Effects of Instructions, Assistance, Narrative, Competition, Challenge, and Age on Performances in Digital Learning Games

https://doi.org/10.3991/ijac.v15i2.30867

Inbal Leuchter(✉), Gila Kurtz
Holon Institute of Technology, Holon, Israel
inballeuchter@gmail.com

Abstract—Studies have shown that digital game-based learning (DGBL) can stimulate learners and increase motivation. However, in order to accomplish these goals, we must understand the role and impact of the game elements. This study aimed to examine the effects of four-game elements on player performance: Instructions and assistance, narrative, competition, and challenge. An additional factor examined was players' age. The data was collected using BIG DATA from the 'Wandering' game platform, which recorded the scores of 3,281 users across nine different games during the period 2015-2020. Users played as part of their visit to 'Musa,' a multidisciplinary museum of local cultural materials in Tel-Aviv, Israel, either in 'Family' game mode or in 'Group' mode. According to the results of our study, players performed better on 'Group' games. In addition, players' performances improved when narrative depth was significant and the play area was smaller. Separating our data into two groups led to additional results: players in 'Family' mode performed better when the game instructions included a video, while in 'Group' modes, participants performed better when a human guide was available to some extent. The results of this study and their implications can assist educators and game designers in planning more accurate and effective learning games.

Keywords—game-based learning (DGBL), instructional game elements, game performances, BIG DATA

1 Introduction and background

Since the 1980s through the early 2000s, researchers have been interested in the new possibilities of enrichment video games can provide. They pointed out that this environment has the ability to contain enormous amounts of content, give immediate feedback, and motivate the participants intrinsically within a fun, safe, and risk-free environment [1, 2, 3]. Other scholars have stressed that video games could function as an excellent 'incubator' for developing life skills, such as identifying patterns, recognizing and solving problems, and making quick decisions [4]. Today, many studies explore the advantages of video games as an effective tool in various fields, including sport, medicine, math, and mental health [5, 6, 7]. Education has been one of

the most popular areas for integrating digital games, offering both great promise and a fascinating research field for many educators and instructional designers [8].

Many studies have shown that digital games can serve as an effective and powerful tool for improving and strengthening learning [9–17]. To be precise, research has shown that the integration of digital games into educational systems can often improve the learning process and usually improve students' motivation, making learning more appealing. Moreover, studies suggest that games promote a stronger positive emotion toward learning than traditional learning methods [18]. For these reasons, digital educational games have become popular in learning environments such as schools, military training facilities, and workplaces [19, 20, 21]. This study examines a set of nine educational digital games designed and operated within a museum environment, in order to understand their effect on participants. In the following section, we review the research literature regarding different types of learning games and the impact of specific game elements on players.

1.1 Motivation and performance in digital learning games

In contrast to standard video games, learning games are designed to achieve an educational goal beyond simple enjoyment [22, 23]. The topic of motivation in digital games has been extensively discussed and researched over the years, due to its critical significance for retaining players in the game, producing better performances, and increasing players' participation [3, 24, 25, 26]. Flow, immersion, presence, and engagement filled the world of game research, as well as questions regarding how to keep players engaged for as long as possible [27–30]. Game developers realized motivation (defined as the desire to participate and the intensity to succeed [31]) is a key factor for encouraging players to play more [32], and in the educational world, it is a key factor to a deeper learning processes [33, 34].

It is important to note that, despite the popularity of digital learning games, there have been studies that question whether or not they are as effective in improving learning outcomes as attributed [17, 35], yet there is hardly a question about their role in enhancing motivation. Studies consistently and unequivocally demonstrate that learning games increase learners' motivation and engagement in the study material and in-class [26, 35, 36, 37].

1.2 Learning games: individual and multiplayer

There are many types of educational digital games available: games designed for an individual (single player or single player facing a computer) and games intended for several participants (collaborating, competing or both). Despite the fact that both types of games are very common, studies have shown that a game that combines collaboration between players in a multiplayer setting produces more effective results than a single-player experience [16, 35]. These findings are in line with studies conducted on traditional educational environments [38, 39] and student preferences [40]. In this study, we examine the data of players from nine different games, all collaborative in nature and some also competitive. Given the similarity between the games, the data will be analyzed

as a whole, as well as in separation between two types of participation — 'Family' mode and 'Group' mode. 'Family' mode was played by independent museum visitors, often families. In this mode, all members played collaboratively on one device but without sharing the game with other users. In other words, the game involved a single user (note that it is a single user and not only one player) and a race against a personal timer. 'Group' mode, however, was played by groups visiting the museum as part of an organized tour. The 'Group' mode was characterized by accommodating a large number of users during one gaming session, allowing them to see each other, and sometimes even to compete (yet always collaborative too, since, like 'Family' mode, each user represents the team of three to four players collaborating on one device). Another characteristic of the 'Group' mode was the joint game time: regardless of when each user logged in, the activity time was dictated in advance for all group players.

1.3 Game elements and their impact on participants in learning games

Game environments contain a wide range of elements, such as rules, feedback, goals, competitions, challenges, narratives, progress, collaboration, rewards, and stages [1, 41]. Werbach and Hunter [42] compared designing a new house (which requires knowledge of different dimensions and the professional skills to combine everything into a successful work) to the complexity of designing and executing a game. Many researchers have realized that, in order to be able to plan a successful game, one must understand more deeply its mechanics. In order to do so, some researchers have chosen to isolate one or more individual game elements and have conducted experiments to reveal their effect on gameplay [21, 36, 37, 41, 43, 44, 45, 46]. They aimed to uncover which of the elements have a significant impact on the player and to understand the mechanism for this: which are key to effective learning, motivation, and enjoyment, and which are weak or not necessary at all. With this knowledge, they believed that educators and game designers could plan accurate game experiences, tailored appropriately to the learning context and the desired outcome. In this study, we focus on examining four common elements: instructions and assistance (instruction method and in-game assistance), narrative integration (station order and narrative depth level), competition, and challenge. The age of players was examined as an additional factor and was considered as a background factor.

Instructions and assistance. Research shows that the type of instruction given before reading a text can influence the cognitive process that takes place during reading and learning. Likewise, it is possible that instructions on participants' performances are important in learning digital games. Our study includes two types of pre-game instructions: one with a video clip and the other without it. We will compare the number of stations completed by participants with and without video, in order to examine the effect of this parameter.

In numerous studies, teachers and instructors have been shown to play a crucial role in determining the success of a learning game [47, 48]. It is a challenging task requiring the instructor to have a broad set of skills including technical abilities, playful literacy, specialization in the material being taught, and a solid pedagogical foundation [49]. A high priority was also placed on the availability and quality of assistance provided

to students during the game. The results of a study of about 250 high school and high school students, in which assistance was offered to players (individual and team) during the game, demonstrated conclusively that help influenced their performance and motivation [50]. The instructor assistance has been shown to be also crucial in university [51]. Clark and his colleagues [35] found that the more humane and massive the assistance provided in a game, the more positive and substantial the impact on players. As part of this study, we will examine whether instructor assistance is a factor influencing participants' performance. To this end, we shall examine two levels of accompaniment offered to players in the 'Group' mode — 'close' and 'distant'. In the 'close' mode, the guide was physically present throughout the game activity, whereas in the 'distant' mode the participants were made aware that the guide was available to them, but he was not in their immediate vicinity.

Narrative. According to researchers, a narrative element in a learning game produces positive attitude and engagement towards the learning material, enhances authenticity and enjoyment, and leads to better participation [37, 43, 46, 52, 55].

Narrative is examined in this study using two parameters — order of stations and narrative depth.

Order of stations. In our study, all learning games will be classified as 'free' or 'linear' based upon the participants' ability to choose their path in the game. In 'free order' games, participants did not have to follow a predetermined station order and were free to decide their game path. In 'linear order' games, however, the order of stations was predetermined by us (the game designers), and participants could not alter it. 'Free' games typically featured a weak narrative of the game, since it was impossible to predict where the participants will go or adapt the narrative accordingly, while 'linear' games typically featured a strong, clear and well-constructed narrative.

Narrative depth. In this study, we separated the games into three categories based on their narrative depth — 'weak,' 'medium,' and 'strong.' Games without any narrative elements, or with a slight narrative layer, were classified as 'weak' narrative depth. We regarded narrative depth as 'medium' for games that were motivated by a story and reflected it to some extent in their graphics. Lastly, narrative depth was classified as 'strong' for games that had an evolving story throughout the game, that was also reflected in their graphics.

Competition. Competition is one of the most common game elements, and usually involves points, tags and scoreboards [19]. A competition can be between individuals or between groups, face-to-face or over a computer, in person, against oneself, against time, against luck, etc. [41, 45]. Although competition effectiveness in improving learning remains uncertain [21, 45], it is still considered one of the most popular game elements. According to many studies, competition improves motivation and learning performance, creates challenges, a sense of ability and meaning, and even encourages greater effort, teamwork, active participation and enjoyment of games [21, 26, 36, 37, 44, 54]. In our study, we compare two different game options that were available in 'Group' mode: competitive and non-competitive.

Challenge. The challenge element is also a popular one in games [1, 3, 26, 41]. Studies show that challenges improve participants' learning, motivation, sense of flow, and performance [27, 55], as well as their level of enjoyment and satisfaction [34, 43]. Providing there is a balance between the abilities of the players and the game difficulty,

it is expected that the players will experience levels of satisfaction and enjoyment [27, 56]. However, if the level of challenge is not appropriate for the participant (i.e., too easy or too difficult), motivation and interest are likely to decrease [2]. This study examines the challenge element using the parameter of 'size game area'. In general, the longer the museum game was, the greater the physical and cognitive effort the players had to exert. For this reason, we categorized our nine educational games into three sizes — 'small,' 'medium,' and 'large.' A 'small' game area included a visit to only one exhibition. A 'medium' play area included visits to two to four exhibitions. A 'large' game area included visiting five or more exhibitions.

Participants' age. Studies have examined game-based learning among different age groups and have produced diverse findings regarding the impact of player age on game performance [14, 17, 18, 35, 53]. In some studies, researchers found that as age increased, performance improved [57, 58], but others found the contrary [17]. Other studies have found no effect at all [59]. Children [10, 17, 58], adolescents [18, 52], and students [14, 26, 54] make up the three main target audiences of learning games, and we have a good representation of all of them in our study data. In order to investigate whether age influences performances in learning games, we will compare the number of stations completed by participants in the 'Group' mode by three age groups: elementary, middle and high school, and adults.

2 Research objective and research questions

The purpose of this study is to examine the effect of four game elements and one background characteristic on motivation and performance in nine museum digital learning games. To this purpose, we used eight independent variables: Game mode, Instruction method, Level of assistance, Order of stations, Narrative depth, Competition, Game area size, Player's age. The dependent variable was the number of stations the players complete, and its values range from 0.75 to 28.322. The station numbers are not round, since we performed a data comparison between the various games. To learn more, see section 5.3. We asked the following research questions:

1. Are there differences in the number of stations completed by participants with 'Family' mode and participants with 'Group' mode?
2. Is there a relationship between the number of stations completed by the participants and the following variables: Instruction method, Level of narrative depth, Size of the play area?
3. Is there a relationship between the number of stations completed by the participants of the 'Family' mode and the following variables: Instruction method, Order of the stations, Level of narrative depth, Size of the play area?
4. Is there a relationship between the number of stations completed by the participants of the 'Multi-player' mode and the following variables: Level of assistance, Competition, Level of narrative depth, Size of the play area, Participants' age?
5. To what extent do the independent variables predict the number of stations completed, among the game's participants?

6. To what extent do the independent variables predict the number of stations completed among the game participants in the 'Family' mode?
7. To what extent do the independent variables predict the number of stations completed among the participants in the 'Multi-player' mode?

3 Research field

The nine museum digital learning games, that were included in this study (See Table 1), were created and played between 2015 and 2020 in 'MUSA - Eretz-Israel Museum, Tel-Aviv' in Israel. The museum, which is one of the largest museums in Israel, showcases local cultures that lived in the area in different periods, next to contemporary Israeli art and craft (http://www.eretzmuseum.org.il). It occupies an area of about 200 dunams, includes fifteen separate pavilions, and has hundreds of thousands of artifacts in its collection. It is also the first museum in Israel to have offered a wide range of games for the use of the public. The content and game design of the learning games were developed by the Museum's Education Department, while the platform and technological interface were developed by the game platform 'Wandering' (known before as 'Experiencity', https://muse.run/wandering). In accordance with a 'place-based learning' model, stations were created to include active tours in the museum exhibits, which required both physical and mental activity on the part of players. As participants completed stations in the game, they earned points and a 'V' mark in the game, and the system kept track of their achievements behind the scenes.

The museum games were always viewed as a social and collaborative event rather than a personal one. Family members or groups were asked to play together on one phone/tablet (recommended for 3-4 players in a squad). Game technology did not include automatic location detection. Hence, players navigated using a paper museum map of the museum or - in some games - from a digital map that appeared on the screen. Because of the large museum area and the system navigation limitations, walking times in the games were sometimes long (read about the game walking differences and the comparison method in 6.3, 'Comparison') .

4 Research population and data collection

We collected all data for this study from the 'Wandering' game platform, which automatically recorded each player's information and score. Based on data collected between January 2015 and July 2020, the study includes the performance of 3,281 users in nine educational games offered by the museum to its visitors. Due to the extent and diversity of the data and their source, they can be considered BIG DATA [60]. As mentioned before, participants for the games were instructed not to play alone, but to play together on one device, in cooperation with other players. Observations have revealed that this guideline were met by the vast majority of participants, so that any registered 'user' (3,290) can be considered as representative of a 4-3 player squad (3.5 on average). By multiplying these numbers, we arrive at an estimate of 11,515 players represented in the data. The data can be broken down into two categories: a group of

players in 'Family' mode, comprising 1694 users (about 52% of respondents) and a group of players in 'Group' mode, comprising 1,587 users (about 48% of respondents).

The 'Family' mode included users from four games: 'Around Musa' (independent version) - 666 users, 'Israeli Picnic' - 63 users, 'The Archaeological Quest' - 497 users and 'The Coins Challenge' - 471 users. 'Family' mode participants were museum visitors who took part in the games independently throughout the museum's open hours. They received explanation postcards from the sellers at the counters. Players in this group were adults and children of various ages (usually families).

The 'Group' mode included users from four games: 'Around Musa' ('multi-player version) - 848 users, 'Need to Product' - 250 users, 'Passcode' - 143 users, 'The map' - 144 users, 'Jacqueline Kahanov' - 44 users and 'Greek experience' - 164 users. 'Group' mode includes museum visitors who have taken part in games in an organized framework - schools, the military, and business organizations. The game mode was offered only during guided tours and participants were not able to continue playing after the time was up. Participants in the 'Multi-player' mode included elementary students from third to sixth grades, middle and high school students, and adults.

5 Research tools

5.1 The data production process

This research is quantitative and based on data collected from the 'Wandering' game platform. Among the data transferred were the username, game date, and number of points earned.

5.2 Data additions and removals

Data additions. The points accumulated by participants during the games were used to automatically calculate the main variable used in this study - the number of stations each user completed. Additional variables were added manually to each file: game type, instructions type, assistance level, age of participants, stations order, narrative depth, competition, and game area size.

Data removals. Data from all users identified as museum staff and developers was cleared. Additionally, we removed users who completed only one station or did not complete any stations at all, since observations revealed that many users enter the game using their personal devices, but soon moved on to play with their teammates, as instructed. Therefore, we did not consider them as playing users, and they were not included in the data.

5.3 Comparison of the data

The nine learning games included in the study had similar types of stations, but differ in the distance that players had to walk between the exhibitions and stations (see Table 1, 'Size of play area' column) and play time (see Table 1, 'Play time' column). As a means of comparing the performance of the participants in the different games,

we calculated the average of the stations completed in each game and divided the game duration by this figure, so we could get the average time spent at each station. Then, we compared the average times across other games of similar size (small, medium, and large; details in '1.3.5 Challenge in an educational game'). This comparison revealed the average completion time of a station per game size (small- 3 min, medium – 5 min, large – 8 min). The difference between them only refers to additional walking time between stations, not the difficulty of the station or the amount of time needed to solve it. Thus, the performance data of medium-area games and big-area games were multiplied (mid-range for 1.6 and big for 2.66), in order to bridge the walking gap and enable comparison. Unusual was the 'Around Musa', which, because it has numerous stations, the walking time in it is like playing a medium-sized game. As a second step, we compared the length differences between the games. To achieve this, we chose the shortest game - 15 minutes - and divided the durations of the other games in a way that would equal this figure. Finally, we divided the performances of the participants by these numbers to arrive at the final result.

6 Findings

6.1 Research question 1

We conducted an independent Samples *t* test to determine whether participants who played in the 'Family' mode completed more stations than those who played in the 'Group' mode. Statistical analysis revealed a significant difference ($p < 0.05$, $t(2669.354) = -9.075$). Participants who played in the 'Group' mode (average = 5.47, standard deviation = 3.97) completed more stations than those who played in the 'Family' mode (average = 4.40, standard deviation = 2.54).

6.2 Research question 2

We conducted an independent Samples *t* test to determine whether the number of stations completed by participants whose opening instructions included a video differed from those whose instructions did not. Statistical analysis revealed a significant difference ($p < 0.05$, $t(2838.631) = -3.910^{**}$). Participants whose game instructions included a video completed a greater number of stations (average = 5.16, standard deviation = 3.89) than those whose game instructions did not include a video (mean = 4.69, standard deviation = 2.73).

Pearson correlations were also conducted to determine whether there is a correlation between the number of stations completed by the participants and the level of narrative.

Table 1. The nine museum digital games names and parameters included in this study

Game Name	No. of Stations	Game Duration	Game Mode Available	Instruction Method	Level of Assistance	Stations Order	Narrative Depth	Competition	Game Area Size	Participants' Age
'Around Musa'	104	Family mode – 40 minutes Multi-player mode – 50 minutes	Family and Multi-player	With video clip	Distant	Free	Weak	Family mode – Yes Multi-player – No	Large	Children, adolescents, adults
'Need to product'	24 (4 for every squad)	20 minutes	Multi-player	With video clip	Close	Free	Weak	No	Medium	Adolescents
'Passcode'	12	50 minutes	Multi-player	Without video clip	Distant	Free	Strong	Yes	Large	Adolescents
'The Map'	8	15 minutes	Multi-player	Without video clip	Close	Free	Weak	No	Small	Adolescents
'Israeli Picnic'	24	50 minutes	Family	Without video clip	No assistance	Free	Weak	No	Large	Families (diversed)
'Jacqueline Kahanov'	7	15 minutes	Multi-player	Without video clip	Close	Free	Medium	No	Small	Adolescents
'The Archaeological Quest'	10	75 minutes	Family	With video clip	No assistance	Linear	Strong	No	Large	Families (diversed)
'The coins challenge'	16	35 minutes	Family	Without video clip	No assistance	Free	Weak	No	Small	Families (diversed)
'Greek Experience'	16	50 minutes	Multi-player	Without video clip	Distant	Free	Medium	Yes	Medium	Children

depth and the size of the game area. However, no significant association was found in either case. As the order of the stations and the age characteristic could not be tested, no analyses were performed on this study question.

6.3 Research question 3

An independent samples t-test was performed on the 'Family' mode players to examine the connection between the number of stations completed to the instruction's method and the order of the stations in the game. The result was a slight but significant difference ($p < 0.05$, $t(1218.403) = –2.694$**). In other words, those who played games with video instructions and linear station order completed slightly more stations (average = 4.63, standard deviation = 2.04) than those who played games without video entry instructions and free station order (average = 4.31, standard deviation = 2.71).

Additionally, Pearson correlation analyses were conducted in order to see if there was a connection between the number of stations completed and the level of narrative depth and the size of the playing area. Calculation showed that the two elements contributed to the number of completed stations in a weak but significant way. The number of stations completed was negatively related to the size of the game area ($p < 0.01$, $r = –0.200$**) while the number of stations completed was positively related to the narrative depth level ($p < 0.05$, $r = 0.058$*). No analysis was conducted for level of assistance, competition, or age characteristics since these factors had a single value in family mode games.

6.4 Research question 4

An independent sample t-test was conducted to examine the impact of guide assistance received by the participants in the 'Multi-player' mode on their completion rate. Analysis revealed that the group receiving remote accompaniment differed significantly from the group receiving close accompaniment ($p < 0.05$, $t(1320.612) = 18.137$**). Those who had a remote instructor accompany their game completed almost twice as many stops (mean = 6.30, standard deviation = 4.12) as those who were accompanied by a close guide (mean = 3.26, standard deviation = 2.40). Additionally, an independent sample t-test revealed a significant difference between the station completed by those who participated in competitions versus those who did not. Statistical analysis revealed a significant difference between the two groups ($p < 0.05$, $t(1320.612) = 18.137$**).

The results demonstrate that those who followed a competitive format completed more stations than those who followed a non-competitive format (average = 6.30, standard deviation = 4.12). Pearson correlations were carried out in order to examine whether there was a correlation between the number of stations completed by players in 'Group' mode and the level of narrative depth and size of the gameplay area. We found that both had a weak but significant impact on the number of completed stations. There was a weak and significant negative relationship between the number of stations completed and the size of the game area ($p < 0.01$, $r = –0.219$**), while the narrative depth level revealed a very weak and significant positive relationship ($p < 0.05$, $r = 0.079$**). A Pearson correlation analysis was used to determine whether there is a

connection between the number of stations completed by participants who played in the 'Group' mode and the participants' age. Based on the calculations, age accounted for a weak but significant effect ($p < 0.01$, $r = 0.151$*). The opening instructions and the order of the stations in the game could not be tested for this research question.

6.5 Research question 5

We conducted a Linear Stepwise Regression Analysis in order to ascertain whether the number of stations completed can be predicted based on the variables examined (opening instructions, narrative depth, game area size) and game mode ('Family' or 'Multi-player'). Game mode and narrative depth level were found to explain the number of stations completed in 2.9% of the cases and both variables are significant, with game mode being the first variable included in the calculation (Beta = –0.170) and narrative depth level being the second (Beta = 0.063). The variable opening instructions and game area size were not included in the model.

6.6 Research question 6

We conducted a Linear Stepwise Regression Analysis in order to ascertain whether the number of stations completed can be predicted using the variables (instructions method, station order, narrative depth level, game area size) examined on the 'Family' mode. Only two variables were found to explain the number of stations completed in 6.3% of the cases, with the size of the game area being the first variable to enter the calculation (Beta = –0.265) and the game instructions being the second variable to enter the calculation (Beta = 0.164). Station order variables and narrative depth levels were not included in the model.

6.7 Research question 7

We conducted a Linear Stepwise Regression Analysis in order to ascertain whether the number of stations completed can be predicted using the variables (assistance level, age of participants, competition, narrative depth level, game area size) examined on the 'Group' mode. Based on the analysis, three variables explained 19.8% of the variation in the number of stations completed: the accompaniment level, the participants' age and the playing area size, with the accompaniment level being the first variable entered into the calculation (Beta = –0.700). The second variable was the participants' age (Beta = 0.291) and the third was the size of the game area (Beta = –0.403). Competition and narrative depth were not included in the model.

7 Discussion and conclusions

For several decades, research has shown that learning games have tremendous educational potential [1, 26]. Recently, researchers have begun to isolate specific game elements and study their impact on players motivation and learning [37, 41, 44, 45,

46, 54]. This study is a direct result of such trends. Our objective was to examine the participants' performances and the game components in order to better understand the elements of the game and their effect on motivation. We explored these issues using Big Data that included the completion rates of thousands of participants, collected over 5 years, from nine learning games offered to museum visitors. According to our results, some of these gameplay elements had a large and significant impact, while some only had only minor impact.

7.1 Game mode

According to our analysis, players playing in the 'Multi-player' mode completed a higher number of stations than the 'Family' mode players, and in the multivariate analysis, the variable predicted (albeit weakly) the performance of the participants. These findings fit to our observations in the museum, but unfortunately, we were unable to determine, based on the data available, the cause behind it. This issue can be examined in future research.

7.2 Instructions and assistance

We found that the addition of video clip to the opening instructions improved participants' performance and that this variable was found as a predictor in the 'Family' mode in the multivariate analysis. These results are in line with the findings of Liao et al. [61] who found that the use of video instruction improved participants' achievement in a digital learning game. Note, however, the effect of opening instructions did not significantly contribute to the analysis of the factors predicting participants' performance using a multivariate analysis. In addition, and contrary to the results of Chen and Law [50], our analysis showed that people who received remote assistance completed a significantly higher (almost double) number of stations, and that this variable was the strongest predictor of the results for 'Group' mode participants. Based on our observations of game players, we suspect that the distance supervision led to a sense of freedom, higher motivation, and better performance.

7.3 Competition

Competition was found to not be a predictor for the players' performance. Our findings are interesting in the light of Van Eck and Dempsey [62] research, who showed a connection between assistance and competition. Sadly, our data prevented us from comparing our results to those of Van Eck and Dempsey [62], but our findings regarding the effectiveness of remote assistance (compared to close assistance) suggest a similar direction.

7.4 Narrative

Our finding showed that narrative was not a predictor for 'Family' mode. Another variable we looked at was the depth of the narrative. The multivariate calculation,

however, found that the narrative depth parameter predicted participants' performance. When we examined this parameter separately in the 'Family' and 'Group' mode, we found that stronger narrative depths had a slight positive effect on participants' performances. We emphasize, however, that the effect was small.

7.5 Size of the gaming area

Our analysis revealed that there was no significant impact of the variable on the number of stations completed by the participants, nor on the prediction of performance. However, when we analyzed the effect of the variable on the 'Family' and 'Group' mode, we found that the size of the area had a weak (but significant) effect on the stations completed by participants (which indicated that a larger game area, and therefore a greater challenge level by our definition, would result in fewer completed stations). Furthermore, the multivariate test showed that the size of the game area plays a key role in predicting the performance of the participants in the game, especially in a 'Family' mode. We hypothesize (based on observations and conversations with participants) that larger area sizes were hard to participants (walking times, difficulty navigating, and longer playing time) and consequently led to a slower pace and even abandonment of the game. There is widespread agreement that a challenge must be suitable to a participant's abilities and not take too long to complete [2, 63]. In that sense, our large area games were probably too difficult and lead to weaker game performance.

7.6 Age of the participants

According to our study findings, as participants' ages increased, they completed more stations, and this factor predicted participant performance in the 'Group' mode. This conclusion agrees with that presented by Erfani and others [57], who showed that older children exhibited superior performance. Nevertheless, this result may raise some questions. In general, it is accepted that children and educational games generate more successful outcomes compared to adults [17, 18, 45] and our findings may require further research.

In summary, the findings of this study are in agreement with many previous studies mentioned above and many others. We would like to emphasize that we chose to study the activity of players in educational games based on a relatively innovative methodology, based solely on information collected automatically. This methodology allowed us to conduct causal (rather than correlative) research, as is often the case in perception studies. This data, collected from an automated system that documented players' performance, allowed us to investigate the impact of various instructional and gameplay elements, in a way that attempts to clarify the impact of participants' perceptions on outcomes, and to examine their performance objectively. Hopefully, this study will help game developers and educators better understand the components of learning-learning experiences by increasing our understanding of learning games. This will surely result in better activities for active participation, enjoyment, learning, and a fascinating experience. Finally, we note that our findings and observations suggest that there are many nuances in player behavior that require further research. Also, we examined all nine games in this study as a whole. Further research should examine each of these games separately.

8 References

[1] M. Prensky, *Digital game-based learning*. New York: McGraw-Hill, 2001.

[2] BECTa, "Computer games in education project," *becta.org.uk*, [Online]. Available: https://cibermemo.files.wordpress.com/2015/12/edujoc2004.pdf [Accessed March 13, 2022].

[3] T. Malone, What makes things fun to learn? A study of intrinsically motivating computer games, cognitive and instructional sciences series. California: Xerox, Palo Alto Research Center, 1980. https://doi.org/10.1145/800088.802839

[4] S. S. VanDeventer and J. A. White, "Expert behavior in children's video game play," *Simulation and Gaming*, vol. 33, no. 1, pp. 28–48, 2002. https://doi.org/10.1177/1046878102033001002

[5] A. K. Kamboj and S. G. Krishna, "Pokémon GO: An innovative smartphone gaming application with health benefits," *Primary Care Diabetes*, vol. 11, no. 4, pp. 397–399, 2017. https://doi.org/10.1016/j.pcd.2017.03.008

[6] Z. E. Page, S. Barrington, J. Edwards, and L. M. Barnett, "Do active video games benefit the motor skill development of non-typically developing children and adolescents: A systematic review," *Journal of Science and Medicine in Sport*, vol. 20, no. 12, pp. 1087–1100, 2017. https://doi.org/10.1016/j.jsams.2017.05.001

[7] M. Birk, G. Wadley, V. Abeele, R. Mandryk, and J. Torous, "Video games for mental health," *Interactions*, vol, 26, no. 4, pp. 32–36, 2019. https://doi.org/10.1145/3328483

[8] S. De Sousa Borges, V, Durelli, H. Reis, and S. Isotani, "A systematic mapping on gamification applied to education," *Proceedings of the 29th Annual ACM Symposium on Applied Computing*, pp. 216–222, 2014. https://doi.org/10.1145/2554850.2554956

[9] E. S. Quellmalz, M. J. Timms, and S. A. Schneider, "Assessment of student learning in science simulations and games," Paper Commissioned for the Committee on the Learning Science: Computer Games, Simulations, and Education of the National Academics Board of Science Education. Available: Academia, https://www.academia.edu/15333866/Assessment_of_Student_Learning_in_Science_Simulations_and_Games [Accessed March 13, 2022].

[10] K. E. Chang, L. J. Wu, S. E. Weng and Y. T. Sung, "Embedding game-based problem-solving phase into problem-posing system for mathematics learning," *Computers & Education*, vol. 58, no. 2, pp. 775–786, 2012. https://doi.org/10.1016/j.compedu.2011.10.002

[11] L. Da Rocha Seixas, A. S. Gomes, and I. J. de Melo Filho, "Effectiveness of gamification in the engagement of students, "*Computers in Human Behavior*, vol. 58, pp. 48–63, 2016. https://doi.org/10.1016/j.chb.2015.11.021

[12] T. M. Connolly, E. A. Boyle, E. MacArthur, T. Hainey, and J. M. Boyle, "A systematic literature review of empirical evidence on computer games and serious games," *Computers & Education*, vol. 59, no. 2, pp. 661–686, 2012. https://doi.org/10.1016/j.compedu.2012.03.004

[13] C. H. Su and C. H. Cheng, "A mobile gamification learning system for improving the learning motivation and achievements," *Journal of Computer Assisted Learning*, vol. 31, no. 3, pp. 268–286, 2015. https://doi.org/10.1111/jcal.12088

[14] I. Yildirim, "The effects of gamification-based teaching practices on student achievement and students' attitudes toward lessons," *The Internet and Higher Education*, vol. 33, pp. 86–92, 2017. https://doi.org/10.1016/j.iheduc.2017.02.002

[15] T. Sitzmann, "A meta-analytic examination of the instructional effectiveness of computer-based simulation games," *Personnel psychology*, vol. 64, no. 2, pp. 489–528, 2011. https://doi.org/10.1111/j.1744-6570.2011.01190.x

[16] P. Wouters, C. Van Nimwegen, H. Van Oostendorp, and E. D. Van Der Spek, "A meta-analysis of the cognitive and motivational effects of serious games," *Journal of educational psychology*, vol. 105, no. 2, pp. 249–265, 2013. https://doi.org/10.1037/a0031311

[17] U. Tokac, E. Novak, and C. G. Thompson, "Effects of game-based learning on students' mathematics achievement: A meta-analysis," *Journal of Computer Assisted Learning*, vol. 35, no. 3, pp. 407–420, 2019. https://doi.org/10.1111/jcal.12347

[18] R. L. Lamb, L. Annetta, J. Firestone, and E. Etopio, "A meta-analysis with examination of moderators of student cognition, affect, and learning outcomes while using serious educational games, serious games, and simulations," *Computers in Human Behavior*, vol. 80, pp. 158–167, 2018. https://doi.org/10.1016/j.chb.2017.10.040

[19] D. Dicheva, C. Dichev, G. Agre, and G. Angelova, "Gamification in education: A systematic mapping study," *Educational Technology & Society*, vol. 18, no. 3, pp. 75–88, 2015.

[20] J. Byun and E. Joung, "Digital game-based learning for K–12 mathematics education: A meta-analysis," *School Science and Mathematics*, vol. 118, no. 3–4, pp. 113–126, 2018. https://doi.org/10.1111/ssm.12271

[21] E. O. Acquah and H. T. Katz, "Digital game-based L2 learning outcomes for primary through high-school students: A systematic literature review," *Computers & Education*, vol. 143, pp. 103667, 2020. https://doi.org/10.1016/j.compedu.2019.103667

[22] I. Iacovides and A. Cox, "Moving beyond fun: Evaluating serious experience in digital games," In Proc. of the 33rd Annual ACM Conference on Human Factors in Computing Systems, pp. 2245–2254, 2015. https://doi.org/10.1145/2702123.2702204

[23] D. Davidson, *Beyond fun: Serious games and media*. Pittsburgh, PA: ETC Press, 2008.

[24] R. Van Roy and B. Zaman, "Need-supporting gamification in education: An assessment of motivational effects over time," *Computers & Education*, vol. 127, pp. 283–297, 2018. https://doi.org/10.1016/j.compedu.2018.08.018

[25] M. D. Hanus and J. Fox, "Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance," *Computers & Education*, vol. 80, pp. 152–161, 2015. https://doi.org/10.1016/j.compedu.2014.08.019

[26] G. Barata, S. Gama, J. Jorge, and D. Goncalves, "Engaging engineering students with gamification," In 2013 5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES), pp. 1–8, 2013. https://doi.org/10.1109/VS-GAMES.2013.6624228

[27] P. Sweetser and P. Wyeth, "GameFlow: A model for evaluating player enjoyment in games," *Computers in Entertainment (CIE)*, vol. 3, no. 3, pp. 1–24, 2005. https://doi.org/10.1145/1077246.1077253

[28] A. McMahan, "Immersion, engagement, and presence: A method for analyzing 3-D video games" In The Video Game Theory Reader, M. Wolf and B. Perron, Eds. New York: Routledge, pp. 67–86, 2003.

[29] H. Schoenau-Fog, "The player engagement process - An exploration of continuation desire in digital games," In Proc. of Think Design Play - 5th International DiGRA Conference, pp. 14–17, 2011.

[30] M. Cheng, Y. Lin, H. She, and P. Kuo, "Is immersion of any value? Whether, and to what extent, game immersion experience during serious gaming affects science learning," *British Journal of Educational Technology*, vol. 48, no. 2, pp. 246–263, 2017. https://doi.org/10.1111/bjet.12386

[31] R. Garris, R. Ahlers, and J. E. Driskell, "Games, motivation, and learning: A research and practice model," *Simulation & gaming*, vol. 33, no. 4, pp. 441–467, 2002. https://doi.org/10.1177/1046878102238607

[32] J. P. Gee, *What video games have to teach us about learning and literacy (Revised and updated edition)*. New York, N.Y: Palgrave Macmillan, 2014.

[33] J. Hamari and J. Koivisto, "Why do people use gamification services?," *International Journal of Information Management*, vol. 35, no. 4, pp. 419–431, 2015. https://doi.org/10.1016/j.ijinfomgt.2015.04.006

[34] C. Y. Hung, J. C. Y Sun, and P. T. Yu, "The benefits of a challenge: Student motivation and flow experience in tablet-PC-game-based learning," *Interactive Learning Environments: Learning Technologies and Learning Environments*, vol. 23, no. 2, pp. 172–190, 2015. https://doi.org/10.1080/10494820.2014.997248

[35] D. B. Clark, E. E. Tanner-Smith, and S. S. Killingsworth, "Digital games, design, and learning: A systematic review and meta-analysis," *Review of educational research*, vol. 86, no. 1, pp. 79–122, 2016. https://doi.org/10.3102/0034654315582065

[36] K. F. Hew, B. Huang, K. W. S. Chu, and D. K. Chiu, "Engaging Asian students through game mechanics: Findings from two experiment studies," *Computers & Education*, vol. 92, pp. 221–236, 2016. https://doi.org/10.1016/j.compedu.2015.10.010

[37] M. Sailer, J. U. Hense, S. K. Mayr, and H. Mandl, "How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction," *Computers in Human Behavior*, vol. 69, pp. 371–380, 2017. https://doi.org/10.1016/j.chb.2016.12.033

[38] E. G. Cohen, "Restructuring the classroom: Conditions for productive small groups. Review of educational research," vol. 64, no. 1, pp. 1–35, 1994. https://doi.org/10.3102/00346543064001001

[39] D. W. Johnson and R. T. Johnson, "Learning together and alone: Overview and meta-analysis," *Asia Pacific Journal of Education*, vol. 22, no. 1, pp. 95–105, 2002. https://doi.org/10.1080/0218879020220110

[40] J. Trespalacios, B. Chamberlin, and R. R. Gallagher, "Collaboration, engagement & fun: How youth preferences in video gaming can inform 21st century education," *TechTrends*, vol. 55, no. 6, pp. 49–54, 2011. https://doi.org/10.1007/s11528-011-0541-5

[41] S. Vandercruysse, M. Vandewaetere, F. Cornillie, and G. Clarebout, "Competition and students' perceptions in a game-based language learning environment," *Educational Technology Research and Development*, vol. 61, no. 6, pp. 927–950, 2013. https://doi.org/10.1007/s11423-013-9314-5

[42] H. Werbach and D. Hunter, *For the win: How game thinking can revolutionize your business*. Philadelphia: Wharton digital press, 2012.

[43] T. Aldemir, B. Celik, and G. Kaplan, "A qualitative investigation of student perceptions of game elements in a gamified course," *Computers in Human Behavior*, vol. 78, pp. 235–254, 2017. https://doi.org/10.1016/j.chb.2017.10.001

[44] C. Brom, M. Buchtová, V. Šisler, F. Děchtěrenko, R. Palme, and L. M. Glenk, "Flow, social interaction anxiety and salivary cortisol responses in serious games: A quasi-experimental study," *Computers & Education*, vol. 79, pp. 69–100, 2014. https://doi.org/10.1016/j.compedu.2014.07.001

[45] C. H. Chen, C. C. Shih, and V. Law, "The effects of competition in digital gamebased learning (DGBL): A meta-analysis," *Educational Technology Research and Development*, vol. 68, no. 4, pp. 1855–1873, 2020. https://doi.org/10.1007/s11423-020-09794-1

[46] C. Jemmali, S. Bunian, A. Mambretti, and M. S. El-Nasr, "Educational game design: An empirical study of the effects of narrative," In Proc. of the 13th International Conference on the Foundations of Digital Games, pp. 1–10, 2018. https://doi.org/10.1145/3235765.3235783

[47] C. Hébert and J. Jenson, "Digital game-based pedagogies: Developing teaching strategies for game-based learning," *Journal of Interactive Technology and Pedagogy,* no. 15, May 16, 2019. [Online], Available: https://jitp.commons.gc.cuny.edu/digital-game-based-pedagogies-developing-teaching-strategies-for-game-based-learning [Accessed March 14, 2022].

[48] J. C. Huizenga, "Digital game-based learning in secondary education," Doctoral Dissertation, University of Amsterdam, Netherlands, 2017.

[49] B. Marklund and A. S. Taylor, "Teachers' many roles in game-based learning projects," In European Conference on Games Based Learning, pp. 359–367, 2015.

[50] C. H. Chen and V. Law, "Scaffolding individual and collaborative game-based learning in learning performance and intrinsic motivation," *Computers in Human Behavior*, vol. 55, pp. 1201–1212, 2016. https://doi.org/10.1016/j.chb.2015.03.010

[51] A. B. Hernández, M. T. Gorjup, and R. Cascón, "The role of the instructor in business games: A comparison of face-to-face and online instruction," *International Journal of Training and Development*, vol. 14, no. 3, pp. 169–179, 2010. https://doi.org/10.1111/j.1468-2419.2010.00350.x

[52] V. Garneli, M. Giannakos, and K. Chorianopoulos, "Serious games as a malleable learning medium: The effects of narrative, gameplay, and making on students' performance and attitudes," *British Journal of Educational Technology*, vol. 48, no. 3, pp. 842–859, 2017. https://doi.org/10.1111/bjet.12455

[53] I. A. Malegiannaki, T. Daradoumis, and S. Retalis, "Teaching cultural heritage through a narrative-based game," *Journal on Computing and Cultural Heritage (JOCCH)*, vol. 13, no. 4, pp. 1–28, 2020. https://doi.org/10.1145/3414833

[54] N. E. Cagiltay, E. Ozcelik, and N. S. Ozcelik, "The effect of competition on learning in games," *Computers & Education*, vol. 87, pp. 35–41, 2015. https://doi.org/10.1016/j.compedu.2015.04.001

[55] F. Cornillie, G. Clarebout, and P. Desmet, "Between learning and playing? Exploring learners' perceptions of corrective feedback in an immersive game for English pragmatics," *ReCALL*, vol. 24, no. 3, pp. 257–278, 2012. https://doi.org/10.1017/S0958344012000146

[56] M. Csikszentmihalyi, *Flow: The psychology of optimal experience*. New York: Harper Perennial, 1991.

[57] M. Erfani, M. S. El-Nasr, D, Milam, B. Aghabeigi, B. A. Lameman, B. E. Riecke, … and S. Mah, "The effect of age, gender, and previous gaming experience on game play performance," In IFIP Human-Computer Interaction Symposium, pp. 293–296, 2010. https://doi.org/10.1007/978-3-642-15231-3_33

[58] R. Homer, K. F. Hew, and C. Y. Tan, "Comparing digital badges-and-points with classroom token systems: Eeffects on elementary school ESL students' classroom behavior and English learning," *Educational Technology & Society*, vol. 21, no. 1, pp. 137–151, 2018.

[59] J. J. Vogel, D. S. Vogel, J. Cannon-Bowers, C. A. Bowers, K. Muse, and M. Wright, "Computer gaming and interactive simulations for learning: A meta-analysis," *Journal of Educational Computing Research*, vol. 34, no. 3, pp. 229–243, 2006. https://doi.org/10.2190/FLHV-K4WA-WPVQ-H0YM

[60] A. Hershkovitz and G. Alexandron, "Understanding the potential and challenges of big data in schools and education," *Tendencias pedagógicas*, vol. 35, pp. 7–17, 2020. https://doi.org/10.15366/tp2020.35.002

[61] C. W. Liao, C. H. Chen, and S. J. Shih, "The interactivity of video and collaboration for learning achievement, intrinsic motivation, cognitive load, and behavior patterns in a digital game-based learning environment," *Computers & Education*, vol. 133, pp. 43–55, 2019. https://doi.org/10.1016/j.compedu.2019.01.013

[62] R. Van Eck and J. V. Dempsey, "The effect of competition and contextualized advisement on the transfer of mathematics skills in a computer-based instructional simulation game," *Educational Technology Research & Development*, vol. 50, no. 3, pp. 23–41, 2002. https://doi.org/10.1007/BF02505023

[63] A. Denisova and P. Cairns, "Adaptation in digital games: The effect of challenge adjustment on player performance and experience," In Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play, pp. 97–101, 2015. https://doi.org/10.1145/2793107.2793141

9 Authors

Inbal Leuchter graduated with a B.A. in Archeology. She holds two M.A. degrees. one in Art History with a focus on Curation, and one in Instructional Technologies. As a training specialist, she has worked in schools, museums, universities, and now in the tech industry. On a more personal note, her life has been filled with games, and she indulges in them wherever she is and whatever she does. (email: inballeuchter@gmail.com).

Gila Kurtz (Ph.D.) is currently the Dean of the Instructional Technologies faculty at Holon Institute of Technology (HIT) in Israel. For several years she was the Academic VP a company that provided e-Learning solutions for the corporate industry. Other positions: a member of the Steering Committee of the European Distance and E-Learning Network (EDEN) and the Editor-in-Chief of The Interdisciplinary Journal of E-Skills and Lifelong Learning (IJELL). She has been a visiting scholar at the University of Maryland University College, University of California Berkeley, Syracuse University and University Roma, TRE. Her main research interests are in the use of innovative technologies in training and learning. (email: Gilaku@hit.ac.il).

This is a revised and extended version of a presentation given at The Learning Ideas Conference 2022, held in New York and online June 15–17, 2022. Article submitted 2022-03-14. Resubmitted 2022-07-10. Final acceptance 2022-10-19. Final version published as submitted by the authors.