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Effects of the instructional message used to introduce game-based learning, prior knowledge, prior gaming experience and flow on learning

Accepted version of the manuscript

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Purpose – This paper examines whether the instructional message used to introduce game-based learning (GBL), prior knowledge, flow and prior gaming experience have an impact on secondary students' learning outcomes, perceived game utility and motivation to use the game.

Design/methodology/approach – Fifty-four 9th grades students enrolled in this quasi-experimental study. Both groups played the same game. The experimental group was told that they would be playing a game, whereas the control group was told that they would be doing an exercise. The game was designed to promote knowledge recall about familiar mathematical concepts. Prior knowledge was assessed. An immediate and a two-days delayed post- evaluated learning outcomes. Flow, prior gaming experience, perceived game utility and motivation to use the game were assessed with questionnaires after playing.

Findings – Introducing the GBL activity as a game increased immediate learning outcomes for low knowledgeable students, but these benefits didn't extend to longer term. Indeed, when the GBL activity was presented as an exercise, low higher knowledgeable students obtained poorer longer-term learning outcomes than more knowledgeable ones; whereas no difference appeared when the GBL was introduced as an exercise. Prior gaming experience and the type of instructional message used to introduce a GBL activity positively influenced perceived game utility and motivation to use the game.

Originality – This study is the first to highlight that the way a GBL activity is framed affects differently low and higher knowledgeable students' learning outcomes and influences perceived game utility and motivation to use the game.

Keywords : *Games, Pedagogical issues, Secondary education, Teaching/learning strategies,*

Article classification: *Research paper*

1. Introduction

Getting secondary school students motivated and active in class is a major issue for teachers. Game-based learning (GBL) is intended to promote learning thanks to a motivating and engaging context. In a *learning-by-doing* approach, GBL is argued to promote self-regulated learning by offering students opportunities to explore and process educational content (Krath, Schürmann, and von Korflesch, 2021; Mayer, 2020; Nebel *et al.*, 2017; Plass *et al.*, 2020; Rapp, 2017). Providing a playful environment to learn sounds suitable to support students' learning, particularly for a fundamental educational requirement such as mathematics (Alt, 2023; Dai *et al.*, 2023; de Almeida and dos Santos Machado, 2023; Kacmaz and Dubé,

2021; Stoyanova, Tuparova, and Samardzhiev, 2017). Most studies on GBL focused on serious games, which are games intended to use entertaining features to promote learning and not merely to entertain the player (Wouters, van Nimwegen, van Oostendorp and van der Speck, 2013). GBL is different from mere gamification techniques that add game-like elements in tasks (such as rewards) to make them more enjoyable (Alt, 2023; van Roy and Zaman, 2018).

Several meta-analyses have shown that GBL can support students' learning outcomes as compared to a control group that does not play a game (Clark, Tanner-Smith, and Killingsworth, 2016; Pan, Ke, and Xu, 2022; Tokac, Novak, and Thompson, 2019; Wouters, Nimwegen, and van der Spek, 2013). Providing instructional support within the game can also improve learning outcomes, as compared to GBL without instructional support (Wouters and Van Oostendorp, 2013). Notably, games that used a direct instruction approach, such as recall practicing, were reported to be particularly relevant for math factual knowledge learning (Kacmaz and Dub, 2022). It is also to be noted that few studies have examined the impact of GBL on long-term learning outcomes (Cameron and Dwyer, 2005; Hailey *et al.*, 2016; Wouters *et al.*, 2013).

Additionally, effects of GBL were also observed on students' short-term motivation (Alt, 2023; Anastasiadis, Lampropoulos, and Siakas, 2018; Erhel and Jamet, 2013; Gunter, Kenny and Vick, 2007; Haruna *et al.*, 2021; Hew *et al.*, 2016; Hwa, 2018; Papastergiou, 2009; Stoyanova *et al.*, 2017; van Roy and Zaman, 2018; Wichadee and Pattanapichet, 2018). Although gamifying high school students' learning activities increases students' motivation, these benefits decline over time (see the reviews by Pan *et al.*, 2022; Ratinho and Martins, 2023). Hence, literature tends to agree that GBL can support learning outcomes, but the question how to best implement GBL in an ecological classroom setting remains open.

Research has also demonstrated that to benefit from GBL, students need to experience a sense of flow, they need to immerse themselves into the activity and to experience a pleasant challenge while playing the game. A meta-analysis by Harris and colleagues (2023) showed that 9 studies on gaming found positive relationships between flow and task performance. However, learning and playing can often turn out to be conflicting goals as playing a game might entail negative outcomes by overloading learners' working memory or by distracting them (Hu and Shang, 2018). Hence, it is critical for GBL to avoid situations in which learners would disregard the educational content (Alt, 2023; Arnab *et al.*, 2015; Gunter *et al.*, 2008; Kenny and Gunter, 2007; O'Neil *et al.*, 2005).

Following prior recommendations (Mayer, 2020; Tsai and Tsai, 2020), we argue that research should better address the issue of understanding how variations in game elements might affect GBL efficiency. Between 2000 and 2018, Tsai and Tsai (2020) have shown that for 12 studies, involving 868 students in total, the averaged effect size of variation of in game-mechanism design is small but consistent (Hedges' $g = 0.405$). Game mechanisms in GBL can refer to game elements intrinsically designed to support learning processes or to gaming mechanisms designed to foster fun and engagement (Arnab *et al.*, 2015). These two features are of tremendous importance as game mechanisms may be so disconnected from the learning objective that they could turn out to be inefficient (Adams and Clark, 2014). Hence, research is needed to examine how changes in the way a GBL is used can influence learning outcomes. Few studies have investigated how the goal provided for GBL activities or the way GBL activities are presented to students can influence learning outcomes and students' attitudes (Davis *et al.*, 2019; Deckert, Heymann, and Metz, 2018; Erhel and Jamet, 2019; Erhel and Jamet, 2013). However, these studies did not examine how the way a GBL activity is framed can influence students depending on their level of prior knowledge, prior gaming experience and flow.

Specifically, in this study, we examined whether using different instructional messages to introduce the same GBL activity to students can influence learning outcomes and game

perception as a function of students' prior knowledge, prior gaming experience and flow. In other words, when two groups of students play the same game to strengthen their knowledge of a course, does telling one group of students that they are going to play a game before starting the GBL activity impacts learning outcomes and attitude differently as compared to telling another group of students that they are going to perform exercises? Further, as flow and students' **prior knowledge and prior gaming experience** can influence the impact of GBL activities on learning outcomes (Ninaus *et al.*, 2017), what is the impact of the instructional message used to introduce a GBL activity after controlling for the impact of students' prior knowledge, flow, and prior gaming experience?

1.1 Exploring the effect of task instructions on students' learning processes and outcomes.

Task instructions can influence how learners understand what the task demands them to do, in other terms, their mental representation of the learning goal (McCrudden *et al.*, 2010; Schoor *et al.*, 2021). The impact of the learning goal has been well-established in research (McCrudden *et al.*, 2010; Schoor *et al.*, 2021; Winne and Hadwin, 1998). For instance, goals can increase the academic standards that students apply during a task (McCrudden *et al.*, 2010; Schoor *et al.*, 2021). For self-regulated learning activities, the goal-setting theory (Winne and Hadwin, 1998) postulates that learners must elaborate a coherent mental representation of the task, then plan the different goals and sub-goals necessary to achieve the task at hand, and, eventually, they must define the strategies needed to reach these goals. All along the task, learners may adapt their action by updating their mental representation of their goal and sub-goals. **Similarly, for functional reading tasks, the REading as problem SOLVing model** posits that students engage in an activity by elaborating a representation of the task context, thanks to environmental cues such as class settings, or who provided the instruction (Rouet *et al.*, 2017). **Students' representation of the context influences their understanding of what the task outcomes should be and how they should behave. For instance, a student could expect that if a teacher requires them to play a game in class, it is most likely because the game offers learning opportunities. Hence, students might have the representation that their in-game behavior should be different from their in-game behavior while playing with friends at home.** A study comparing university students' reading behavior in a university and in a personal context, showed that participants spent longer dwell time on task and they made a greater number of document rereading in the **university context as opposed to the personal one (Schoor *et al.*, 2023).**

Likewise, in digital GBL, a study compared the impact of a multimedia learning environment that was presented to students as a game (experimental group) or as an educational program (control group) (Erhel and Jamet, 2013). Results showed that adults who used the multimedia learning environment framed as a game had poorer comprehension outcomes (Erhel and Jamet, 2013). These authors replicated their study by adding in the entertainment condition feedback to help learners know whether they had found the correct answer. Results showed that with the presence of feedback, **when the module was framed as a game, students had** better comprehension outcomes (Erhel and Jamet, 2013). Recently, another study showed that labeling a GBL activity as a game or as an inquiry task can affect students' behavior. When students received the instructional message "game play" before completing the activity, it fostered their attention towards winning. In contrast, the "inquiry play" instructional message led their attention towards the educational content (Davis *et al.*, 2019).

To summarize, the instructional message used to introduce a GBL activity can influence students' learning goal and behavior. Off note, research has also demonstrated that learning goals can determine students' motivation, engagement, and their will to initiate and sustain deep learning behaviors during the activity (Bernacki, Byrnes, and Cromley, 2012; Elliot and Dweck, 2005; Urdan and Kaplan, 2020). However, little is known about the impact of the way a GBL activity is framed for students with low or higher prior knowledge.

1.2 Examining the interplay between task instructions and motivation in game-based learning

Quality learning requires students' engagement and motivation. Motivation is a multifaceted concept that drives students' learning behavior (Deci and Ryan, 2012; Moos and Azevedo, 2009; Moos, and Marroquin, 2010; Moreno and Mayer, 2007). Motivation encompasses perceptions of self (such as self-efficacy), of the task (such as perceived task value), intrinsic-extrinsic motivation and other dimensions such as interest (Moos, and Marroquin, 2010). GBL is positively related to learners' motivation in terms of positive experience, positive attitudes towards gaming as a learning activity (Papastergiou, 2009; Stoyanova, *et al.*, 2017; Sun *et al.*, 2022; Vidergor, 2021; Wichadee and Pattanapichet, 2018; Yang, 2012; see also Makri, Vlachopoulos, and Martina, 2021 and Sailer and Homner, 2020 for reviews). Motivation can promote deep learning and can ensure that learners devote their cognitive resources to processes that supports learning outcomes.

The task instructions of GBL activities are argued to promote fun, motivation, and engagement (Arnab *et al.*, 2015), which should support students' deep processing of the to-be-learned content. However, as pointed out before, GBL also faces the challenge of provide instructions that do not distract learners from the actual learning objectives (Adams and Clark, 2014). How can we help students engage efforts in relevant learning strategies instead of placing their effort on the playful components of the game? Examining the impact of the instructional message used to introduce a game-based learning activity can enlighten researchers and educational practitioners and support the effective use of GBL. In addition, as pointed out in a recent review, beyond the mere effect of GBL instructions, research should also consider how students' interindividual differences and flow can affect GBL (Pan *et al.*, 2022).

1.3 Relationships between game-based learning and flow on learning outcomes and game perception

Previous research has emphasized how flow can contribute to the benefits of gaming on learning (Erhel and Jamet, 2019). Flow is defined as an optimal state reached when individuals achieve high concentration, feel fun and interest when performing an activity (Csikszentmihalyi *et al.*, 2014). Flow is characterized as individuals' ability to achieve a balance between the skills they engage in a task and the task challenges. As flow is intrinsically motivating and rewarding, individuals tend to seek for it (Nakamura and Csikszentmihalyi, 2009). Studies have discriminated the elements of flow in three groups: flow antecedents, flow experience and flow consequences (Kiili, 2005; Kiili and Lainema, 2008). Flow antecedents comprise clear goals and immediate feed-back. Flow antecedents include gamefulness and frame story. Flow experience, or flow state, encompasses autotelic experience, sense of control, loss of self-consciousness, concentration, and time distortion (Csikszentmihalyi *et al.*, 2014; Kiili, 2005; Kiili and Lainema, 2008). During flow state, players are totally focused and immersed into the game. Finally, flow consequences are related to learning outcomes and in-game behavior (Kiili

and Lainema, 2008; Hou, 2015). In line with studies showing that flow can foster meaningful learning (Erhel and Jamet, 2019; Hou, 2015), we argue that flow could also influence in-game perception. For instance, in a comparative approach, Hwang, Wu, and Chen (2012) showed that students using a computer game had greater learning achievement than students using computerized exercise worksheets. Hence, flow consequences could be connected to students' game acceptability. This is crucial for GBL as perceived game utility can impact learning behavior and learning outcomes.

Thus, flow is argued to encourage deep information processing in GBL (Kiili, 2005). These findings emphasize that that instructional designers should pay careful attention to design GBL environments that do not disrupt flow experience (Adams and Clark, 2014). Despite the tremendous amount of research, some studies have also pointed out that the relationships between GBL, flow and learning outcomes can be inconsistent (Almeida and Buzady, 2019; Bitrian *et al.*, 2020, Krath *et al.*, 2021). One key to understand these inconsistent findings may be that flow can be related to students' characteristics such as motivation or prior knowledge (Ninaus *et al.*, 2017).

1.4 Contribution of learners' prior knowledge and player experience to game-based learning

It is now well-established that learners' prior knowledge is a critical factor for learning achievement (Wang, Stebbins, and Ferdig, 2022). Prior knowledge influences how students choose to process information and how they integrate new knowledge. Few studies attempted to demonstrate how prior knowledge can predict learning outcomes with GBL (for a review of the moderators of GBL on learning outcomes related to students' characteristics, see Pan *et al.*, 2022). Some studies provided positive evidence (Tsai *et al.*, 2012; Wang *et al.*, 2022; Yang and Quadir, 2018), whereas other failed to find a significant influence of prior knowledge on learning outcomes (Wang *et al.*, 2022). In addition, Wang, Stebbins and Ferdig (2022) showed that prior knowledge impacts students' strategies, such as visual processing of game elements, during the game.

Other interindividual characteristics may influence the impact of GBL on students' learning outcomes and perceptions. For instance, Sun, Chou and Yu (2022) showed that 11 and 12 years-old students' prior gaming experience was significantly related to problem-solving performance when using a digital game. Weingärtner and Weingärtner (2023) tested the use of a prototype of a Tic-Tac-Toe type of game adapted for quantum mechanics learning. Their results showed that many participants experienced some difficulties to understand the game itself. Most of them needed a few tries to start enjoying the game. These findings emphasize that individuals' prior gaming experience can impact GBL outcomes. In this study, prior gaming experience can refer to experience with the game or to general gaming experience. Usually, in prior studies, prior gaming experience refers to individuals' experience with gaming and how confident they feel when playing games (Pardim, *et al.*, 2023). Despite these findings, empirical evidence on the impact of prior knowledge and students' prior gaming experience on GBL is still scarce.

Current study aims and hypotheses.

The literature review has provided evidence regarding the potential benefits of GBL on learning outcomes and the relationships between GBL instructions, flow, students' prior knowledge and prior gaming experience (Erhel and Jamet, 2013; Erhel and Jamet, 2019, Ninaus

et al., 2017; Pan *et al.*, 2022) as well as the lack of empirical evidence on the effect of GBL on longer-term retention (Cameron and Dwyer, 2005; Wouters and Van Oostendorp, 2013)., **Consistently**, the current study examines whether the instructional message used to introduce a GBL activity to students can affect learning outcomes, motivation to use the game again and perceived game utility as a function of students' level of prior knowledge, flow, and prior gaming experience. In the present study, secondary school students were asked to play an escape game tackling familiar mathematical knowledge. All students played the same game. However, before starting the game, the experimental group was told that they were about to play a game; whereas the control group was told that they were about the solve exercises to train their math knowledge. The following research questions (RQs) were explored:

RQ1: *Does the instructional message used to present a GBL activity impact immediate and delayed learning outcomes for low and higher knowledgeable students?*

We expected that introducing the game as a game would improve immediate learning outcomes for students with low and higher prior knowledge. Indeed, introducing the GBL activity as a game should support students' motivation and deeper information processing during the game (Erhel and Jamet, 2013; 2019; Graesser *et al.*, 2009; Makri, 2020; Moreno and Mayer, 2007) (H1a). As empirical findings on long-term effects of GBL on learning outcomes are scarce (Cameron and Dwyer, 2005; Hailey *et al.*, 2016; Wouters and Van Oostendorp, 2013), we had the exploratory assumption that introducing the GBL activity as a game would increase deeper processing and, consequently, delayed learning outcomes (H1b). We also expected that introducing the GBL activity as a game would be more beneficial for low prior knowledge students than for higher prior knowledge one (H1c).

RQ2: *To what extent prior knowledge, flow, prior gaming experience, and the type of instructional message used to introduce GBL can predict learning outcomes, motivation to use the game again, and perceived **game** utility?*

In line with prior works (Erhel and Jamet, 2019; Kacmaz and Dubé, 2022; Pan *et al.*, 2022; Ratinho and Martins, 2023), we hypothesized that students' prior knowledge, flow and prior gaming experience would better predict learning outcomes (H2a), perceived game utility (H2b) and motivation to use the game in future classes (H2c).

Following previous studies emphasizing **how to best implement GBL** in a course is a major concern (Alt, 2023; Kacmaz and Dubé, 2023), we examined our RQs in an ecological classroom setting. The GBL activity examined in the present study was a part of 9th grades school students' mathematics curriculum. Hence, the game designed for this experiment was created by the students' professor and was conducted at the end of the semester. The game had a pedagogical purpose: to help students get ready for their final exam. The game tackled mathematics knowledge that had been previously studied throughout their school year. As highlighted in recent meta-analyses (Pan *et al.*, 2022; Tsai and Tsai, 2020), the function of the game was to help students recall prior knowledge and practice their understanding of math concept to solve problems. Hence, the game aimed at helping students retrieve prior math knowledge.

The current study provides original contributions regarding: (i) the impact of the instructional message used to introduce a GBL activity to students, and (ii) the interplay between the instructional message used to introduce a GBL activity, flow, prior knowledge and

students' prior gaming experience on learning outcomes, motivation to use the game and perceived game utility.

3. Methods

3.1 Research Design

The present quasi-experimental study had a mixed study design. As recommended in the research field, the learning material used in the experiment was created by teachers and the experiment was run in ecological classroom settings by the students' usual teacher, to warrant for any potential novelty effect of the presence of the researcher. The type of instructional message used to introduce a GBL activity was a between-subject independent variable (IV) (*i.e.* as a game or as an exercise), whereas posttest timing (immediate or delayed) was a within-subject IV. The impact of our 2 IVs was studied on learning outcomes, perceived game utility, flow, and motivation to use the game. Following recommendations from prior works, short and longer-term learning outcomes were considered (Cameron and Dwyer, 2005; Wouters and Van Oostendorp, 2013). Students' prior knowledge and prior gaming experience were collected as controlled variables and potential predictors of learning outcomes and motivation.

3.2 Participants

Participants were 54 9th grades students distributed in 4 different classes from a French secondary school. Age ranged from 14 to 16 years old (*Mean* = 15.7 *SD* = 1.18, 61,8% girls). There were 28 students in the experimental group (gaming instructional message), and 26 students in the control group (learning instructional message). Participants were all French speakers.

3.3 Material

Educational game

The escape game was specifically designed for the present experiment by the math teachers involved in the project, which warranted for the educational relevance of the game content. The classrooms were filled with accessories related to the game theme. Teams of four students worked together under time pressure and used their prior mathematical knowledge to crack codes, to solve puzzles and riddles to discover items that contained pieces of a code that were needed to free themselves from a "locked" room. Following recommendations (Makri, 2021), the maximum time allowed for the game was 50 minutes, teams involved 4 players and the game involved a hybrid experience with digital and analog resources in the physical classroom. We decided to have students play in groups of 4 for practical reasons: escape games are usually played in teams, and it was not possible for teachers to have students play individually within a 50 min class session. In addition, collective play is argued to contribute to the benefits of GBL and to flow (Goncalves *et al.*, 2023; Makri, 2021).

Each team had one tablet; students had to share it to collectively solve the game enigmas. Enigmas were displayed on Genially, action bound and pixel art. Regarding analog resources in the physical classroom, each team had a locked briefcase and a locked glass jar that contained two pieces of a code. For each team, the teachers hid a glass jar and an envelope that contained 2 additional pieces of a code. To solve the game and find the code that will help them "leave" the "locked room", students had to solve two enigmas to open the locked briefcase and the glass jar to find the first two pieces of the code. Students also had to find the two hidden items to

solve the enigmas they contained and to discover the last 2 pieces of the code. Students could complete the enigmas in the order they wanted. Figure 1 below provides examples of problem-solving tasks displayed on students' tablet and embedded in the game.

Insert Fig. 1 here

Fig. 1: examples of problem-solving tasks displayed on students' tablet and embedded in the game.

Instructional messages used to introduce the GBL activity

The experimental group received an instructional message that emphasized the gaming dimension of the activity. Students were told they were about to play a game and that they had to solve enigmas within a 40-minutes time limit to leave the room. The control group was told that they were about to solve different problems to practice for two final exams afterwards. The material and tasks did not differ between the two groups. Both groups played the same game, only the instructional messages given at the beginning of the game were different.

3.4 Measurement

Prior knowledge and learning outcomes

The same 11-item questionnaire was used to assess prior knowledge, immediate and delayed learning outcomes. Delayed learning outcomes was assessed two days later. Teachers were not able to conduct the delayed posttest later due to class constraints. Note that prior studies tend to recommend longer delay to assess longer term retention (a minimum of two weeks All, Castellar, Van Looy, 2016; Cameron and Dwyer, 2005). Although this represents a limit, as recommended (All *et al.*, 2016), students were not informed that they would have a follow-up test two days later, which increases validity. Item order was randomized across the 3 testing times. The questionnaire assessed knowledge about concepts involved in the game enigmas. The 11 questions of the knowledge questionnaire deal with mathematical concepts that students need to know by the end of 9th grade in France. Scoring of the questionnaire was elaborated prior to the experiment by the teachers involved in the project. For the 9 single-answer MCQ, one point was granted for the correct answer. For the 3 multiple-answers MCQ, 2 points were granted when the 2 correct answers were identified. The maximum score was 15. The percentage of success was used in the analyses. The knowledge questionnaire was filled in with paper-pencil. Sample of the questionnaire used can be found in Appendix 1.

Prior gaming experience

Prior gaming experience was self-assessed by students with 2 questions on a 5-point Likert scale (ranging from not at all to very much). See Table 1 for the items used.

Flow, Motivation to use the game in future classes and Perceived game utility

Flow was measured using a 10-item questionnaire based on prior works (Cai, Engeser and Rheinberg, 2008; Erhel and Jamet, 2019). Items were rated on a 5-point Likert scale ranging from not at all to very much. Items can be found in Table 1 below.

Motivation to use the game was measured with 1 5-point Likert scale item that asked students "If I could vote, I would vote to use this escape game in class again". Perceived game utility was assessed with three 5-point Likert scale items (see Table 1 below).

Table 1: items used to measure flow, motivation to use the game in future classes, perceived game utility, and prior gaming experience

Insert Table 1 here

3.5 Procedure

Prior to the experiment, parents received information about the research. First, participants started by filling in a computer-based questionnaire individually. They read and signed an informed consent and agreed to participate. Next, demographic information, prior gaming experience, motivation and prior knowledge were assessed. A few days later the main stage of the experiment took place. The material (enigmas, tablets, items for the game) was placed and the classroom was decorated prior to students' arrival. Upon arrival, a music was launched to support students' flow. Task instructions were given. Participants were informed that the activity would last for 55 minutes in total, and up to 40 minutes maximum for the main phase. The teacher presented the material needed to perform the activity. Then, students had to gather in groups of 4 to complete the activity. Teachers remained in the room to provide support if students demanded help. After 40 minutes, the game ended. Finally, participants completed the immediate posttest. Two days later, participants completed the delayed posttest in their regular mathematics class with their teacher.

3.6 Analyses

Data were analyzed with JAMOVI v.2.2.5. To examine how the instructional message used to present a GBL activity as a game or as a learning exercise can impact immediate and delayed learning outcomes as a function of students' level of prior knowledge (RQ1), mixed repeated ANOVAs were conducted with prior knowledge groups and the type of instructional message used to introduce the GBL activity as between-subjects variables and posttest timing as a within-subject variable. To examine whether prior knowledge, flow, prior gaming experience, and the type of instructional message used to introduce GBL can predict learning outcome, motivation, and game perception, we conducted multiple hierarchical regression analyses. The first block of variables included prior knowledge and flow (as z-standardized variables) as predictors (Model 1). In the second block we added students' prior gaming experience (Model 2). Finally, the third block included the type of instructional message used to introduce the GBL activity (1 = GBL activity introduced as a game, 2 = GBL activity introduced as an exercise).

4. Results

4.1 Preliminary analyses

Reliability analyses

A Cronbach's alpha of .69 was found for the knowledge pretest. A Cronbach's alpha of .81 was found for the 9 items of the flow scale (Mean = 3.50, SD = .69). A Cronbach's alpha of .83 was found for the 3 items of the students' perception of the usefulness of escape games as learning activities scale (Mean = 3.50, SD = .69).

Descriptive statistics

No differences were found between the experimental and the control groups regarding students' prior knowledge ($t(52) = -.29, p = .77$) and prior gaming experience ($t(52) = -.59, p = .56$). Table 2 shows means and standard deviations for all dependent variables.

Table 2: Means and Standard deviations for students' prior knowledge and prior gaming experience.
Insert table 2 here.

Following prior works that investigated the impact of prior knowledge in GBL (Wang *et al.*, 2022), mean split ($M = 62.5, SD = 20.6$) was used to discriminate students into two groups depending on their level of prior knowledge. Based on their pretest score, participants were assigned to the lower or higher prior knowledge group. The low and higher prior knowledge group significantly differed in their prior knowledge score ($t(52) = -9.67, p < .001$).

4.2 RQ1 Results: Does the instructional message used to present a GBL activity impact immediate and delayed learning outcomes for low and higher knowledgeable students?

Mixed repeated ANOVAs were conducted with prior knowledge groups and the type of instructional message used to introduce the GBL activity as between-subjects variables and posttest timing as a within-subject variable. The dependent variable was learning outcomes.

Results showed that the instructional message used to introduce the GBL activity and posttest timing had no significant impact on learning outcomes, $F(1,42) = .01, p < .92, \eta^2_p < .001$ and $F(1,42) = .28, p = .60, \eta^2_p = .007$. Prior group knowledge was significant, $F(1,42) = 28.45, p < .001, \eta^2_p = .40$: students with higher prior knowledge had better learning outcomes than students with lower prior knowledge (respectively $M\% = 76.4 SE = 3.33$ and $M\% = 49.2 SE = 3.87$). The interactions between posttest timing and the type of instructional message, between posttest timing and prior knowledge groups, and between the type of instructional message and prior knowledge group were not significant ($F(1,42) = 0.05, p < .82, \eta^2_p = .001$ and $F(1,42) = .84, p = .36, \eta^2_p = .02, F(1,42) = .01, p < .921, \eta^2_p < .001$). Interestingly, the triple interaction between posttest timing, gaming context and prior knowledge reached significance, $F(1,42) = 4.76, p = .035, \eta^2_p = .10$). See Fig. 2.

Insert Figure 2 here

Fig. 2: results of the interaction between the instructional message used to introduce the GBL activity, prior knowledge groups and posttest timing on learning outcomes.

Bonferroni's post hoc comparisons showed that for the immediate posttest, when the GBL activity was introduced as a game, the impact of prior knowledge group was not significant ($t(42) = -2.87, p = .18$). However, when the GBL activity was introduced as an exercise (control group), students with lower prior knowledge had poorer learning outcomes than students with higher prior knowledge ($t(42) = -3.55, p = .027, M\% = 47.5 SE = 6.52$ and $M\% = 76.9 SE = 5.11$).

The opposite pattern was observed for the delayed posttest. When the GBL activity was introduced as a game, students with higher prior knowledge had better performance than students with lower prior knowledge ($t(42) = -4.68, p < .001$): $M\% = 46.7 SE = 5.29$ and $M\% = 81.0 SE = 5.09$). In contrast, when the GBL activity was introduced as an exercise (control group), the impact of prior knowledge group was not significant ($t(42) = -2.92, p = .016$). See Fig. 2 and Table 3 for means and standard deviations.

Table 3: Means and (SD) for the immediate and delayed learning outcomes as a function of prior knowledge group and the type of instructional message used to introduce the GBL activity.

Insert Table 3 here

Summary of results for RQ1

Unlike expected (H1a and H1b), the type of instructional message used to introduce the GBL activity had no significant impact of learning outcome. Prior knowledge supported learning outcomes. Interestingly, the triple interaction showed that for immediate learning outcome, when the GBL activity was introduced as an exercise, students with low prior knowledge had lower learning outcomes than students with higher prior knowledge. However, when the GBL activity was introduced as a game, this difference disappeared. This pattern may be explained by the fact that framing the GBL activity as a game tended to increase learning outcomes for novice students whereas it tended to slightly reduce learning outcomes for higher knowledgeable students.

However, these benefits do not extend to longer term learning outcomes. For delayed learning outcomes, when the GBL activity was introduced as a game, low prior knowledge students were outperformed by higher knowledgeable ones. No significant relationship between the type of instructional message and prior knowledge groups appeared for delayed learning outcomes when the GBL activity was introduced as an exercise. Hence, H1c is not fully confirmed.

4.3 RQ2 Results: To what extent do prior knowledge, flow, students' gaming experience, and the type of instructional message used to introduce a GBL activity can predict learning outcomes, motivation to use the game again, and perceived game utility?

Means and standard deviations for learning outcomes, flow, perceived game utility, and motivation to use the game again in future classes as a function of the type of instructional message used to introduce the GBL activity can be found in Table 4 below.

Table 4: Means and (SD) for learning outcomes, flow, perceived game utility, and motivation to use the game again in future classes for the experimental and the control groups.

Insert Table 4 here

To test our predictions, we conducted multiple hierarchical regression analyses with three blocks of variables. The first block included prior knowledge and flow (as z-standardized variables) as predictors. In the second block we added students' prior gaming experience. Finally, the third block included the type of instructional message used to introduce the GBL activity (1 = GBL activity introduced as a game, 2 = GBL activity introduced as an exercise). Learning outcomes, perceived game utility and motivation to use the game in future classes were entered as dependent variables. Effects of covariates was controlled for (for all dependent variables, Durbin Watson statistics were between 1.58 and 2.03, all $ps > .05$). Table 5 presents an overview of the results of the multiple hierarchical regression analyses for all our dependent variables.

Table 5: Results of the hierarchical multiple regression analyses on the four dependent variables (bold characters represent the most significant model).

Insert Table 5 here

Learning outcomes

For immediate learning outcomes, results showed that the first model that included prior knowledge and flow was the most significant. Model 1 accounted for 30.2% of the variance, $F(2,49) = 12.03, p < .001, \Delta R^2 = .30$. Adding the impact of students' prior gaming experience and the type of instructional message used to introduce the GBL activity showed no improvement. ($p = .88$ and $p = .84$). Results of model 1 showed that prior knowledge increased immediate learning outcomes ($b = .62, SE = .13, t(49) = 4.63, p < .001$). Flow had no significant influence ($b = .67, SE = 3.94, t(49) = .17, p < .87$).

The same pattern of results was found for delayed learning outcomes. Results showed that the first model was the most significant and accounted for 40.3% of the variance, $F(2,49) = 15.88, p < .001, \Delta R^2 = .40$. Adding the impact of gaming experience and the type of instructional message used to introduce the GBL activity showed no improvement. ($p = .69$ and $p = .81$). Results of model 1 showed that prior knowledge increased delayed learning outcomes ($b = .72, SE = .13, t(49) = 5.38, p < .001$). Flow had no significant influence ($b = .49, SE = 4.09, t(49) = .12, p < .90$).

Perceived game utility

Interestingly, a different pattern of results was found for perceived game utility. Results showed that the third model, that included prior knowledge, flow, prior gaming experience and the type of instructional message used to introduce the GBL activity was the best predictor of perceived game utility, ($F(4,47) = 8.93, p < .001, \Delta R^2 = .38$). Model 3 was significantly better than Model 1 ($p = .017$). Overall, prior knowledge, flow, prior gaming experience and the type of instructional message used to introduce the GBL activity accounted for 38.4% of the variance. Prior knowledge and flow had no significant impact (respectively $b = .007, SE = .006, t(49) = 1.26, p = .21$ and $b = .23, SE < .17, t(49) = 1.35, p = .18$). However, prior gaming experience increased perceived game utility ($b = .52, SE < .13, t(49) = 4.18, p < .001$). Finally, introducing the GBL activity as a game increased perceived game utility as compared to introducing it as an exercise ($b = .54, SE < .22, t(49) = 2.46, p < .02$).

Motivation to use the game again

A similar pattern of results was found for students' motivation to use the game in future classes. The first model failed to reach significance ($F(1,49) = 2.45, p = .09, \Delta R^2 = .05$), whereas model 3 was the best fitted one ($F(4,47) = 6.56, p < .001, \Delta R^2 = .30$). Indeed, model 3 showed significant improvement as compared to model 2 ($p = .02$). Overall, prior knowledge, flow, prior gaming experience and the type of instructional message used to introduce the GBL activity accounted for 30.3% of the variance. Prior knowledge and flow did not reach significance ($b = -.003, SE = .006, t(49) = -0.43, p = .67$ and $b = .26, SE < .19, t(49) = 1.39, p = .17$). However, game experience increased students' motivation to use the game in future classes ($b = .53, SE < .14, t(49) = 3.88, p < .001$). Finally, introducing the GBL activity as a game increased students' motivation to use the game in future classes as compared to introducing it as an exercise ($b = .57, SE < .24, t(49) = 2.35, p = .02$).

Summary of results for RQ2

Unlike expected (H2a), prior knowledge was the only significant predictor of learning outcomes. However, as we expected (H2b and H2c) considering prior gaming experience and the type of instructional message used to introduce the GBL activity accounted for a larger proportion of the variance of perceived game utility and motivation to use the game again than prior knowledge and flow. Interestingly, introducing the GBL activity as a game (as compared to introducing it as an exercise) **and prior gaming experience** increased perceived game utility and motivation to use the game **again**.

5. Discussion

The present study aimed at examining: (i) how the instructional message used to introduce a GBL activity and prior knowledge could influence immediate and delayed learning outcomes and (ii): how prior knowledge, flow, prior gaming experience and the type of instructional message used to introduce the GBL could predict learning outcomes, perceived game utility and motivation to use the game again in future classes. To this point, secondary school students played the same game. In the experimental group, the GBL activity was introduced as a game, whereas in the control group, the GBL activity was introduced as an exercise.

Does the instructional message used to present a GBL activity impact immediate and delayed learning outcomes for low and higher knowledgeable students?

Findings showed that the instructional message used to introduce a game had no significant main impact on immediate and delayed learning outcomes. Prior knowledge was the best predictor of students' learning outcomes. As a reminder, the game designed for this experiment tackled mathematical knowledge that students had previously studied with their teacher. Hence, the pedagogical purpose of the game was to help students recall prior knowledge to enhance long-term quality learning. As highlighted in a recent meta-analysis (Pan *et al.*, 2022), most of the math learning games aim at supporting prior knowledge recall. In the present experiment, to solve the enigmas, students could only rely on their own prior knowledge or their team. Under these circumstances, the important main effect of prior knowledge observed is not surprising. Hence, the present finding also extend Pan and collaborators' work (2022) by showing that prior knowledge is the main predictor of learning outcomes for GBL activities that support knowledge retrieval.

However, the present study is the first to highlight that framing a GBL activity as a game or as an exercise does not affect low and higher knowledgeable students in the same way. When students were told that the GBL activity was a game, no significant differences were observed between low and higher knowledgeable students for immediate learning outcomes. In contrast, when the GBL activity was presented as an exercise, low knowledgeable students had lower immediate learning outcomes than higher knowledgeable ones. It is possible that when the GBL activity was introduced as a game, the trial-and-error nature of the game and the positive experience helped novice students engage deeper efforts to solve the problem-solving activities of the game, to recall what they could remember and to understand more efficiently the concepts at stake. Eventually, by supporting deeper processing, presenting the GBL activity as a game helped less knowledgeable students coped with their low level of prior knowledge. In addition, as students were playing in teams of four, they also probably helped each other during the game. It is indeed very likely that when the GBL activity was introduced as a game, students cooperated to a higher extent, which increased low knowledgeable students' learning outcomes.

Indeed, cooperation in playful and gamified learning contexts was reported to be positively related to motivation and engagement (Ratinho and Martins, 2023). However, framing the GBL activity as game slightly reduced higher knowledgeable students' immediate learning outcomes. When the GBL activity was introduced as a game, students with higher prior knowledge may have been more focused on helping their team solve the enigmas and win the game. Consequently, they may have spent most of their efforts explaining concepts that they had already mastered to their less knowledgeable peers, at the expense of allocating efforts to strengthen their own understanding of less familiar concepts. Hence, framing a GBL activity that aims at strengthening prior knowledge as a game can decrease the impact of prior knowledge for immediate learning outcomes. This finding may seem contradictory to prior findings showing that an entertainment instruction led to shallow processing and poorer learning outcomes (Brom *et al.*, 2018; Erhel and Jamet, 2013). However, unlike these studies, the present study focuses on younger participants and included teamwork.

In addition, the current study points out that the benefits observed on immediate learning do not extend to longer term learning outcomes. Indeed, when the GBL activity was framed as a game, the low prior knowledge group had poorer longer term learning outcomes than the higher prior knowledge group. In contrast, this difference did not appear when the GBL activity was introduced as an exercise. The game did not trigger enough deep cognitive processing to guarantee qualitative and lasting learning for low knowledgeable students. This pattern may give fuel to the shallow hypothesis (Brom *et al.*, 2018; Erhel and Jamet, 2013) by highlighting that framing a GBL activity as a game can focus novice students' attention on the game and not on deep information processing. Cooperating with more knowledgeable students during the game was beneficial for short term learning outcomes, but it did not allow novice students to sufficiently process information and understand the concepts to support longer term learning.

To what extent prior knowledge, flow, prior gaming experience, and the type of instructional message used to introduce GBL can predict learning outcomes, motivation to use the game again, and perceived game utility?

Findings show that flow and prior gaming experience did not predict immediate and delayed learning outcomes better than prior knowledge for a GBL activity that relies on prior knowledge recall and not on new knowledge construction. It is possible that the game was easy enough to understand and to play, so that even students who had low prior gaming experience could perform this activity without being overloaded by the game rules. This pattern also extends prior recommendations to carefully consider students' prior knowledge before implementing a GBL activity in classes (Pan *et al.*, 2022). Indeed, prior gaming experience and flow do not cope for low levels of prior knowledge for GBL activities based on prior knowledge recall.

To the best of our knowledge, the present study is the first to show that the instructional message used to introduce a GBL activity and prior gaming experience influence perceived game utility and motivation to use the game. First, findings showed that introducing the GBL activity as game increased students' motivation and perceived game utility as compared to introducing the same GBL activity as an exercise. This provides fuel for the performance-preference paradox. In line with prior works (Haruna *et al.*, 2021; Stoyanova *et al.*, 2017), introducing the GBL activity as a game increased students' motivation but not learning

outcomes. In addition, such framing may have given students the illusion that the game would be more beneficial for learning than another activity.

Second, unlike a prior study (Iten and Petko, 2016), the present findings showed that prior gaming experience and not prior knowledge was the best predictor of students' motivation to use again a GBL activity and perceived game utility. Prior gaming experience supported the *mise en place* of a GBL situation (Hassinger *et al.*, 2017) and helped students process the game rules, which eventually increased students' motivation to play again in future classes. Students with prior gaming experience may have seen the GBL situation as a situation that could foster their autonomy and thus engaged in a more planned and purposeful way in the game. In contrast, students who were not familiar with gaming might have felt disoriented and might have allocated resources to process the game rules, objectives, and the reason why their teacher would introduce this activity in their curriculum. Consequently, students with low prior gaming experience did not perceive the GBL activity as useful for learning as students with higher prior gaming experience.

Finally, in line with some prior studies that did not find a significant impact of flow in GBL (Almeida and Buzady, 2019; Bitrian *et al.*, 2020, Krath *et al.*, 2021) our findings showed that flow was not a predictor of learning outcomes, perceived game utility and motivation to use the game. Flow was quite average in the present study. So it is possible that students did not reach an optimal flow state. In our view, it is also very likely that this pattern may be related to the type of game we used. Hence, future studies could investigate whether flow can have a significant impact on learning outcomes when the game requires to recall and apply prior knowledge to solve problems.

6. Limitations and future studies

First, sample size represents a limitation in our study. Four classes were recruited for this experiment (two per condition). However, as the experiment occurred for two weeks at different times, many students did not attend the different sessions, which caused loss of data. Second, no data was recorded regarding actual in-game performance. Future works should consider to what extent effective engagement in the game may moderate the impact of GBL on learning outcomes. Third, as the present study was set in the most ecological setting as possible, we chose not to control how students grouped themselves for the game. Groups may have been heterogenous in terms of prior knowledge, which could also influence our results. Future works should better determine whether framing a GBL activity as a game and not as an exercise can alter teamwork and learning outcomes.

The similarity of the two conditions may be seen as limit that could account for the lack of clear impact of our main independent variable: the type of instructional message used to introduce a GBL activity. Indeed, apart from the instructions used to introduce the game, no changes were made between the two groups. However, we argue that this is one of the major originalities of the present study. Following a valued-added approach (Mayer, 2020), we wanted to discriminate whether the impact of GBL is related to the effects of the game mechanics or on the framing of the GBL activity as a game for novice and more expert students. As our findings showed that the instructional message used to frame a GBL activity can influence learning outcomes as a function of students' level of prior knowledge and game perception, future studies should examine how the way a GBL activity is framed can affect students' understanding of what GBL activities require.

Conclusion and Implications

In a nutshell, the present study is the first to emphasize that framing a GBL activity as a game can support short term learning outcomes for students with low prior knowledge when the GBL activity requires to recall prior knowledge. However, the benefits of introducing a GBL activity as a game to novice students in such settings is limited to short term learning outcomes and does not support longer term quality learning. Prior gaming experience and the way a GBL activity is introduced also influence students' perceived game utility and motivation to use the game again in future classes, at the risk of having them overestimate the actual benefits of the game on their learning outcomes.

Hence, educational practitioners should introduce GBL activities as games to promote low knowledgeable students' engagement, to support short-term learning outcomes, perceived task utility and motivation. However, caution should be taken because framing a GBL activity as game can reduce longer term learning outcomes. Hence, scaffold or support is needed to help low knowledgeable students engage deep processing to foster qualitative long-term learning. Finally, the way a GBL activity is introduced can increase perceived game utility and motivation to use the game.

On a theoretical point of view, the current study showed that the context that surrounds a learning activity, in our case the way a GBL activity is framed, can influence how students perceive the activity, what they do and what they will learn from it. Hence, the present study is the first to provide some evidence that the task context can influence students' understanding of **the task requirements in GBL.**

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Credit statement

Author 1: Conceptualization, Methodology, Resources, Data Collection and Analysis, Writing – review and editing.

Author 2: Conceptualization, Methodology, Data Formal analysis, Writing – original draft, review, and editing.

Declaration of conflict of Interest.

The authors declare that they have no conflict of interest.

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Appendixes

Appendix 1: Sample of the knowledge test used (in French, as originally provided to participants).

Insert appendix 1 here