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Drills, Games or Tests? Evaluating Students' Motivation in Different Online Learning Activities, Using Log File Analysis

Galit Ben-Zadok
Tel-Aviv University and
The Center for Educational Technology (CET), Tel Aviv, Israel

galitb@cet.ac.il

Moshe Leiba
Tel-Aviv University and Levinsky College of Education, Tel Aviv, Israel

moshelei@post.tau.ac.il

Rafi Nachmias
Tel-Aviv University, Tel Aviv, Israel

nachmias@post.tau.ac.il

Abstract

The main purpose of this study is to compare students' behaviors in three types of learning activities (drills, games, and self-tests) in order to explore students' motivation to learn in each one of them. For that purpose, the actions of 7,434 third to sixth grade students, who learned in two learning units, were documented in log files and analyzed. The comparison between their behaviors was based on three variables: (a) the number of students who performed each activity, (b) the percentage of students who completed each activity until they succeeded, and (c) the average response time to questions in each activity. The study was carried out in two stages. Firstly, the students' behavior was examined in one unit and the results were recorded. Thereafter, the behavior was examined in another unit with different activities, in order to validate the results. Results show significant differences in students' behavior with respect to activities in both units. This implies that the drills and the self-test served as motivating tools for learning to a greater extent than the games. We conclude that a greater emphasis should be given to identify under which conditions online activities are more motivating for students' learning processes.

Keywords: online learning behaviors, motivation for learning, log file analysis.

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Introduction

Motivation is an essential component of the learning process (Anderman & Dawson 2011; Anderman & Wolters 2006; Schunk & Zimmerman, 2006) and in many cases impacts the students' behaviors in the learning environment. It is for this reason that much educational research focuses on efforts to learn about its varied aspects and implications. From the point of view of developers of online learning environments, there is a need to offer students a variety of educational tools, such as interactive exercises and games, that may promote motivation to learn and thereby enhance learning (Gee, 2003; Mayer, 2011; Mintz & Nachmias, 1998).

Students in online environments may choose their own learning path based on their preferences and needs. Their choice is exercised, for example, by the type or amount of content they consume, the time they dedicate to learning, and the effort they are willing to make (Sims & Hedberg, 1995). Motivated students consume more content and use more tools, dedicate more time to thinking, and make an effort to answer questions correctly (e.g., Cocea & Weibelzahl, 2007). Hence, it is clear that developers should be informed about students' behaviors in order to enhance the design of the environments for better learning (Pahl, 2004).

Assessment of learners' motivation in online environments has been a challenge for researchers as well as developers due to the fact that it is a difficult factor to evaluate without physically observing the students in the learning process. Traditional research tools, such as surveys and questionnaires, as well as the LMS (Learning Management Systems) of the learning environments, provide limited information to the issue posed. This gap may be bridged with log file analysis, which makes it possible to learn about the online learner by automatically and continuously collecting digital traces (Hershkovitz & Nachmias, 2009). Therefore in this study we have used log file analysis as a methodological tool to learn about the students' actual behavior in different activities and to try and infer their motivation for learning. The study builds on aspects and measurements of motivation that have been previously described in the literature.

Background

Educational Tools in Online Learning

Online learning environments contain a variety of educational tools to enhance students' knowledge and skills in a specific subject domain. These tools are often rich in media such as simulations, games, and other interactive tools (Mayer, 2011). However, perhaps the most prevalent tool for students are the drills in which they get immediate feedback regarding the accuracy of their answers (Egenfeldt-Nielsen, 2005; Weiss & Muller, 2008). Previous research described the influence of this feedback on learning by suggesting that it helps students to assess their knowledge and competence and to focus on their learning process (Chickering & Gamson, 1987; Gibbs & Simpson, 2004). On the other hand, in some studies, it was found that these tools have achieved only limited success in helping students develop advanced knowledge and skills. The reasons mentioned in this regard are that such tools have been poorly designed and are simplistic, boring, and repetitious, and they do not allow users any possibilities for active exploration (Kirriemuir & McFarlane, 2004; Schank, 2005).

Games are another common tool in online environments. A growing volume of research indicates that games have promising potential as learning tools. Alongside their ability to improve students' knowledge and skills, they generate motivation for learning by means of components such as competition, fun, and creativity (Gee, 2003; Gredler, 2004; Mintz & Nachmias, 1998). Some studies even point out the link between playing games and learning outcomes (Klopfer, Osterweil, & Salen, 2009; Mor, Winters, Cerulli, & Björk, 2006; Sandford, Ulicsak, Facer, & Rudd, 2006).

Nevertheless, there is a problem in integrating games into formal education (Jantke, 2006; Weiss & Muller, 2008). Research has found that there is a lack of acceptance of games as an educational tool among the majority of teachers as well as among many students. The reason for this is that games tend to be perceived as a leisure time activity with no pedagogic value (de Freitas, 2006; Egenfeldt-Nielsen, 2005; Schrader, Zheng, & Young, 2006). Moreover, there are some findings that reflect students' negative attitudes regarding the integration of games into the educational processes. In the research of Chen, Chen, and Liu (2010), for example, it was found that most of the students in the study (56.5% of them) were philosophically against online gaming.

Extracting Educational Data from Log Files

While learning in online environments, students are allowed to choose their own learning path. In fact, nobody stands "over their shoulders" to examine whether they perform one activity or another. The LMS in these environments does indeed record some of their actions but the information extracted from this recording is limited and provides only basic data about learners' activities, such as login frequency, visit history, and the number of messages on the discussion boards (Hung & Zhang, 2008). Educators want and need to learn more about these processes for a variety of reasons, such as improving the learning environments, providing accurate feedback for students, and personalizing the learning tools for each learner. Extracting students' actions from well prepared log files can help to achieve this goal for a large population of students (Castro, Vellido, Nebot, & Mugica, 2007; Merceron & Yacef, 2005; Pahl, 2004; Srivastava, Cooley, Deshpande, & Tan, 2000).

Researchers who use log file analysis to learn more about online learning processes usually document the entire student-system interaction. It means documenting the student's choices and the system's responses within every component on the web page. This data is then analyzed and interpreted to gain new insights into the online learning processes (Romero & Ventura, 2007). The log file analysis is part of the data mining method that is common especially in the commercial field. By contrast, in the educational field, this is a very new area of research which is called Educational Data Mining (EDM). The first few publications on EDM appeared in 2006, and they involved researchers from the fields of computer science, information systems, and education (Hung & Zhang, 2008; Winters, 2006). The use of data mining techniques is growing due to the awareness that the log file may serve as a valuable source of information about cognitive and motivational aspects of the learning processes in the learning environments.

Learning about Students' Motivation

Motivation plays an essential part in the learning process. Hence, a lot has been done in this field of research (e.g. Anderman & Dawson, 2011; Anderman & Wolters, 2006; Schunk & Zimmerman, 2006; Wenzel & Wigfield, 2009). Motivation usually impacts on the behavior of students in the learning environment and determines the amount of content and tools they consume, the way they consume them, and the effort they are willing to make on a specific assignment (Cocea & Weibelzahl, 2007; Dweck, 1986; Hershkovitz & Nachmias, 2008). In addition, in some cases, motivation influences the learning outcomes (Martinez, 2003).

It is accepted in the literature to distinguish between internal and external motivation. The motivation is internal especially when the student performs an activity because he is interested in it, and it is external when the student performs the activity in order to benefit from it (Deci & Ryan, 1985). In terms of learning assignments, one can say that if a student makes an effort to succeed in a test, the reason may be to achieve a high mark, while making an effort in assignments that are not rewarded may be driven by internal motivation. Current research places special emphasis on the features of games, such as the challenge, control, and competition that can generate internal motivation (Gee 2003; Gredler, 2004; Mayer, 2011).

Evaluating the motivation of students while they engage in the online environment is a challenging task and, unlike configurations in which the instructor sees the students and is able to infer their motivation levels from facial expression, online learning would seem to disable motivation assessment (Hershkovitz & Nachmias, 2009). Most of the studies in this field use surveys and questionnaires as well as self-reports for this purpose (Anderman & Dawson, 2011). The main disadvantages of these methods are the absence of objectivity and a lack of observation in practice. Tracing the students' actions in the learning environment makes is possible to overcome these barriers.

Studies that set out to examine students' motivation or students' engagement based on their actual behavior, suggest a variety of ways in which this can be assessed. Baker, Corbett, and Koedinger (2004), for example, characterized the behavior of "gaming the system" by measuring the response time of answering questions as well as the use of the clues from the educational system's reservoir. Beck (2004), in his study, built a model to predict students' engagement by measuring the difficulty of the questions, the student's response time, and the accuracy of his answer. Cocea and Weibelzahl (2007) tested the students' engagement by variables such as the number of pages read, the number of tests taken, and the time spent on the assignment. Hershkovitz and Nachmias (2009) developed a measuring tool for motivation which focuses on three dimensions: the extent of engagement, its energization and source based on variables such as time on task percentage, average session duration, and average pace of activity within sessions. Nevertheless, there still remains a great deal to discover regarding the question of what types of activities encourage students' motivation to learn.

Research Questions and Variables

Research Questions

The study poses two main questions:

1. Are there any differences in student behavior in various types of activities – drills, games and self-tests – based on:
   (a) The number of students who perform the activity?
   (b) The percentage of students who complete the activity till success?
   (c) The average response time to questions in the activity?
2. Are these behaviors characteristic of a specific learning unit?

Variables

The students' learning behaviors were compared by using three variables that could indicate the students' motivation based on the literature: (a) the number of students who performed each activity, (b) the percentage of students who completed each activity till success, and (c) the average response time to questions in each activity. Below is a description of the variables:

The number of students who performed each activity

While learning in an online environment, the students are often able to choose whether to perform a specific activity or not. Previous studies used the information concerning the extent of the activity in the students' performances to describe and also predict their motivation to learn (e.g. Cocea & Weibelzahl, 2007). In the current study, we have taken into account the students' choices of whether to perform an activity within the unit web page or to avoid it.

The percentage of students who completed each activity till success

According to the literature, student motivation to learn in a specific activity is also realized by the desire to succeed in it. This desire can either be driven by internal motivation (e.g., interestingness, enjoyment) or external motivation of the student (e.g., a wish for high grades, fear of parental sanctions) (Deci & Ryan, 1985). We examined a student's desire to succeed in a specific activity by testing whether he completed all the questions successfully before leaving the unit. This is because the immediate feedback given to him in each activity enables him to improve his answers till success. On the other hand, he may also leave the activity without a positive feedback for all questions.

The average response time to questions in each activity

The response time to a question has been used in recent studies as a variable for evaluating motivation or engagement in learning (e.g., Beck, 2004). A reasonable time taken for answering may indicate responsible learning, serious thinking, and motivation to succeed, while quick answers may reflect disengagement in learning and a lack of motivation. Therefore, we use this variable to examine which activity the students dedicated more time to thinking about questions and, hence, demonstrating greater motivation for learning.

Method

Student actions in two online science units were documented in log files and statistically analyzed in order to learn about their learning behaviors in each learning activity and their motivation to learn in them as a result.

Participants

7,434 students from various elementary schools throughout Israel took part in this study. This included 9 to 12 year-old children between the 3rd and 6th grades who learned in the research units as a part of the curriculum. 3,075 students learned in the first unit and a further 4,359 students learned in the second unit. The log file was anonymized and it did not contain any personal characteristics of the students, such as gender, previous knowledge, or grades.

The Learning Environments

Two units were chosen for this study, both of which deal with domains in astronomy and are part of Ofek (http://ofek.cet.ac.il) – an online learning environment in science to which over 1,000 elementary schools throughout Israel subscribe. Students often learn independently in this environment, whether in the class as a part of the lesson with their teacher or at home after school hours. Either way, the assignments given by the teacher are mandatory. The teacher is not aware of the students' learning behaviors or their final grades. These units serve as learning activities and not as assessments activities.

Both units include visual simulation of scientific phenomenon as well as three types of activities, in the following order: drills which contain questions with immediate feedback to the students; interactive learning games which contain questions to students and feedback with wins or losses at the end; self-tests which contain ten summary questions of the unit as well as auto-checking and grading. The self-test is located on a different web page. In all the activities the students may choose to correct their answers till success or leave without success. In the game it means a loss situation, while in the test it means obtaining a score below 100.

The content and the type of games differ in each unit. The domain in the first unit is the phenomenon of the moon orbit. The domain in the second unit is the phenomenon of the earth’s rotation. The aim of the game in the first unit is to complete the monthly moon phases. It contains 10 questions and has three levels of success. The second unit is an interactive trivia game which also contains 10 questions for the students and has wins and losses at the end.

Procedure

The study was carried out in two stages; first, the students' behaviors were examined in one unit and the results were obtained. Thereafter, the behaviors were examined in another unit with different activities in order to validate the results and ensure that they did not characterize the specific unit. The procedure in both units was similar and included the following five steps:

Data collection

Every component in the learning units (e.g., a question, an action button, a computerized feedback) was coded in order to document the full interaction of student-computer during the learning process. Data was collected over a period of a school year (September 2009 – June 2010) and documented in a log file.

Data cleaning

This phase focused on excluding users who were not students from the data set, such as administrators, teachers, or visitors as well as students that activated the simulation in the units but did not perform any of the activities.

Computing variables

Algorithms for calculating the variables were formulated and implemented using EXCEL. The calculation of each variable regarding every student was carried out in the following way:

(a) The activity performed was taken into account where a student answered all the questions in it before leaving the unit, even if not all his answers were correct or corrected.

(b) The completion of an activity till success means that all the computerized feedback given to the students were positive before he left the unit. In the drills, it means that all his answers were marked as correct answers, while, in the game, it means win situations, and, in the test, it means leaving with a score of 100.

(c) The student's response time to a question was measured as the time spent from his last mouse click in the previous question to his mouse click in the current question. The average response time in each activity type was only calculated in respect of students whose learning pace was less than 600 seconds.

Implementation of descriptive statistics

SPSS was used in order to examine the distributions of the students' behaviors. Independent *t*-tests were performed for comparing the response time of groups in both units.

Results

Stage 1

The number of students who performed each activity

Figure 1 describes the number of students in each activity in the first unit (the activities are presented in the same order as they appear in the unit). Results show that not all students complete all the activities within the unit. Of the 3,075 students who performed at least one type of activity, the largest number of students, approximately 93% (2,851 students) performed the drills. 78% of the students (2,386 students) performed the self-test activity, while only 73% (2,251 students) played the game.

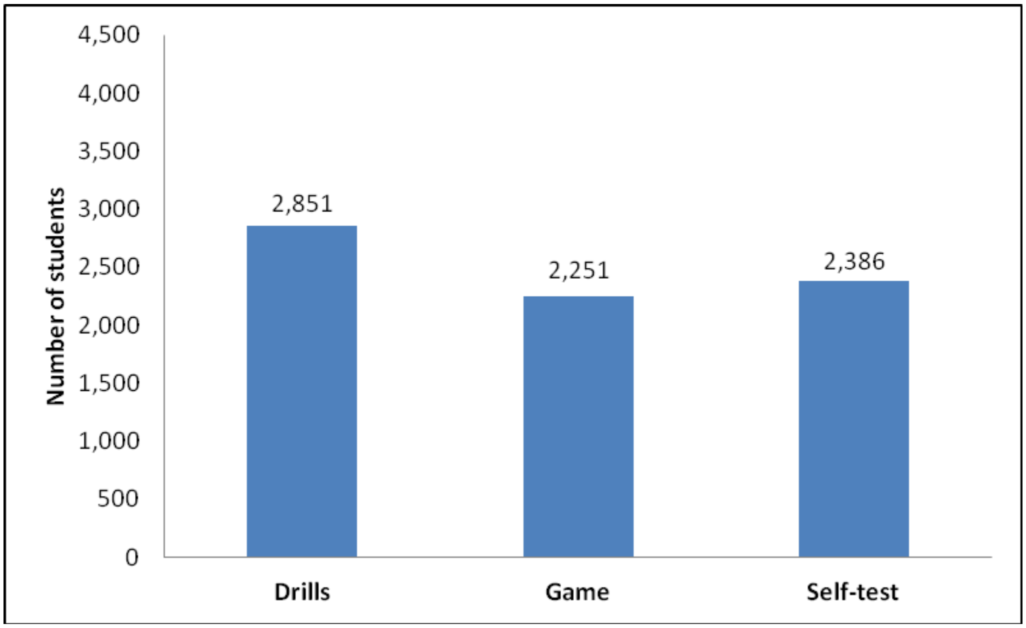

Figure 1: The Number of students who performed each activity

The percentage of students who completed each activity till success

It was found that, out of 2,851 students who performed the drills, almost all of them - 99.68% (2,842 students) - left only after completing all the questions successfully, i.e., after obtaining positive feedback from the system for all questions. Of course, this includes the students whose answers were incorrect and who corrected them in response to the negative feedback they received. In the self-test, this number declined where only 83.30% of the students who performed the self-test (1,987 students) made an effort to achieve a score of 100 in the test before exiting the self-test. In the game, the picture is fundamentally different. Approximately half the students - 57.43% of them (1,295 students) - exited the game after obtaining positive feedback (winning). The remaining students left the game without succeeding. The results are shown in Figure 2.

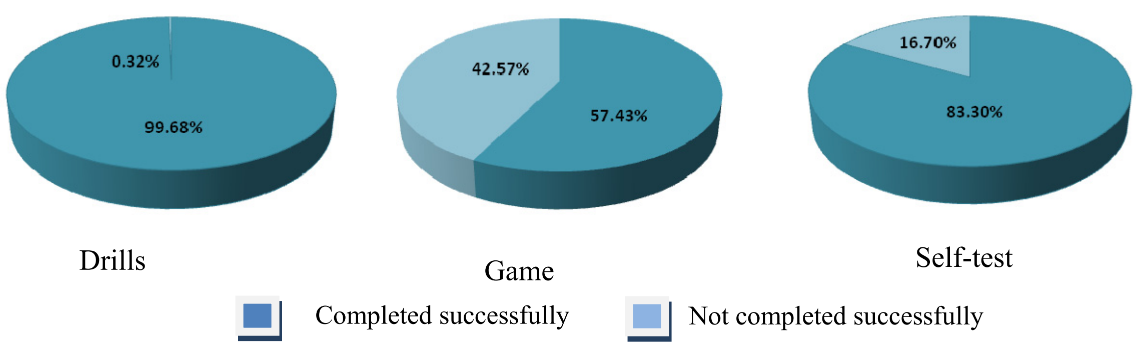

Figure 2: Students' completion of each activity type till success

These results that relate to the number of students who did not play the game till success were unexpected. Therefore, it was decided to examine whether this was due to the difficulty of the game. For this purpose, an analysis was done of each student who did not complete the game successfully, the number of tries required to succeed in the game before exiting it, i.e., the number of negative feedbacks the student received from the system before exiting. For the sake of comparison, a similar examination was conducted in the self-test, namely counting the number of tries required to score 100 before exiting the activity. Figures 3 and 4 describe the distribution of students' attempts before exiting the game or the self-test without success.

A review of the figures reveals a similar distribution in both activities. In the game as well as in the self-test, approximately 60% of the students who exited before succeeding made only one or two tries before doing so. In the game activity, 26% of the students made 3 to 5 unsuccessful tries before exiting, compared with 30% of the students who made 3-5 tries in order to score 100 in the test. In both activities, only a few students went beyond 5 tries. These results imply that abandoning the game without success apparently wasn't because of the difficulty of the game.

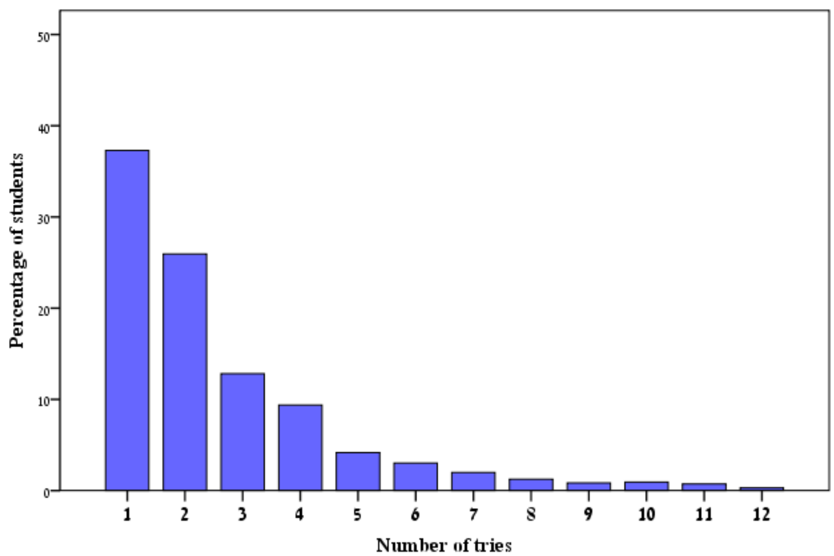

Figure 3: Distribution of students' tries before leaving the game without success (N=956)

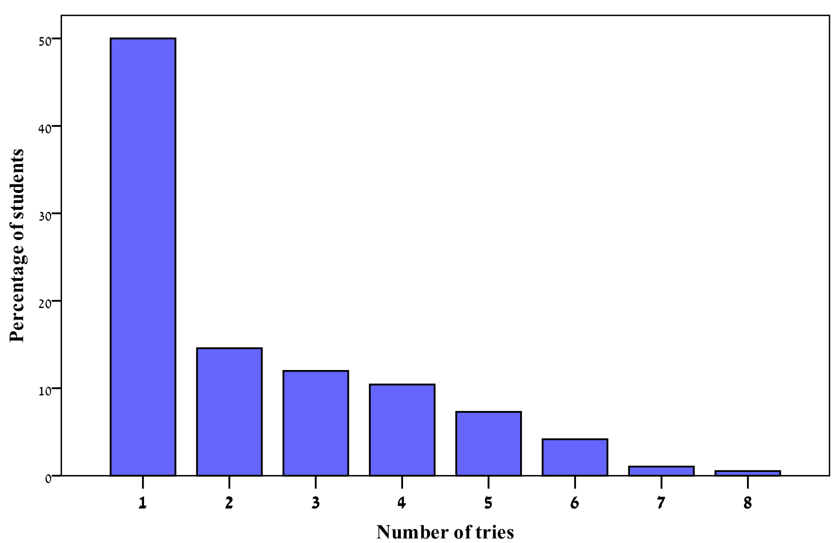

Figure 4: Distribution of students' tries before leaving the test without success (N=399)

The average response time to questions in each activity

Results suggest that the longest average response time to answer a question was found in the self-test (Figure 5) – 12.27 seconds (SD=18.25) – while the average response time in the drills was 9.48 seconds (SD=11.59) and the average response time in the game stood at a mere 7.87 seconds (SD=13.93). In order to examine the significance of these results, the *t*-test was applied. Significant differences were found in all cases: the average response time in the drills compared to the average response time in the game: $t(2,090)=4.25$, $p<0.01$, the average response time in the self-test compared to the average response time in the game: $t(2,090)=9.15$, $p<0.01$, and the average response time in the self-test compared to the average response time in the drills: $t(2,090)= -6.84$, $p<0.01$.

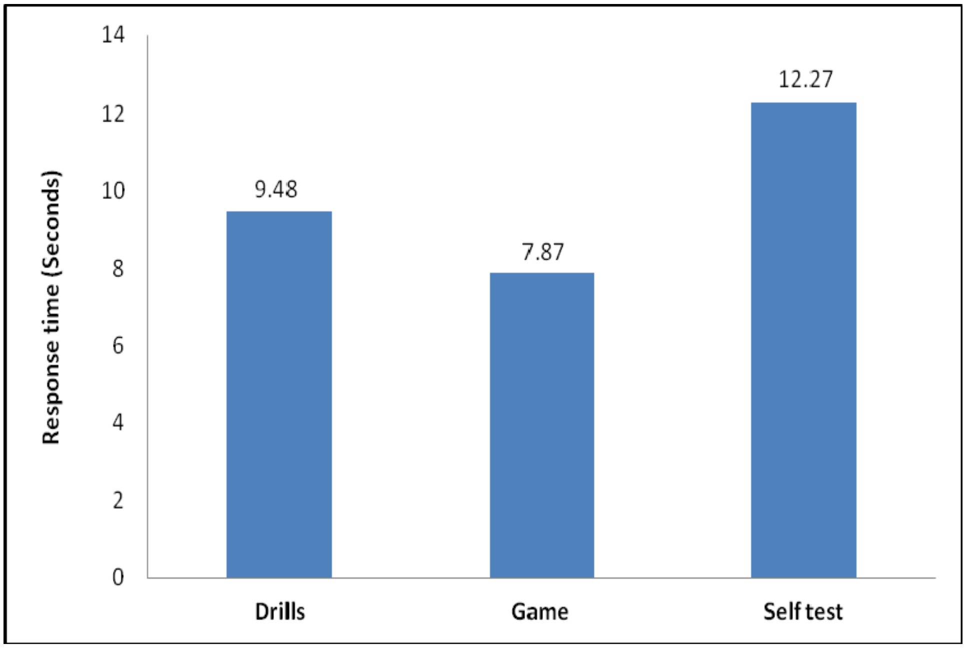

Figure 5: The average response time in each activity type

Stage 2

In this stage the behavior of an additional 4,359 students' behaviors were examined in another unit, with different activities and content, in order to validate the results obtained and to clarify whether the behaviors found in the first stage are characteristic only of the specific researched unit. The results are set forth below.

The number of students who performed each activity

4,359 students performed one or more activities in the second unit. The largest number of students performed the drills – 92% of them (3,998 students) – while 82% of them (3,590 students) performed the self-test, and only 80% (3,519 students) played the game.

The percentage of students who completed each activity till success

Results indicate that almost all the students who performed the drills, 99.87% of them (3,992 students), exited them after successful completion and then turned to other activities. 91.23% of the students (3,275 students) who performed the self-test left it after successful completion, while only 65.67% of the students (2,310 students) who played the game left it after achieving success.

The average response time to questions in each activity

A comparison of the average response time in each activity type indicates minor differences. The average response time in the drills was 10.81 seconds (SD=13.23), in the self-test it was 10.25 seconds (SD=18.21), and in the game it was 9.46 seconds (SD=13.65). These results were found to be significant in the *t*-test: the average response time in the drills compared to the average response time in the game: $t(3,282)= 4.30$, $p<0.01$, the average response time in the self-test compared to the average response time in the game: $t(3,282)= -2.04$, $p<0.01$, and the average response time in the self-test compared to the average response time in the drills: $t(3,282)= 1.48$, $p<0.01$.

Table 1 summarizes the results obtained in the first stage (Unit 1) and in the second stage (unit 2) regarding the three defined variables.

Table 1: A summary of the results in Unit 1 (N=3,075) and in Unit 2 (N=4,359)

Variables	Unit	Drills	Games	Self-tests
The number of students who performed each activity	Unit 1	2,851	2,251	2,386
	Unit 2	3,998	3,519	3,590
The percentage of students who completed each activity till success	Unit 1	99.68%	57.43%	83.30%
	Unit 2	99.87%	65.67%	91.23%
The average response time to questions in each activity in seconds (SD)	Unit 1	9.48 (11.59)	7.87 (13.93)	12.27 (18.25)
	Unit 2	10.81 (13.23)	9.46 (13.65)	10.25 (18.21)

It is evident in both units that optimal values in terms of the number of students performing the activity and percentage of students who complete the activity successfully characterize the drills. The lowest values in all the three variables are obtained in the game. In addition, while the longest response time in Unit 1 characterizes the self-test, the longest response time in Unit 2 characterizes the drills, but the differences in this unit are relatively small in this domain.

Discussion

This study presents a comparison of young students' learning behaviors in different learning activity types (drills, games, and self-tests) and yields new insights regarding students' motivation to learn in each one of them. While learning independently, with significant control over their learning choices, the log file analysis can reveal this valuable information to the educators and researchers. Based on the variables that were defined, results indicate some differences in the students' behaviors and consequently their motivation.

High motivation to learn was found in the drills. Most of the students performed these activities in both units. We assume that one of the reasons for this may be the structure of the units. In both units the drills are introduced as the first activity in the unit. Hence, it is recommended that developers of the environments restructure the unit so that the most significant activities are located at the beginning of the unit, when students still have the willingness and motivation to learn. However, an unexpected finding in both units was that least number of students played the games, although, chronologically, the games appeared before the self-tests, and the self-tests were located on different web pages. Therefore it is reasonable to assume that some students skipped the games and moved directly on to the self-tests. From these findings we can conclude that, although students like to play games even for practice at school (Bragg, 2003; Gredler, 2004; Kirriemuir & McFarlane, 2004; Mintz & Nachmias, 1998), they may not really comprehend that the game is a learning tool (Bragg, 2007) and when time is limited they prefer to move on to the "real learning activities." This conclusion is in line with several studies that point out that students, as well as the majority of teachers, perceive the game as a leisure time activity with no pedagogic value (de Freitas, 2006; Egenfeldt-Nielsen, 2005; Schrader et al., 2006).

This interpretation is validated when examining the students' completion of each activity. While almost all students used the drills and self-tests until they completed them successfully in both units, the situation is different when examining the game. Almost half of the students who played the game in the first unit (42.57% of them) didn't play it until they completed it successfully. Similar results were found in the second unit where 34.33% of the students didn't played the game until they completed it successfully.

With regards to the response time to a question in each activity, in the first unit it was found that students took more time to respond to questions in the self-test than in the other activities. This may imply an external motivation (Deci & Ryan, 1985), which is realized as the desire to achieve a high score in the test. However, these results were not repeated in the second unit, so there is a need for further research on this issue.

In summary, our findings indicate that greater motivation to learn was found in the drills and the self-test than in the learning game. These findings reveal the need to discuss in greater length under which conditions learning activities, in general, and games, in particular, should be integrated into online learning environments. This may include, for example, re-arranging the order of the activities in the unit, teacher intervention in the learning process, or re- thinking the characteristics of the activities that are presented to the students. Further investigation is required in this issue.

The evaluation of students' motivation in different activities by using information that relies solely on data stored in log files has many advantages, such as being a non-intrusive and an objective method of research in a large population of students, but it also has its limitations. First, the lack of interaction with the students does not facilitate obtaining more in-depth information, such as personal characteristics and attitudes. Second, our evaluation relied only on variables that relate to the extent of content consumed, the effort to complete the activity, and the response time required to answer questions. Similar variables are well established in the literature for reflecting or predicting motivation and engaging in learning, as was previously described. However, we are aware that many factors may influence the motivation for learning besides for the behavioral aspects, such as prior knowledge, existing skills, and online learning experience. Therefore these issues still require further investigation that examines how these attributes are realized while learning through different learning tools.

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Biographies

Galit Ben-Zadok is a Ph.D candidate at the School of Education, Tel Aviv University, an educational Learning Objects' developer in the science department at CET (the Center of Educational technology) and a lecturer at Or Yehuda Center for Academic Studies. Galit's research interests are ICT in Science Education, ICT implementation in Elementary School and Web-Mining of On-line Learning.

Moshe Leiba is a Ph.D candidate at the School of Education, Tel Aviv University and a lecturer at Levinsky's Teachers College. He acts as the EU research coordinator for the knowledge Technology Lab at Tel Aviv University and a research assistant at the DynaLearn project (supported by the EU 7th Framework Programme). Moshe's research interests are ICT in Science Education, Mathematical problem solving, Web-Mining of On-line Learning and ICT in teachers' training.

Rafi Nachmias is a Professor of Science Education at the School of Education of Tel Aviv University. He is currently heading the School of Education, the Science and Technology Education Center (SATEC) and the Virtual TAU project at Tel Aviv University. He has published over 100 papers and several books on the topic of ICT in Education. He is involved in several national and European research projects as principle researcher.