvantaged backgrounds benefited from using the designed learning environment. 2) We show how the students achieved a balance between having fun and learning 3) We provide implications for future designs that could be deployed in similar contexts.

## BASELINE RESEARCH: UNDERSTANDING THE NEEDS OF THE COMMUNITY
Borg El-Arab city, originally populated by Bedouin, is in the North-West coast of Egypt, about 40 KM west of the Alexandria metropolitan area. Borg El-Arab had major developments in the past couple of decades, with the establishment of an industrial zone, a science park, an airport, and a stadium. It then attracted immigrants from other country and urban areas in Egypt. Old Borg El-Arab is part of the city that is mainly populated by Bedouin, and the least receiving to governmental services.

The researched primary school was in Old Borg El-Arab, where 60% of its students were city residents and 40% lived in villages far from the school. The school had a computer lab that accommodated up to 30 students and contained ten personal computers. Computer classes were optional for primary students. The computer activities included watching cartoons, children songs, and digital curriculum software. About 12 students visited the lab on regular basis.

Our interview with a schoolteacher revealed some stresses students and teachers experience in the school. The teachers, despite being specialized in one subject (e.g., math), had to teach other topics due to the lack of qualified teachers in that rural community. Moreover, teacher training opportunities were rare. On average, three students from each classroom were expected to leave the school after the primary stage (6 years) as their parents would not appreciate the value of further education. Sometimes parents would keep male students in the school if they get good grades.

In her class, about 50% of students found mathematics difficult. Multiplication facts were particularly challenging as the curriculum had one semester gap between teaching multiplication facts, and teaching division. The students struggled with the later if they were not fluent in memorizing the facts. Her teaching pedagogy focused on helping the students memorize the facts through hand counting, or incremental addition. She tried to engage them using activities such as signing and interactive plays. She posted the activities on the school Facebook group to involve their parents as well. She did some experiments with collaborative activities (e.g., team competitions) that appealed to her students. She did not continue her attempts because the physical set up of her classroom was not supportive for teamwork, and she had to rotate all the desks for each collaborative activity.

We conducted interviews with 13 students from the chosen school, eight of them were Bedouin. The students were from the third grade (eight and nine year olds). All of them, except three from Bedouin origins, had computers at home. They used them to play games that were not "educational". The students' favorite subjects were (some of them reported more than one subject): 8 Arabic (the mother tongue language), 4 mathematics, 3 English, 1 French, and 1 drawing. The students preferred school subjects that they thought easy, fun to study, and/or useful. For instance, they reported that studying Arabic helped them learn new words, and write letters to friends. The students did not receive detailed feedback on their homework or their exam sheets.

We further administrated an individual questionnaire about learning mathematics. The questionnaire was an appropriated, shortened, and translated version from the Motivated Strategies for Learning Questionnaire [17]. The adapted questionnaire included 13 questions with 5-point Likert scales. We used sad and happy smiley faces in the scale so the students could easily mark their preferences. A researcher was present to explain the questions to the students. The students' responses to the following question were considerably negative.

Q: Even when I do poorly on a test I try to learn from my mistakes ("Strongly disagree", reported 7 times)

The question was related to the intrinsic value of learning mathematics. The students' inability to learn from their mistakes, we argued, aligned with their complaints about not receiving feedback on their schoolwork. We did not feel the teacher would be comfortable discussing this issue with us.

## SUPPORTING LEARNING USING TECHNOLOGY

Based on our understanding of the community needs, synthesizing the literature, and our observations during pilot studies, we developed the following design criteria.

*Conceptualizing learning:* The teacher spent most of her time assisting the students in rehearsing and memorizing the multiplication facts instead of explaining different representations and models for multiplication, and solving complex examples. Further, the students did not often receive sufficient feedback on their exam and school reports. The fact that the school served the Bedouin community, where many of the parents were illiterates, could explain the teacher's need to practice inside the classroom as the parents would not necessarily help the students at home.

The review by Kirkwood and Price [11] showed that in technology-enhanced learning, there are multiple reasons for designing technology interventions: replicating or supplementing existing teaching practices, or transforming students' experience through structural changes of learning activities. We argued that the learning experience for the students in the researched school could be enhanced by offloading the multiplication facts practice on the part of technology. We therefore conceptualized learning as memorizing the multiplication facts. Further, our view of enhancing learning included the quantitative improvements of memorization times and test scores, and the qualitative changes in learning (e.g., students' engagement with and attitudes towards technology).

*Minimal Intervention*: we proposed embedding the learning component in the technology intervention. Therefore, the learning environment could be administrated by a facilitator rather than a qualified teacher. The teacher's time could be then dedicated to helping the students understand the mathematical underpinnings of multiplication.

*Digital Games:* the students were lacking motivation in their current learning environment. We proposed a technology intervention in the format of a game as educational games were proved successful in engaging students with challenging topics [26].

*Retrieval Practice*: following our characterization of learning as memorizing, the game employed the retrieval practice learning strategy. That is, encouraging the students to get information "out" of their minds through practice [1].

*Team Play*: we proposed a collaborative game design to allow the students who lack educational support at home to benefit from interacting with more capable peers.

*Visible Play*: during the pilot studies, we tested multiple game prototypes with two input styles: an interactive floor, and a keyboard. The physical movement on the floor made the students' recall tactics and their effort to memorize visible to their peers thus encouraging them to help one another. Therefore, we used the interactive floor in our study.

## RELATED WORK

Digital games have been explored to assist students develop conceptual understanding [4,8] and/ or achieve fluency in memorizing multiplication facts [18]. Plass et al., [20] compared individual, competitive, and collaborative play of a multiplication facts game. The competition and collaboration modes of play led to more enjoyment. Further, collaboration increased students' willingness to play the game again, while competition led to greater in-game learning. Bakker [2] compared three conditions for playing online multiplication games in a wide-scale longitudinal study. The treatment conditions were: playing at school, playing at home, and playing at home with debriefing at school. The last condition was found to be the most effective.

The previous studies took place in developed education systems, where students were likely to receive reasonable support from school and/or home. It was difficult to predict a similar impact or attitude towards technology in our rural school given that play is sometimes considered an unaffordable goal in developing countries [9]. We informed our design with literature that explored technology use in similar low-resource contexts.

Using low-cost interfaces for educational entertainment (edutainment) applications was introduced in [22], and [25]. An information kiosk was designed including a computer that was fully contained behind a shop window. Street kids accessed the computer by tracking their fingers on an inexpensive fabric externally mounted on the shop window.

Minimal invasive learning was introduced by Sugata Mitra after his famous Hole-in-the-Wall experiments [17]. Mitra left an unattended computer fixed to a slum wall in India. The slum children learned how to use the computer and the Internet on their own. When tested, they achieved comparable scores to students who studied school computing curriculum [10,14]. Dangwal and Thounaojam [7] showed that children at the Hole-in-the-wall learning stations adopted self-regulatory learning strategies. The strategies were correlated with self-motivation that derived the children to determine their learning goals, plan, observe, and evaluate their behavior. Dangwal and Kapur [6] further examined the social patterns used by children while working on those stations. They explored knowledge transmission and sharing along with self-learning strategies employed by the children, while they learned computer skills. They collected data from 250 children in 17 sites across India for nine months (average age 10-11 year olds). They identified individual learning strategies (e.g., trial and error, rehearsal, self-discovery, demonstration, verbal input, observation, practice and drill) that were used by the children. The group learning strategies included outsider help, input from peer leader, and practice and drill. The children learned in groups and kept working individually to consolidate what they learned and master the computer skills. Dangwal and Kapur [5] provided insights into group dynamics at the Hole-in-the-wall stations. The learning stations built on the children curiosity to learn so they became active learners who explored the world alone and with the help of their peers.

## MULTIPLICATION FACTS GAME

This section describes the hardware and software components of the game.

### Interactive Mat

The interactive mat (Figure 1) was introduced in [12] as a low-cost technology that could be used for edutainment applications. The technology consisted of a computer, a thick brown paper mat, and an inexpensive webcam. The floor mat was the game playground or its input physical space. It contained a nine-block grid (3× 3). In a standard set up, the computer running the game was connected to the camera for position tracking, and a data show to project the game on a wall. The camera was mounted on the ceiling, and the floor mat was encompassed in the camera's field of view. The movement on the mat was tracked by the camera and mapped into one of the nine blocks. The game interface had a nine-block grid matching the floor grid. Since almost every school in Borg El-Arab had a data show, and at least one computer in its lab, the proposed setup was affordable.

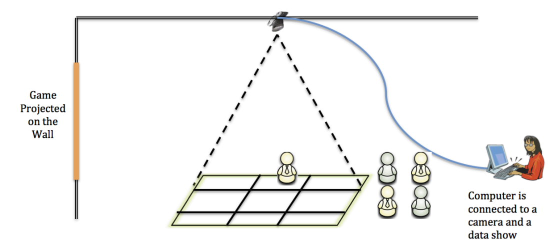


**Figure 1: Interactive Mat, Figure replicated from** [12].

### Game Mechanics and Interface

The multiplication facts game was designed to help the students memorize facts using retrieval practice. The game had ten basic levels matching multiplication tables from one to ten. In a typical play scenario, a student started at the first basic level (multiplication table 1). After correctly solving a pre-defined number of questions, the student was qualified to play in the next level and so forth. Starting from the basic level 3, the game had revision levels following each basic level. Questions in a revision level were picked randomly from the previous basic levels. The purpose of including a revision level was to reward the student for successfully passing a basic level (i.e., memorizing a new table), by solving less challenging questions and gaining game points.

Figure 2 shows a snapshot from the game interface. The question on the screen had eight possible answers matching the eight blocks of the mat (game board). The block in the middle was used for camera calibration. The potential answers were randomly distributed on the game board, where one answer was correct. The incorrect answers were put according to a parameter called board_difficulty. The parameter took values between zero and seven, and hence each question had 8 possible boards. The board_difficulty represented the number of wrong answers that could be confused with the right answer (e.g., the digits were swapped, + or - one to the correct answer). For instance, a zero board_difficulty indicated that all the mistaken answers were 3-digit numbers and thus cannot be confused with a correct answer, which was often a 2-digit number.

When a student stood on a certain block, the block number was sent to the game. The text matching the block, on which the student stood, turned to red and a depleting progress bar appeared to signal the remaining time until submitting the answer. Based on our pilot studies, we used six seconds as the timeout value. If the student changed the block before the bar ends, the timeout value was reset to six seconds. Upon submitting the answer, a visual feedback appeared to the student denoting a right or a wrong solution. For each basic or revision level, the questions were chosen randomly from a question bank. The game adapted to the individual differences in learning by allowing students to advance at their own pace. The questions were selected from the same level until the student correctly answered a pre-defined number of questions to pass that level. Table 1 shows the game parameters that were refined in the pilot studies.

According to the framework introduced by Borkulo et al. [3] for multiplication facts games, the game design provided the following learning-supportive characteristics. *Challenge*: the game challenged students to answer as many questions as they could in their turns, and to correctly solve a certain number of questions to pass a basic or a revision level and enter the next level. Furthermore, we arranged team competitions. *Feedback*: the game showed whether a submitted answer was correct or wrong. The score was shown on the screen right top corner so students could check their progress with respect to the other players. *Reward*: students were rewarded by reaching the next game level when the challenge was fulfilled. There was a form of external recognition in our setup, when a winner team was announced. *Practice*: for each basic level $x$, the question bank included 12 possible questions ($x \times 1$ to $x \times 12$), where each question had 8 possible boards. That led to 96 possible practice options for table $x$. Since the questions were randomly selected, some of them were repeated to students with different board_difficulty, and thus the students had numerous opportunities to practice the same question. They had additional practice in revision levels. For the domain-specific supportive characteristics, the game provided practice of the commutative property ($a \times b = b \times a$).

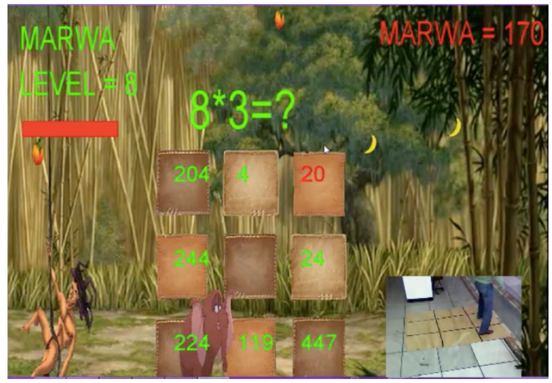


**Figure 2: A snapshot from the multiplication facts game.**

| Parameter | Value |
|---|---|
| Turn time | 2 mins |
| Progress bar timeout | 6 secs |
| # of questions per board_difficulty in basic levels | 3 |
| # of correct questions to pass a basic level | 16 |
| # of correct questions to pass a revision level | 12 |
| Maximum board_difficulty in a revision level | 8 |

**Table 1: Game parameters refined over multiple pilot studies.**

## APPROACH

Our research team included a former math teacher, who established a rapport with the school administration, teachers, and students. Over one year, the team conducted the baseline research and ran several pilot studies in the school's computer lab to refine the game parameters. We could not run the formal study as an after-school club since all the school activities had to end at 2 PM allowing students enough time to reach their homes in daylight. We ran the study in our lab during the winter break. The school arranged for picking up the participating students from their homes, and we picked them up from the school. Two staff members from the school were present with the students all the time.

### Participants

Chosen students were recruited with the help of the teacher we interviewed, who provided the history of potential participants' grades. The students were selected to form a mixed ability and gender sample. The school communicated with their families, and helped us getting the parents' consents. The study was observed by two schoolteachers. The students were informed they could withdraw at any point. We selected ten students from the school, all in the third primary grade (ages between eight and nine year olds). Another three students, from higher grades (4th to 6th), joined the trial. Two students were added based on a request from our gatekeeper to the school, and the third was the son of a schoolteacher. It is worth noting that refusing to take the new students would have been interpreted as if we refuse to help community children. Further, it would have affected the trust we built with the school. We managed to enroll them in our setup by categorizing them based on their pre-test results as explained in the next section.

We started the trial with 13 students (8 males and 5 females). Only eight students (5 males and 3 females) continued until the last day as shown in Table 2. Four students dropped because the study coincided with emerged family plans for the winter break. One student was dismissed when he bullied another student. In the pilot studies, we observed that some students did not attend school regularly. We thus considered the commitment from the eight students as a positive sign, especially the trial took place during their school break.

Many of the students had their own mobile phones or tablets with them. We did not ban using the electronic devices during the trial. We asked them to stop using the devices when they were fully distracted from the study, often playing games. That happened once or twice in the whole trial.

### Study Description

We administrated a pre-test in the first day of the trial that included questions covering the multiplication facts. The questions were similar to the practice problems in the school workbook. The students solved the test individually. The test was marked out of 20 points. Based on their scores, the students were divided into 4 categories ($A \geq 15$, $15 > B \geq 10$, $10 > C \geq 5$, and $5 > D \geq 0$), and assigned to three teams (T1, T2, and T3 as shown in Table 2).

We used the Teams-Games-Tournament (TGT) collaboration technique [21]. In a typical TGT, mixed ability and gender teams have the chance to revisit the material together as a team. Then, the teams play in a tournament, where team representatives (with the same ability), play against each other. The representatives' scores of each team are added together to form the team score.

In our TGT, each team was seated on a table, and given one revision sheet that had multiplication facts from table one to table ten. We did not provide review instructions to the teams. Instead, we suggested they ask one another questions from the sheet. Further, the students' roles in the teams were not assigned by the researchers. The review phase took ten to 15 minutes. The tournaments started after the students finished the review. The students took turns to play, each turn was timed to two minutes (Table 1). A and B students from the three teams played in one tournament, while C and D students played in a second tournament. Since the students could benefit from watching the game feedback before their turn, we randomized the students' order in every tournament to avoid such learning effect. We explained to the students that to excel in the game, they needed to correctly solve as many questions as they could in their turns.

A round was completed when all the students took turns in their tournaments. The students played four to five rounds. They had a lunch break after the second or the third round. We frequently checked whether the students experienced physical fatigue, and provided chairs so the spectators could sit and watch the play. The students' scores in the tournament were shown on the game interface. We recorded the tournaments' scores on a white board. At the end of each day, we gathered the students around the white board and announced the winner team of the day. A team score was calculated as the mathematical mean of its representatives' scores in all the rounds. We used the mean so the team would not be penalized when some team members did not show up. We explained the purpose of using the mean and the calculation method to the students. The scoring system rewarded individual learning and teamwork [21].

The schoolteachers observed the study, and we agreed that they would not interfere with the students' activities. The research team had three members. One focused on data collection instruments and registering the students to the game at the tournament time. Two researchers facilitated the sessions by guiding the students to their team tables, maintaining the scores on the white board, and randomizing the students' order in the tournaments.

We set a contract with the students before they join the trial. As they watch the game, they should not shout with the correct answer if a player does not know it. That was a behavior we observed in the pilot studies. We explained that getting scores by cheating would not help the player to learn multiplication facts. A couple of days after the trial started, we had to set another policy. Five points were deducted from the team score for each time a student misbehaved with her/his colleagues (e.g., light pushing). Such behaviors were considered typical in a Bedouin-dominant community, especially the trial was perceived as a play experiment more than a typical classroom. The schoolteachers thought the deduction policy was appropriate. We would advise the penalized student and her/his team several times, since it is a team punishment. We would then write a note about the deduction on the board. We removed the note if the students managed to apologize to each other. Otherwise, we implemented the deduction when the teams' scores were calculated, and the winner team was announced.

The trial lasted for eight days. On the ninth day, we invited the students to receive awards based on their collective team performances; nonetheless, we awarded all of them.

### Research Questions

The research questions aimed at identifying quantitative and qualitative improvements, if any, to the students' learning experience as a direct result of the designed learning environment. We use the term environment because the design included social resources (peer students), and material resources (the paper-based revision sheet, the white board, and the digital game), all of which contributed to the students' learning experience. The first question explored quantitative improvements of students' performances in memorizing multiplication facts. The second and third questions focused on qualitative developments. The second question examined the students' use of self-regulation strategies to take control of their learning without the teacher's guidance. Such behavior was evidenced in the minimally invasive Hole-in-the-Wall experiments [7]. The third question examined the implications of designing the digital intervention in the format of a game.

RQ1: Did the students' performances improve in memorizing multiplication facts? to what extent?

RQ2: How, if any, did the students (individuals or teams) use self-regulation skills during the revision phase?

RQ3: What, if any, were the perspectives brought by the game play to the students' learning experience?

## DATA COLLECTION
We recorded videos for each team at the review time, and for all the students at the tournament time, when they gathered around the mat to play. The game logged, for each student, the questions they answered correctly and the time they took to answer them. Further, semi-structured interviews were conducted with each team in the last day of the trial to reflect on their learning experience. The teams were told that reporting negative comments will help us with developing the next version of the game. Each student had a chance to answer. The questions included: Did you like the game? why/why not? What did you do to score in the game? What do you think about group play? Did you encounter any physical fatigue? What did you do when your group members did not get good scores or when they did not show up to the trial? Who is your favorite player/team?

An individual post-test, with difficulty comparable to the pre-test, was administrated after the last day of the trial. The students were not informed about the test in advance. We did not arrange a team review session before the post-test.

## DATA ANALYSIS
We used a mixed-method analysis approach as follows. For RQ1, we compared the pre-test and post-test scores. We further used the game data to examine the improvements in "thinking time", or the time between the question's appearance on the screen and the student's standing on the answer block. As for RQ2 and RQ3, we transcribed the recorded videos of the review and play sessions. The transcription included the students' talk, their interaction and play techniques, and spectators' behavior. We further transcribed the interviews. We used the transcriptions to devise individual and team profiles. The team profile described the team members' review strategies with any other interesting observations from the videos. The individual profile described the student's background information, play technique, and views as expressed in the interview. We used the profiles to answer RQ2 and RQ3.

## FINDINGS

### RQ1: Improvements in Memorizing Multiplication Facts
A paired-samples t-test was conducted to compare the pre-test and the post-test results for the eight students who completed the trial. A significant difference was found between the scores of the pre-test (M= 10.25, SD= 5.31) and the post-test (M= 15.63, SD= 3.50), with p-value= 0.01 < 0.05*. Table 2 shows the tests' results.

The two A students remained in the same category. The two B students advanced to category A, while three C students progressed to category B. One student, Stu05, progressed from category C to category A. Stu05, though finishing the game at basic level six, achieved an A-level performance in the post-test. That, in turn, suggested she did not only learn from her play, but also from reviewing with her team, and/or watching other students' play in advanced levels.

| Student | Gender | Team | Pre-test score – out of 20 - (category) | Post-test score – out of 20 - (category) | Last Basic Level |
|---|---|---|---|---|---|
| Stu01 | M | T1 | 17 (A) | 20 (A) | 10 |
| Stu02 | F | T1 | 6 (C) | 11 (B) | 9 |
| Stu03 | M | T1 | 13 (B) | 16 (A) | 7 |
| Stu04 | M | T1 | 0 (D) | N/A | 1 |
| Stu05 | F | T2 | 5 (C) | 19 (A) | 6 |
| Stu06 | F | T2 | 11 (B) | 18 (A) | 7 |
| Stu07 | M | T2 | 18 (A) | 17 (A) | 10 |
| Stu08 | M | T2 | 7 (C) | N/A | 5 |
| Stu09 | F | T2 | 4 (D) | N/A | 2 |
| Stu10 | M | T3 | 5 (C) | 12 (B) | 7 |
| Stu11 | M | T3 | 7 (C) | 12 (B) | 8 |
| Stu12 | M | T3 | 20 (A) | N/A | 7 |
| Stu13 | F | T3 | 2 (D) | N/A | 1 |

**Table 2: The students' pre-test and post-test scores (N/A indicates dropping out from the trial). The right column presents the last basic level completed by the student.**

Figure 3 shows the mean "thinking time" across the game levels, and its corresponding linear regression trends. The "thinking time" was calculated for the questions that were correctly answered. Therefore, the decrease in "thinking time" reflects an improvement in memorization skills.

The "thinking time" for all the students (except for Stu06) decreased as they progressed in the game levels. Stu06 thinking time increased as she progressed suggesting she found higher multiplication tables difficult to memorize. The A students, Stu01and Stu07, had the lowest "thinking time", aligning with them being the high achievers in the tests' scores. Their "thinking time" slightly reduced as they advanced in the game levels.

Stu05 showed the steepest curve aligning with the fact that she progressed from category C to category A.

Even though the "thinking time" of Stu02 showed an exemplary trend as she finished the basic level 9, her achievements were not mirrored in the post-test. She scored

11 out of 20 (borderline B). Reviewing her profile revealed that she preferred to do homework with her father because she often worried about making mistakes. We thus argued that teamwork provided her with the self-assurance she needed to progress in the game, the thing that she missed when she solved the post-test alone.

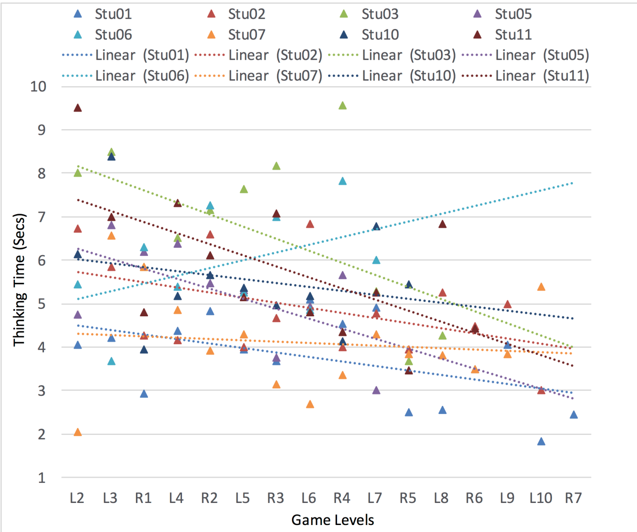


**Figure 3: Mean thinking time in basic levels (Ls) and review levels (Rs) for all the students. We start by L2 since L1 (multiplication table 1) does not require memorization.**

## RQ2: Self-Regulatory Behavior

Self-regulatory behavior is an essential quality for students' learning and academic progress. It includes three components: actual cognitive strategies students use to learn (e.g., rehearsal), students' meta-cognitive strategies for planning, monitoring, and modifying their cognition; and students' management and control of their effort to maintain cognitive engagement [17].

### *Cognitive Strategies*

On the first day, the students noticed that the revision sheet had the multiplication tables from one to ten, while the game included questions such as $x \times 11$ and $x \times 12$. That was an unintended mistake from the research team. The students completed the revision sheet with the missing facts. We believe the behavior started in one team, and replicated by the other two teams. When the students did not know the answers to the new questions (i.e., $x \times 12$), they asked the research team for assistance.

Some students started the rehearsal for the game at home, the night before, or in the morning while they were waiting for the bus. On the bus, the teacher accompanied them wrote the multiplication facts on small notes, and they used it to practice. The teams adopted various revision and rehearsal strategies as follows.

Team members took turns in holding the revision sheet and reading aloud, where each student read one multiplication table of her/his choice. Alternatively, they put the sheet on the table, where all of them could see the answers, and one student read aloud. A singing strategy is where the whole team repeated the multiplication facts. Moreover, they used review strategies that focused on questions and answers. For instance, one student asked questions from the sheet, and the rest took turns to answer. As another option, a student repeated a multiplication table from memory, a second student held the sheet and corrected any mistakes in the rehearsal. One team, T2, had trouble memorizing multiplication table seven. They divided the table into chunks, each included 3 questions (i.e., $7 \times 1$, $7 \times 2$, $7 \times 3$). They repeated each chunk ten times, asked one another questions about that chunk, and then moved to the next one.

### *Metacognitive strategies*

The students identified gaps in their knowledge or multiplication tables they found difficult to memorize without help from the research team. Further, they put more effort in rehearsing those tables. Stu10 had difficult time memorizing table six. He asked one of his teammates to review the table with him (i.e., Stu10 rehearsed the table from memory, and his teammate corrected his mistakes). Further, Stu10 read the table loudly from the sheet, and then asked another teammate to review the table again with him. Another example is Stu06, who decided to review table seven although she was playing basic level four.

The team T1 agreed that each student should review the multiplication facts required for her/his next level in the game. Stu01, A-level student and the team leader, monitored the performance of the team. At revision time, he asked his teammates random questions from their assigned multiplication tables. If they made many mistakes, the team would review the tables together. Stu01 praised his team when they answered his revision questions, even if they did not do well later in the game. When he observed they were getting low scores, he suggested a punishment policy that his father used with him. They rehearsed the table and then took turns to ask and answer questions. If someone answered incorrectly, another teammate would hit her/him gently on the back of the hand several times (they agreed on the number of times). When we discussed their policy in the interview, they thought it was, at least partially, beneficial.

- *Stu01: Stu02 got 310 instead of 270.*
- *Stu02: yes, the punishment worked for me*
- *Stu03: It worked a bit for me, I did not care about it, the most important thing was to memorize.*

### *Management and Control of Effort*

The students were not focused on watching the game all the time. We witnessed incidents such as a student was playing the game, and two male students were waiting for their turns and fully concentrating on the game questions. At the same time, two female students were playing a traditional girls' game. The other students were alternating between talking and watching the game. The students controlled their effort during the session. They would focus right before their turn "*When Stu07 played before me, I concentrated while he played.*". Some students used the game time, when they were not playing, for revision "*I reviewed with the person sitting next to me, we took turns to whisper the answer [...] sometimes, when no one was available to review, I did it by myself*".

The students' might have been previously aware of the cognition and metacognition strategies. Nonetheless, the literature suggests they must be motivated to use them [17]. The learning environment, we argue, provided sufficient motivation for the students to develop or use previously known self-regulation strategies.

### RQ3: Examining the Students' Play

The students reported in the interview they liked the game because it taught them the multiplication facts through a novel playful experience. Our observations supported what the students said. Despite the competition, when a student played, spectators from all the teams cheered and supported her/him. They cheered "bravo" for the correct answer and "yeee" for the wrong one. When a student was close to score 100, for the first time in the game, everyone cheered "100..100". Some spectators, occasionally, hugged the player after finishing his turn on the mat. They praised play techniques who led to the highest individual scores.

Stu01, A-level student, once cried when his teammates got bad scores. After comforting him, we discretely discussed his emotional reaction. He felt he was putting extra effort to increase his scores but his team was letting him down. We explained to him that he was learning and progressing, which was valuable. We encouraged him to explore ways by which he could assist his teammates to get better scores.

The physical interaction on the mat made visible the play strategies adopted by the students during their "thinking time". We summarize them as follows.

*Strategy a*: a student moved directly to the correct answer if s/he knew it (mostly adopted by A-level students).

*Strategy b:* a student stepped away from the camera's field of view or kept rotating on the mat, while rehearsing the multiplication table from the beginning. When s/he identified the answer, s/he stood on the corresponding block.

*Strategy c:* a student stood on a random block, and rehearsed the table from the beginning, while monitoring the progress bar at the same time. When the progress bar was about to end, and the student did not figure out the answer, s/he moved to another block to reset the bar time. When s/he decided on answer, s/he stood on the matching block.

*Strategy d*: Stu05 adopted a shortcut strategy, when all the blocks had 3-digit numbers except for one block that included a 2-digit number, (i.e., *board_difficulty*=0), she would immediately stand on the 2-digit block. Her strategy was then adopted by the rest of the students. She monitored whether the strategy worked all the time or not. In the interview, she told us that once Stu01 stood on a block that was corresponding to a 3-digit answer and the game showed he was correct. She recalled the question, 10×11, and we told her that the correct answer was a 3-digit number.

*Strategy e*: another shortcut strategy, was initially suggested by us, when we observed that some students kept moving on the mat for a relatively long time without deciding on the answer. We suggested submitting a random answer so they use the remaining time to solve other game questions.

The students perceived the timeout (the duration of the red progress bar) according to their ability. High achievers (A students) thought it was very long to wait for six seconds after standing on the correct block, as they could use the time to solve more questions. Other students thought it was quite short, as they needed more time to recall the correct answer. Stu03 thought the progress bar was the best thing about the game. When he did not know the answer to a question and the bar ended, he was pleased that he did not need to think about the question.

Some students employed distinctive body postures during their play: jumping or walking to the answer block, putting the hands in pockets, or holding the hands in front of the body. We believe they did so, at least partly, to be accurately captured by the camera, based on some issues with the lighting in the pilot studies. The students did not try to mimic the play techniques or body postures of one another except for employing the shortcut *Strategies d* and *e*. They did not discuss their techniques during the revision time. We believe they were trying to develop personal play styles that were not necessarily relevant to memorizing multiplication facts.

## DISCUSSION

We feel that our strongest contribution is evidencing the transformative effect for integrating ICT in educational settings, when technology responds to local challenges. In the studied community, the challenges were: the limited opportunities for the teacher to develop her practice, the lack of social support and academic feedback for the students, and the lack of motivation to study mathematics. The research showed the feasibility of shifting the rote learning to the game. The designed learning environment helped the students maintain or advance their academic achievements. The students developed mutual dependence in rehearsing the facts and used self-regulation strategies during the team phase, with minimal supervision from adults, supporting the findings from [7]. The teacher could improve her pedagogy through using the time spared by the game to focus on the conceptual understanding of multiplication, and integrate 21$^{st}$ century learning skills in her lessons. Incorporating visible play in the game mechanics made the students' thinking explicit, and allowed them to receive feedback on their strategies. The shortcut *Strategy e* encouraged the students not to spend too much time on a difficult question and attempt others. Practiced in the game, the strategy could potentially benefit medium and low achievers in exams.

The results have limitations stemming from the small sample of students and the fact that the experiment was conducted in a lab during the school break. The study period was short and the findings could have been influenced by the novelty of the technology. The positive results from our small study motivated the school to engage in future design-based research. We utilize our working relationship with the school to plan follow-up studies in school settings.

Our findings support the studies arguing that a successful integration of ICT in educational settings does not stop at introducing physical and digital resources [23]. In the researched school, the computer lab had ten underutilized computers. Our design required one computer and a bespoke game, combined with peer-learning as a social resource to positively affect the students' study skills and their academic accomplishments. Moreover, the students achieved a balance between fun and learning with almost no effort on our part to reinforce such balance. Therefore, the study contributes to the debate about the role of play in ICT for development [9] by demonstrating that a fun learning experience is a practical goal in developing countries.

### Implications

Based on our findings and observations, we suggest the following design implications.

*Accommodate high achievers* adopting group assessment approach put the high achievers at a disadvantage. They had to help their less-capable peers and tolerate team loss when other teammates neglected to study. The game mechanics should accommodate high achievers by allowing them to solve more questions. For instance, the timeout for the progress bar could be shortened if the "thinking time" hit a low threshold. The game could additionally reward the helping behavior, which may require logging the students' activities during the revision phase.

*Incorporate learning analytics* the game analytics (Figure 3) provided insights into the students' performances such as Stu02 who performed well in the game despite her low results in paper-based exams. Future designs should examine using the game analytics to provide a personalized and improved learning experience [19,20] .

*Enable emerged behavior* our design was influenced by the individual assessment in the Egyptian system. The students solved the questions "alone", despite their collaboration during the revision. In the pilot studies, we observed a student who was physically moving his teammate to stand in the right block, when that teammate did not know the correct answer. Adopting the institution perspective, we interpreted the student's attempts as cheating and discouraged such behavior in the formal study. We observed another unusual, and relatively successful, form of interaction in the review phase of T1. The gentle pat on the back of the hand was against the institution view on physical punishment. Both observations raise questions about the extent to which educational games, when played inside the school, should adopt its institutional views. Moreover, how such adoption might preclude emergent and possibly effective forms of collaboration as defined by the children and influenced by their culture and play norms.

*Play down the role of competition* the competitive nature of the game engaged the children with memorizing the facts. In a rough community, the continuous competition could eventually create tensions among students. Thus, competition should not be the sole driver for learning. The game design should highlight the value of learned knowledge by linking the game to classroom discussions as suggested by [2]. The game could occasionally offer a non-competitive play mode, where the students' scores are not recorded.

## CONCLUSIONS

The study demonstrated that digital games, as a component of the designed socio-technical learning ecology, motivated the students who did not receive proper support to thrive intellectually. The students, besides having fun, progressed academically using self-regulating strategies. The introduced learning environment, we argue, could be beneficial in similar challenging contexts such as poor neighborhoods, and refugee camps. We plan studies in school settings, where the game is re-designed per the proposed implications. We explore alternatives to provide consistent technical assistance for the school staff, including technical solutions to reduce game setup time and efforts. We plan to engage teachers in re-designing the game, and explore interaction between the game and classroom activities.

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