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Fun to Enhance Learning, Motivation, Self-efficacy, and Intention to Play in DGBL

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Abstract. Digital Game-Based Learning (DGBL) has been attracting increasing attention from researchers and educators, especially as related studies suggest it can enhance learning and positively affect students' motivation, attitude, self-efficacy, and intention to play similar games. However, research into DGBL is not explicit about the role of fun in DGBL. In our study we hypothesized that the perceived fun while playing with an educational game has a positive impact on children's measured- and perceived learning, motivation, attitude, self-efficacy and intention to play similar games. We conducted an online survey study with secondary school students (N = 28, mean age = 13.54) before and after playing with an online educational game on the topic of biology. The results indicate that the fun they experience while playing the game has a significant and positive effect on the perceived learning, the change in students' motivation and self-efficacy, and the intention to play similar games. However, no significant effect was found on the measured learning and the change in attitude towards the subject. Our findings partially support the contention that making DGBL more fun improves learning. Future research should seek further empirical evidence in other topic areas and for different ages, and to explore how DGBL can help improve attitudes towards the topic as well.

Keywords: Digital Game-based Learning, Educational Game, Fun, Motivation, Attitude, Self-efficacy, Intention, Biology.

1 Introduction

Digital learning games have gained popularity [1] due to the increased availability of computer and multimedia technologies at schools. A recent systematic review by Hainey et al [2] indicated that digital game-based learning (DGBL) has been widely applied to various topics in science, mathematics, languages, social issues, history, and music. There is a growing body of empirical evidence showing that DGBL enhances students' learning [3], [4] and their motivation to learn [5]–[8]. Additionally, DGBL is associated with increased self-efficacy [5], [9]–[12], increased attitude toward the subject [10], [13] and increased intention to play learning games in the future [14].

Teaching with digital games builds on the idea that learning with digital games resembles the leisure time that people spend playing video games: it is fun and

intrinsically motivating [15]. Accordingly, in DGBL literature the assumption that educational games are fun is rarely doubted or verified through measurement. As follows, empirical research with measured entities is scarce on the possible effects on fun in DGBL, and often contradictory. For example, Sim, MacFarlane and Read [16] found that the fun seven and eight years-old children experienced while learning with a digital game was not correlated with learning. Iten and Petko [17] reported similar results with primary school children: their regression analysis revealed that the enjoyment of the game is not associated with the self-reported learning, nor to the measured learning. However, a meta-analysis on computer games as learning tools [18] and a literature review on game-based learning suggested a direct link between learning and enjoyment [4]. Additional to the aforementioned findings, previous research on serious games pointed out that children's interest to engage with similar subjects increased according to the perceived enjoyment, and that children's intention to use similar games was significantly influenced by their attitude (anticipated simplicity and usefulness) toward the game [17]. Given the wide interest in this topic, the empirical research on the role fun plays in DGBL is quite limited and the results are inconclusive.

In this study, we set out to investigate how the experienced fun while playing a digital game influences students' learning, motivation, attitude, self-efficacy, and intention to play similar games. We recruited secondary school students to play a biology educational game - Code Fred: Survival Mode. Before and after playing the game, we administered a knowledge assessment test, students' motivation, attitude, and self-efficacy, and after playing the game we additionally measured students' perceived learning, intention to play similar games and we asked them to report on the fun they have experienced while playing. In the following sections of the paper we introduce related research, followed by the study methods, results and the discussion of the herein introduced findings.

2 Related Research

2.1 Digital game-based learning

Digital game-based learning (DGBL) is a recently emerged term that refers to acquiring knowledge and skills through playing engaging computer games [19]. It is frequently used interchangeably with other terms such as educational games, learning games, serious games, and edutainment. Throughout the paper we use the term DGBL, and we refer to games as educational games.

Nowadays, educational games are being used across a wide range of subjects. In a recent literature review Boyle et al. [3] found that science, technology, engineering, and mathematics (STEM) are the most popular subject disciplines where DGBL is applied. This confirms earlier studies [2], [4], [20] and is of particular relevance as STEM abilities are seen as crucial for future development of oneself as well as the society [21].

2.2 Fun in DGBL

In this paper we operationalize fun based on the work of Tisza and Markopoulos [48]. Accordingly, any learning activity, including game-based learning is fun when one is intrinsically motivated for participation, feels in control of the activity, immersed in the experience by losing sense of time and space, the level of skills meets the level of challenge, the activity evokes positive and not negative emotions, and it supports the abandonment of social inhibitions.

It is often assumed that DGBL is fun. However, Yee [22] argued that educational games require players to do many tasks, making students feel tired and tedious. In other cases educational games were found to take too long and were no longer fun to play after the novelty effect was gone [23].

The effect of fun on learning with digital games is more controversial. Some studies found a positive association [4] and others no relation at all [16], [17]. Long [24] reported on a game for learning to program from which 80% of the study participants learnt something, while Sim, MacFarlane and Read [16] examined three educational applications for young children and reported no significant correlation between the observed or the reported fun and students' learning. When an educational game reaches its purpose and it is indeed fun to play with then the perceived enjoyment of the game motivates students to continue learning about the subject taught in the game [17] and increases students' attitude about the subject [17]. Additionally, previous research found that a higher level of game enjoyment is correlated with a higher motivation to learn [17]. However, the same article [17] reported that the enjoyment of the game had no influence on students' intention to play again, despite other studies suggesting the opposite [16]. There appears to have been no prior studies examining the possible relationship between fun in DGBL and self-efficacy.

2.3 Learning in DGBL

As mobile technology advances, digital games are no more bound to desktop computers and video consoles and can be played at different locations and times of the day [3], [25], [26]. Learners are having ample opportunities to play digital games, which has spawned the interest in their potential benefits regarding knowledge and skill acquisition, but also their affective, motivational, perceptual, physiological and cognitive outcomes [3], [4]. Research in DGBL has mostly focused on learning outcomes [3], [4], [27]. Empirical findings to date are divided. Some studies indicate that digital games are suitable for learning purposes for varied subjects including math, science, biology and psychology [3], [4], [20], [24], [28]–[30], while other studies report an adverse effect of digital games on learning [31]–[33]. For the assessment of learning in DGBL, researchers use either knowledge tests [15], [34]–[37] or measure learning based on the learners' self-report [17], [38].

2.4 Motivation, Attitude, Self-efficacy, and Intention to Play in DGBL

DGBL can enhance motivation to acquire certain knowledge [39], [40], which is a key element of successful learning [41]. Tüzün et al. [42] found that primary school students had a significantly higher intrinsic motivation and lower extrinsic motivation in a geography DGBL environment as compared to their motivation in the traditional school context. Others reported that students' motivation for mathematics was significantly higher for students learning in a mathematical game-based learning environment in comparison to a control group [5]. Such a positive relationship between students' learning motivation and DGBL is further supported by other studies [6]–[8]. On the other hand, Huizenga, Admiraal, Akkerman, and Dam [35] reported no significant differences in motivation between children learning in a DGBL and those in control groups.

Earlier research demonstrated that learning in DGBL can improve participants' attitude toward the subject [10], [13], [17]. Iten and Petko [17] found that the more children enjoy playing a DGBL the more they get interested in the subject matter. Akinsola and Animasahun [13] also found that students' achievement and positive attitude toward mathematics can be improved by the use of simulation-games environments. Sung and Huwang [10] developed a mindtool-integrated collaborative educational game, which was found to promote students' learning related attitudes.

Self-efficacy refers to students' perceptions and beliefs about their academic capabilities [43], and was found to be an effective predictor of academic motivation and achievements [44]. Hun, Huang, and Hwang [45] reported that students gained more self-efficacy in a mathematical game-based e-book learning environment compared with traditional instruction methods. Afari, Aldridge, Fraser, and Khine [12] measured students' academic efficacy before and after playing a mathematics game, and reported a significant improvement. Meluso, Zheng, Spires, and Lester [9] also suggested that after playing an educational game students demonstrated an increase in self-efficacy toward science.

Another study investigating serious games [17] reported that the anticipated usefulness and the anticipated simplicity of the learning game - which they labeled as attitude - are significant and positive predictors of the intention to play similar games. This is in accordance with Çankaya and Karamete [46] who found that DGBL had a positive influence on participants' intention to play the game again and with Rambli, Matcha and Sulaiman [47] who reported on children's strong willingness to play again with an augmented reality learning game.

The contradictory results of previous research on the effect of fun in DGBL may be attributed to inconsistent conceptions and measurement of fun and enjoyment in earlier studies. For many of the studies reported above, the notion of enjoyment and fun are left implicit [16], [17], [24]. Additionally, some of them used measures that may lack a theoretical basis, and consist of a single item [16], [24] where the predictive validity is questionable. Others used informal observations [16], which are not sufficient in conceptualizing and quantifying the role of fun in DGBL. The only study that comes close is that of Iten and Petko [17], however, despite using multi-item measures, they did not provide a clear definition of fun, which they use interchangeably with

enjoyment. Nevertheless, they questioned the role of fun in serious games and called for research to investigate possible aspects of engagement from different angles.

2.5 Hypotheses

To address the apparent gap in earlier research regarding the potential benefits of DGBL we conducted a study aiming to understand how fun can impact students' learning, motivation, attitude, self-efficacy, and intention to play similar games in DGBL.

Accordingly, we hypothesized that:

- H1: The experienced fun during DGBL positively affects students' reported learning.
- H2: The experienced fun during DGBL positively affects students' measured learning.
- H3: The experienced fun during DGBL positively affects students' motivation.
- H4: The experienced fun during DGBL positively affects students' attitude.
- H5: The experienced fun during DGBL positively affects students' self-efficacy.
- H6: The experienced fun during DGBL positively affects students' intention to play similar games.

3 Methods

3.1 Participants

We recruited students from a Dutch bilingual secondary school. Our selection criteria were to have a good level of English comprehension and to be between age 13 and 14. The study was approved by the Ethical Board of Eindhoven University of Technology, Department of Industrial Design and informed consent was obtained from the participants and their parents before the study took place. In total, 28 of the second-year students participated in the study (12 boys, 16 girls, mean age = 13.54, SD = 0.508).

3.2 Procedure

The study took place in the spring of 2020. Since all formal educational activities took place online due to the COVID19 pandemic, participants took part in this study (i.e. played the game and responded the questionnaires) in an online classroom setting instead of the traditional physical environment. All students had access to laptops and had experience with using laptops to follow online lessons. Before the study started, the students were informed about the procedures by the teacher and informed consent was obtained. At the beginning of the lesson, students received a step-by-step guide to follow. This instructional document introduced the steps to take during the lesson and provided links to the questionnaires and the game. Throughout the lesson all participants were present in an online group meeting, so whenever a question or a problem emerged, students could ask help directly from the researcher and the teacher.

The study consisted of three sections: the pre-game data collection followed by playing the game Code Fred: Survival Mode, and the post-game data collection. Responding to the questionnaires before and after the game took approximately 7

minutes each. Students had approximately 25 minutes to complete the game. Ten minutes before the end of the lesson we asked students to stop playing the game - if they were still busy at that time - and do the post-game questionnaire.

3.3 Measures

To assess the interaction between the experienced fun and students' learning, motivation, attitude, self-efficacy, and intention to play similar games, we adopted validated measures and collected data from the study participants before and after playing the game. The pre-game questionnaire investigated students' motivation, attitude, and self-efficacy, along with a knowledge assessment test for the measured learning. The post-game questionnaire additionally investigated students' self-reported (i.e. perceived) learning, the fun they have experienced during playing the game and their intention to play similar games. The used measures, their operational definition, the items we used, and their respective sources are presented in Table 3 in the Appendix.

For the assessment of fun we used FunQ [48]. FunQ is a recently developed theoretically founded and validated questionnaire that specifically assesses adolescents' perceived fun. In our study, we excluded three items referring to social interactions given that participants played the game alone. Accordingly, participants rated their agreement on a 5-point scale (1 - Strongly disagree; 5 - Strongly agree) along fifteen items.

According to Bloom's taxonomy [51], six levels of learning can be distinguished. In this study we addressed two levels by collecting data on knowledge acquisition (*Knowledge*) and perceived learning (*Evaluation*). For the assessment of knowledge acquisition, we designed a test consisting of six multiple choice, single selection questions. The six test questions refer to six chapters of the game by asking about the knowledge and the related task to save Fred. For example, in chapter one the message appears on the screen "Danger is detected. Send adrenaline to these organs to escape: eye, hearth, liver". In the knowledge test we ask students the following: When your body detects danger, it reacts by sending adrenalin to the following body parts to escape EXCEPT: eyes / lungs / liver / brain. To gain a point, students must select the correct response (lungs). For each question participants could gain one point, resulting in a maximum of six points. We used the difference between the pre-game and the post-game scores as an indication of learning (i.e. measured learning).

The perceived learning was measured by a single item measure adopted from previous research [52], [53]. Participants were asked 'Have you learned something new today about biology?' and they could indicate their agreement on a 5-point scale (1- Not at all; 5 - A whole lot).

To evaluate students' attitude toward biology, we adapted three items from the Motivated Strategies for Learning Questionnaire [54]. During adaptation we slightly changed the original items to fit better the study purpose (e.g. instead of 'It is important for me to learn the course material in this class.' we used 'It is important for me to learn what's taught in the biology class.' as we were interested in students' general attitude toward biology classes, not the specific gamified class we conducted for the study).

Students indicated their agreement with the items on a 5-point Likert scale (1 - Strongly disagree; 5 - Strongly agree).

For the assessment of students' motivation toward biology we adapted three items from the Attitudes toward Mathematics Inventory [55]. During the adaptation we exchanged the word 'mathematics' into 'biology' to fit the study purpose (e.g., original item: 'I am willing to take more than the required amount of mathematics'; adapted item: 'I am willing to take more than the required amount of biology'). Students rated their agreement with the items on a 5-point scale (1 - Strongly disagree; 5 - Strongly agree).

For the measurement of students' self-efficacy, we adapted three items from the Motivated Strategies for Learning Questionnaire [54] to have the focus on biology classes in general and not the gamified learning setup applied for the study (e.g., original item: 'I expect to do well in this class.'; adapted item: 'I expect to do well in biology class'). Students were asked to indicate on a 5-point scale their agreement with the items (1 - Strongly disagree; 5 - Strongly agree).

To address students' intention to play similar games we adapted three items from the Motivated Strategies for Learning Questionnaire [54], which were evaluated on a 5-point scale (1 - Strongly disagree; 5 - Strongly agree). For this dimension, we used original items that indicate task value and extended it to become a reasoning for playing similar games again (e.g., original item: 'I think the course material in this class is useful for me to learn.'; adapted item: 'I want to do similar activities in my biology classes because I think these kinds of activities are useful').

Cronbach's alpha values indicate a good internal consistency for all used scales (see Appendix).

3.4 The Game

To test these hypotheses, we asked children to play Code Fred: Survival Mode (see Figure 1). In choosing the game we had several requirements:

- The subject covered is equally suited for boys and girls. Research has shown that among STEM subjects, biology is most equally appealing for both genders [49], [50].
- The length of a game session is suitable for classroom use, taking no longer than 30 minutes.
- The game covers a certain topic sufficiently, so that knowledge acquisition can be measured meaningfully.

- The game is fun and educative and aligns well with participants' knowledge and curriculum.

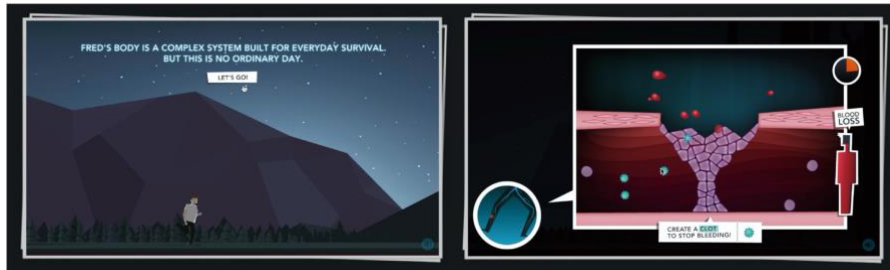


Fig. 1. Screenshots of Code Fred: Survival Mode. Left: opening scene. Right: episode 5 – gather elements from across the body to quickly heal the wound.

The game is developed by the Museum of Science + Industry Chicago and it teaches the player about the human body. The player leads the injured Fred through twelve episodes, e.g., to get oxygen to the muscles, to stop bleeding, to heal a wound, to inspect and disable bacteria, and to maintain a stable blood sugar level. The game is completed when the player completes all twelve episodes and brings Fred safely back to his camp. The game takes about 25 minutes, it has a well-defined topic and connects well to the curriculum, and it is fun to play for both boys and girls.

4 Results

To assess the fun experienced during the herein introduced study we calculated the FunQ scores by summing the values after correcting for the values of the reversed items. This resulted in an average score of 51.43, ($SD = 12.04$) from the possible range of 15 – 75, from which we conclude that students had fun while playing the game. Correlation analysis between the FunQ and the item “During the activity, I had fun” indicates a significant correlation ($r = 0.910$, $p < 0.001$), supporting the validity of the aforementioned claim.

Regarding the measured learning, we first calculated the scores for the pre-game and the post-game knowledge assessment tests ($mean_{pre-game} = 2.39$, $SD = 0.96$; $mean_{post-game} = 3.57$, $SD = 1.40$). Independent sample t-test found no gender difference in the knowledge test scores ($p_{pre-game} = 0.781$; $p_{post-game} = 0.266$). Then, we subtracted the pre-game test scores from the post-game scores. This resulted in an average score of 1.18 ($SD = 1.16$) for the measured learning. Paired sample t-test indicates that this difference is significant ($p < 0.001$), thus we conclude that based on the measured learning scored students have learned by playing the game.

To address participants' perception about their learning and test we asked them after playing the game whether they thought they had learned something new about biology.

Students self-rated their learning on average 2.93 (SD = 1.09) on a 5-point scale, which translates to having learnt ‘something’.

To compare students’ reported learning with the measured learning scores we applied correlation analysis. We did not find a significant correlation between the measured and the perceived learning ($r = 0.246$; $p = 0.206$).

The reported average score for students’ motivation at the beginning of the study was 2.64 (SD = 0.81), and it was 2.82 (SD = 1.04) on a 5-point scale after playing the game. We did not find any gender difference (independent sample t-test, $p_{\text{pre-game}} = 0.110$; $p_{\text{post-game}} = 0.865$). The average change in the motivation score is 0.18 (SD = 0.67). Paired sample t-test indicates that the change is not significant ($p = 0.170$).

As for students’ attitude toward biology, the average score at the beginning of the study was 3.60 (SD = 0.80), and it was 3.63 (SD = 1.00) on a 5-point scale after playing with the game. Independent sample t-test indicates no gender difference in the scores ($p_{\text{pre-game}} = 0.708$; $p_{\text{post-game}} = 0.930$). The average change in the attitude toward biology score is 0.04 (SD = 0.53). Paired sample t-test indicates that the change is not significant ($p = 0.725$).

Regarding the self-efficacy, the reported average score at the beginning of the study was 3.58 (SD = 0.49), and it was 3.64 (SD = 0.70) on a 5-point scale after playing with the game. No gender difference was found (independent sample t-test, $p_{\text{pre-game}} = 0.203$; $p_{\text{post-game}} = 0.741$). The average change in the self-efficacy score is 0.06 (SD = 0.58). Paired sample t-test indicates that the change is not significant ($p = 0.592$).

Regarding students’ intention to play similar games, the reported average score at the end of the game was 3.43 (SD = 1.19) on a 5-point scale.

For a summary of the pre- and post-game scores and the related statistics see Table 1.

	Pre-game	Post-game	p	Cohen’s D	Gender difference
Measured learning	mean = 2.39 SD = 0.96	mean = 3.57 SD = 1.40	< 0.001	0.984	$p_{\text{pre}} = 0.781$ $p_{\text{post}} = 0.266$
Motivation	mean = 2.64 SD = 0.81	mean = 2.82 SD = 1.04	0.170	0.192	$p_{\text{pre}} = 0.110$ $p_{\text{post}} = 0.865$
Attitude	mean = 3.60 SD = 0.80	mean = 3.63 SD = 1.00	0.725	0.039	$p_{\text{pre}} = 0.708$ $p_{\text{post}} = 0.930$
Self-efficacy	mean = 3.58 SD = 0.49	mean = 3.64 SD = 0.70	0.592	0.099	$p_{\text{pre}} = 0.203$ $p_{\text{post}} = 0.741$

Table 1. Pre- and post-game mean scores of measured learning, motivation, attitude, self-efficacy, and intention to play. All items were evaluated on a 5-point scale (1 – Strongly disagree; 5 – Strongly agree).

4.1 Fun and Learning

To quantify the effect of fun on the measured learning and test hypothesis 2, we conducted a regression analysis. The analysis reveals that the experienced fun explains 7.1% of the variance in the measured learning scores ($R^2 = 0.071$; $\beta_{\text{std}} = 0.266$, $p =$

0.172). In other words, the effect of the experienced fun on the measured learning is small and non-significant.

To understand how the experienced fun affects the perceived learning and test hypothesis 1, regression analysis was applied. The analysis reveals that the experienced fun explains the 42.4% of the variance in the perceived learning scores ($R^2 = 0.424$; $\beta_{std} = 0.651$, $p < 0.001$). In other words, children who experienced more fun with the game report to have learnt more compared to those who experienced less fun.

4.2 Fun and Motivation

To test hypothesis 3 regarding the effect of fun on students' motivation, a regression analysis was applied. Results indicate that the experienced fun while learning with a digital game explains 21.2% of variance in the motivation change ($R^2 = 0.212$; $\beta_{std} = 0.460$, $p = 0.014$). Thus, having fun while learning significantly contributes to students' increased motivation toward the subject.

4.3 Fun and Attitude

To quantify the effect of fun on students' attitude and to test hypothesis 4, we conducted regression analysis. Results show that 13.4% of the variance in the attitude change is explained by the experienced fun ($R^2 = 0.134$; $\beta_{std} = 0.366$, $p = 0.055$), but this effect is not significant. In other words, having fun while playing a digital learning game does not contribute significantly to students' attitude change.

4.4 Fun and Self-efficacy

To assess the relationship between fun and self-efficacy and to test hypothesis 5, a regression analysis was applied. The analysis indicates that fun accounts for 14.9% of the variance in the self-efficacy change scores ($R^2 = 0.149$; $\beta_{std} = 0.386$, $p = 0.042$). Thus, having fun while playing with an educational game significantly contributes to students' increased self-efficacy.

4.5 Fun and Intention to Play

To test the final hypothesis (H6) regarding the effect of fun on students' intention to play similar games we applied regression analysis. Results show that 70.3 % of the variance in the intention to play similar games scores is explained by the experienced fun ($R^2 = 0.703$, $\beta_{std} = 0.838$, $p < 0.001$). In other words, having fun while learning with a digital game has a considerable impact on students' willingness to play similar games.

For a summary of all regression analysis results see Table 2.

	R²	β_{std}	p
Measured learning	0.071	0.266	0.172
Perceived learning	0.424	0.651	< 0.001
Motivation	0.212	0.460	0.014
Attitude	0.134	0.366	0.055
Self-efficacy	0.149	0.386	0.042
Intention to play	0.703	0.838	< 0.001

Table 2. Summary of the regression analysis results. The effect of fun on students learning, motivation, attitude, self-efficacy, and intention to play.

5 Discussion

Our study investigated the role that fun plays in DGBL, for which earlier research is scarce and results are contradictory. Some researchers found no relationship between fun and learning while playing with an educational game [16], [17], while others [4], [18], [24] report on a significant association between the two. While we did not find a significant relationship between the experienced fun and the measured learning (H2), we did find that the experienced fun while playing a digital learning game has a significant and positive effect on students' perceived learning (H1). Hence, hypothesis 1 is supported and hypothesis 2 is refuted. A possible explanation by Koriat and Bjork [56] is that perceived learning often does not reflect the actual learning achievement since the judgment of learning is influenced by various factors. Furthermore, we suggest that students' perception of their learning might not only refer to factual knowledge but includes other skills that are not part of the knowledge assessment test. Additionally, the two measures address different levels of learning according to Bloom's taxonomy [51], which also explains the discrepancy between the two scores.

As for the effect of fun on students' motivation, our results provide an explanation to previous findings [5]–[8], [39], [40], [42], as we found that having fun while learning with a digital game has a significant and positive influence on students' motivation (H3). Thus our results support hypothesis 3. While previous studies on DGBL found that DGBL enhances students' motivation, they did not investigate from where exactly this relationship derives from. Our findings suggest that experiencing fun while learning with a digital game affects significantly students' motivation, resulting in the previously often found positive effect of DGBL on students' motivation.

Nonetheless, the effect of fun on attitude toward biology was not significant in our study (H4), contrary to an earlier report of a significant effect of fun on students' subject-related attitude [17]. Since research is scarce on this matter, we call on further research to for a thorough understanding.

Our results indicate that having fun while learning with an education game has a significant influence on students' self-efficacy (H5). Thus hypothesis 5 is justified. We propose that this finding refines and explains earlier reports [5], [9], that DGBL enhances students' self-efficacy.

Regarding the effect of the experienced fun while learning with a digital game on students' intention to play similar games in the future (H6), our findings support previous research [16] and concur with the one of Iten and Petko [17] as we found that fun is a strong influencer on students' willingness for engaging with similar games in the future. Accordingly, hypothesis 6 is supported by the results.

In sum, our study supports designers, researchers and educators in making digital game-based learning fun as our research demonstrated a positive effect of fun on students' motivation, self-efficacy and intention to engage with similar games, which are considered as key factors to successful learning. On the other hand, our results also shed light on the underlying effect of fun on the often-found positive association between DGBL and motivation and self-efficacy. Moreover, we provided a possible explanation for the disputed effect of fun on learning. To end with, we encourage both designers and researchers to not take fun granted in DGBL and we call for future research for a better understanding of fun in digital game-based learning.

6 Limitations and Future Work

This study has been conducted as an online class, which is different from the traditional formal learning environment. Nevertheless, since the game was online and students had access to the researcher and their class teacher during the study, we argue that student's experience was not hindered by the setup. The use of the single-item measure for the perceived learning, we believe, did not hinder the predictive validity given that the item was successfully used in previous research and it measures a concrete and simple construct. Nevertheless, future research is required focusing on the differences between the measured and perceived learning. Furthermore, while there was a clear increasing tendency in students' motivation, attitude and self-efficacy scores, the difference between the pre-game and post-game scores were not significant. We attribute this finding to the properties of the game and speculate that a different topic or a more fun game would have resulted in a stronger increase in the aforementioned scores. Accordingly, we call for future research with different games and on different subjects to investigate the herein revealed effects.

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Appendix

Table 3. The measured factors, their sources, operational definitions, and respective questions. All items were evaluated on a 5-point scale (1 – Strongly disagree; 5 – Strongly agree)

Factor and source	Operational definition	Item/Question
Fun [48] ($\alpha = 0.940$)	The degree to which students experienced fun during the activity.	I did this activity because I had to. (reversed item) I did this activity because I wanted to. I want to do something like this again. During the activity... I knew what to do. I felt I was good at this activity. I did something new. I was curious. I had fun. I was happy. I felt that time flew. I forgot about school. I felt good. I felt bad. (reversed item) I felt angry. (reversed item) I felt sad. (reversed item)
Perceived learning [52]	The degree to which students indicate their learning during the activity.	Have you learnt something new today about biology?
Motivation [55] ($\alpha_{pre} = 0.789$; $\alpha_{post} = 0.912$)	The degree to which students indicate their motivation toward the subject.	I am willing to take more than the required amount of biology. I plan to take as much biology as I can during my education. The challenge of biology appeals to me.
Attitude [54] ($\alpha_{pre} = 0.822$; $\alpha_{post} = 0.850$)	The degree to which students indicate their attitude toward the subject.	I think what we are learning in biology class is interesting. It is important for me to learn what's taught in the biology class. I think what I'm learning in the biology class is useful for me to know.

Self-efficacy [54] ($\alpha_{pre} = 0.608$; $\alpha_{post} = 0.757$)	The degree to which students indicate their self-efficacy toward the subject.	I'm certain I can understand the ideas taught in the biology class. I expect to do very well in biology class. I know that I will be able to learn the material for the biology class.
Intention [54] ($\alpha = 0.945$)	The degree to which students indicate their willingness to play similar games.	I want to do similar activities in my biology classes because I find these kinds of activities are interesting. I want to do similar activities in my biology classes because I think these kinds of activities are useful. I want to do similar activities in my biology classes because I feel these kinds of activities are important.
Measured learning [n.a.]	The difference between the post- and pre-score on the knowledge test.	<p>1. When your body detect danger, it reacts by sending adrenalin to the following body parts to escape EXCEPT: <i>eyes / lungs* / liver / brain</i></p> <p>2. Your body delivers oxygen from the lungs to leg muscles by the help of: <i>neuroglobin / cytoglobin / hemoglobin* / myoglobin</i></p> <p>3. When your body is losing blood, it needs to quickly heal the wound by gathering the following elements EXCEPT: <i>platelet / clotting factor / fibroblast / epithelium*</i></p> <p>4. When your body is invaded by bacteria, it will inspect the bacteria in your: <i>blood / infected cells / lymph node* / spinal cord</i></p> <p>5. When your body sends an 'infection alert', the following happens: <i>your body warns you to take a paracetamol / your body releases antibodies to disable bacteria before they multiply and infect cells* / your body makes you thirsty, so you'll drink a lot and flush the bacteria away / your body releases antihistamine to kill bacteria before they attack your organs</i></p> <p>6. When your body has high blood sugar, it needs to release: <i>glucose from pancreas / glucose from liver / insulin from pancreas* / insulin from liver</i></p>

* Indicates the correct answer for the knowledge test.