Insect World: Game-Based Learning as a Strategy for Teaching Entomology

ABSTRACT

The use of game activities is spreading in diverse contexts, including stimulating teamwork and creativity, selecting job candidates, and as a teaching aid. Games are recognized as promoting interaction and engagement among children through an abstract challenge, which often results in emotional reactions. We investigated whether a game-based activity is useful as a tool for teaching entomology, as assessed on the basis of the learning achieved and the feedback provided by students. Student feedback was positive regarding card content, the rules manual, game-play design, and game use (the functional perspective). Likewise, the students also considered the game a fun activity, fast and competitive, and even challenging (the personal perspective). Some difficulties were indicated, such as the amount of initial information required to play. Nonetheless, the game increased student learning, demonstrating its usefulness as a didactic activity in the classroom. In addition to encouraging creativity and healthy competition among students, the game represents an integrative and dynamic teaching mode that is different from traditional classroom methods.

Key Words: analogic game; didactic activity; education; insect science; learning experience.

Introduction

“All grown-ups were once children, but only a few of them remember it” (de Saint-Exupéry, 1943). This quote from The Little Prince illustrates the notion that as we age we are integrated into a social position that requires behavior consistent with our biological age, which implies a reduction in playful activities. However, is the interruption of such activities really necessary? More particularly, must we stop playing and enjoying games? In his Theory of Fun for Game Design, Koster (2013) defines a game as “a system in which players engage in an abstract challenge, defined by rules, interactivity, and feedback that results in a quantifiable outcome often eliciting an emotional reaction.” Thus, the questions stated above seem to have a negative answer because, during the past 20 years or so, games and game playing have been spreading. They have been used in diverse contexts for various reasons, including stimulating teamwork and creativity, selecting job candidates, and as a teaching aid – all of which are typical adult activities (Kapp, 2012).

The teacher’s concerns regarding game-based learning are related to the infrastructure needed (e.g., physical space, internet) and the effective relationship between the time expended in game playing and the learning achieved by students, as compared with the traditional teaching–learning experience (Eastwood & Sadler, 2013). However, in the game-based learning approach, learners engage in social interactions, dealing with problems and unexpected challenges, whereby they are able to assess their own activities and the consequences of those activities, which allows them to find and eventually pursue more than one viable solution to the same problem. Thus, the learners are active participants in knowledge acquisition within a constructivist approach (Piaget, 1952; Freire, 1972; Vygotskii, 1986). Therefore, game-based activities are a potential teaching tool at different educational levels, with learning feedback provided by game performance and improvement. Furthermore, the approach brings the teacher closer to the student’s world, adding dynamics to the classroom interaction.

We were interested in how game playing might enhance learning in an entomology classroom, a context in which all kinds of insects are introduced – indeed, they are often physically present. Teaching about (and with) charismatic insects such as honeybees is easy, and the same is true for insects that provide ecological services (e.g., biological control of pests). By contrast, teaching about (and with) noncharismatic insects like cockroaches, or those associated with negative contexts (e.g., disease vectors), is more difficult because these creatures are unappealing. We wondered how game-based activities might be used to close the gap between students and unattractive (or even disliked) subjects. We speculated that a ludic environment in which the game itself involves both charismatic and noncharismatic insects could foster such an assimilation, thus motivating students’ understanding of the insect world. Therefore, we designed a role-playing game to investigate whether such a game-based activity is an amenable and effective strategy for teaching entomology.

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Game Design

Based on game classifications reviewed by Abdul-Jabbar and Felicia (2015), our game type is a role-playing game (RPG), developed to encourage creativity and healthy competition among students. The game’s subject matter is science fiction, which allows the players to become immersed in diverse and hypothetical entomological topics. It is a card game played by pairs of students, each of whom creates a strategy (through card choice) based on an interrelation among different card types and then meets the opponent for a (ludic) battle.

The game, called Insect World, consists primarily of 288 cards (made of cardboard), which explore the subjects of taxonomy, physiology, morphology, and behavior of insects within a ludic environment of learning. The card types in this entomological deck are (a) “monster-cards,” which exhibit a realistic photograph and describe the order and family of the insect, its morphological traits, its skills, and a power level (for attack/defense); (b) “gadget-cards,” which exhibit an external morphological trait of the insect and offer a supplement that improves given insect skills; (c) “trap-cards,” which depict entomological instruments (e.g., an entomological net) and can be used to destroy, cancel, steal, and block skills from the other cards; (d) “ritual-cards,” which report a physiological process (e.g., respiration) that can increase the monster’s power level (attack/defense), invite a new and stronger monster, restore life-points, or destroy another monster; and (e) “place-cards,” which describe the insect’s habitat (e.g., forest) and provide advantages for the insect’s skills (Figure 1). The game also includes two playing boards and manuals (see the Supplemental Material available with the online version of this article, which includes a manual entitled “Rules of Insect World”).

Dynamics in the Classroom

The activity was developed for undergraduate students in entomology and invertebrate zoology courses, and/or for students already familiar with the subject at the high school level. The sample used to test the game consisted of 92 undergraduate students.

The students are invited to read the rules, and then each player builds a strategy using 30–40 cards. The strategy should reflect the student’s knowledge of the game’s topics, which can be highlighted by the level of interrelation among different card types. A coin toss is used to decide who will start the game, and both players begin with 4000 life-points. Subsequently, the players are able to purchase additional cards (five cards per individual) and put them down on the board. The game play is defined by the count of animal or “monster” card-points (attack/defense) and the strategic use of various card types to confront the opponent’s cards on the board. To win the game, a player will need to either cause his or her opponent to lose all life-points or capture all the opponent’s cards. The enclosed rule book provides additional details and examples (see Supplemental Material).

Data Collection

Game Feedback

General student behavior when playing the game (e.g., interaction, perception, difficulties, and enthusiasm) was assessed by direct observation and by audio recording with the intent of capturing the students’ perspectives on the game and on the classroom dynamics. These approaches allowed us to recognize and explore

Figure 1. Examples of the five card types in the Insect World deck.
characteristics not usually measurable in experimental tests. In addition, we used an electronic form with open and closed questions to obtain feedback from the participating students on the functional performance of the game and the students’ personal experiences of the activity (the form is available at https://forms.gle/j21TAtVbA4gIuCq9). Observational and descriptive analyses were used to explore the students’ opinions.

**Learning Outcome & Card Interaction Index**

We assessed student learning by tallying the numbers of correct answers on electronic forms that contained closed, multiple-choice questions exploring the subjects of the game activity (available at https://forms.gle/Pm7qpf6yQvdi9wEu5). These forms were completed twice (i.e., pretest and posttest) by each participant, and the change in the number of correct answers in the posttest provided the desired assessment of the student’s learning performance in relation to the game. The difference in learning outcome between pretest and posttest was determined by a paired t-test ($P = 0.05$).

We also measured the card interaction index, a score of all the possible “effective interactions” among cards, through a photographic record of each strategy built by the participants. We considered combinations of cards that reflected a real context (e.g., Coleoptera + Elytra wing card; score = 2) to be effective interactions. Noneffective interactions were penalized with a reduced score (e.g., Coleoptera + Hemelytra wing card; score = 1). Subsequently, the card interaction index was correlated with the learning outcome from the pretest form to evaluate whether the specific entomological knowledge of the player exhibited any relationship with the interaction among cards, which could reflect a better strategy. This relationship was tested through linear regression analysis.

**Outcomes & Interpretations**

The opinions of students on the classroom dynamics and their general behavior throughout the game provided feedback with a functional perspective of the game (i.e., Is the game playable?) and a personal assessment of the game-playing experience by the player (i.e., Do you like it?).

Regarding the functional perspective, we verified that 59.8% ($n = 55$) of the students either were familiar with or had played RPGs, which suggests the popularity of these games and, consequently, a better acceptance of this didactic activity in the classroom. According to the electronic forms, 95.7% ($n = 88$) of the students had previous knowledge of the game’s subject, and 96.7% ($n = 89$) regarded the cards’ contents as important in helping them learn entomology. The rules manual was recognized as informative, succinct, and easy to understand (83.7%, $n = 77$). In terms of game design, the game materials were considered attractive (94.6%, $n = 87$), exhibiting a variety of colors and information, which facilitated game play by establishing links among the colors of the cards and their places on the board. Finally, the level of difficulty of grasping the game’s dynamics, from understanding of the rules up to the final scoring, was recognized as ranging from normal to very easy by 82.6% ($n = 76$) of the students, which accounts for the positive feedback about the understanding of the game manual and design (Figure 2).

The positive feedback on the game’s functionality is likely related to its RPG design, which offers plasticity in decision making and problem solving within a rich context that includes various challenges. However, the cards’ contents, the rules manual, and easy game play also contributed to player immersion and engagement. The students were able to use the narrative and informational elements from the cards and manual to make links between an insect and a specific card (e.g., coleopteran with elytral wings) and thereby make educated rather than random choices of cards. This is important because knowledgeable action, as opposed to random action, is required to proceed with game play in a game environment (Barab et al., 2012; Abdul-Jabbar & Felicia, 2015).

A frequent suggestion found in students’ feedback was to change the game platform from analog to digital (86.9%, $n = 80$). This is consistent with the findings of Abdul-Jabbar and Felicia (2015) that digital games are more commonly used in game-based learning and are preferred by the users. Indeed, we agree with this suggestion and recognize that digital games are promising in game-based learning activities, quickly achieving a broad public response. However, there are some limitations related to digital games that led us to choose the analog (cardboard) approach, including the low sociability achieved with the former (i.e., low face-to-face interaction) and eventual difficulties with accessing electronic media, which is a common problem particularly in third-world countries (West, 2015).

From a more personal perspective, the students considered the game to be fun (100%, $n = 92$), fast (<20 minutes; 96.7%, $n = 89$), and competitive (94.6%, $n = 87$). They also recognized the activity as challenging (96.7%, $n = 89$) because of the functional strategy required to effectively confront the opponent’s cards (Figure 2). Fun and competitive elements are expected in games (Koster, 2013), and their incorporation into game play engages learners emotionally and cognitively, with significant impacts on learning and motivation (Koster, 2013; Abdul-Jabbar & Felicia, 2015). However, a game’s challenges require a precise balance, because too great (or even too little) of a challenge may result in low acceptance by potential players (Bochennek et al., 2007), compromising the continuation of the activity or even leading to more frustration than enjoyment (Bopp, 2006; Ke & Abras, 2013). In other words, a game that is too challenging may act as a deterrent rather than a motivator. However, a more positively balanced challenge incites curiosity toward the content and enhances understanding of the topic, as demonstrated by Tan et al. (2013) and as seen in our results.

The main difficulties with the entomology game, as pointed out by the participating students, are the amount of initial information required to play (i.e., reading of the manual and the cards) and the building of a strategy with adequate interaction among cards. The students also reported some difficulties related to small misconceptions in the interpretation of the game’s rules (e.g., position of cards/card-interaction mistakes), which compromised strategy building and game performance; this could be minimized in a digital format. We have a few hypotheses regarding these difficulties: (1) the students did not favor long, text-rich content (Ramirez et al., 2010); (2) the students had reading difficulties (Ke & Abras, 2013); or (3) the instructions are unclear. Given that the rules manual contains little text and instead relies mostly on illustrations (which were recognized as informative and easy to understand by the students themselves), we reject the first
and third hypotheses in favor of the second one – potential reading difficulties. This limitation would be mitigated by further exposure to the game, as observed in other studies (Bochennek et al., 2007; Ke, 2008; Buur et al., 2013). Nevertheless, the occurrence of reading disorders among students (e.g., dyslexia, autism spectrum disorder, and/or attention-deficit hyperactivity disorder; August & Garfinkel, 1990; Pennington & Ozonoff, 1996) will increase the game’s initial level of difficulty.

Even so, the students considered the game a relevant tool for learning entomology and even suggested that the game can be expanded to other public audiences (e.g., high school students). They scored the classroom activity as outstanding or excellent (79.3%, n = 73) and would like to play the game again (95.7%, n = 88), including with other people (Figure 2). Additionally, they indicated the following qualities as strong points of the game: the easy game play and attractive design, the inclusion of a biological context, its value as a mechanism of science popularization, and its potential for use as a game/didactic interface to allow learning and entertainment in a group.

**Learning Outcome & Card Interaction Index**

Game-based activities are interesting teaching tools within an educational context, making use of ludic and competitive approaches to retain student attention. However, a major issue to consider is this: “Can students actually learn with the game?” Here, we observed an increase in learning outcomes when comparing the scores obtained in the pretest and posttest forms (18.09 ± 0.67 and 20.11 ± 0.66, respectively) (t = 8.72, df = 91, P < 0.001), which highlights the better performance achieved when playing the game (Figure 3).

The students’ improved knowledge-based performance after playing indicates that the game was able to expose them to the desired subject matter, enhancing the use of creativity for knowledge construction. Furthermore, the emotional state of engagement and enjoyment detected among the students while playing the game was arguably an important factor favoring learning (Bopp, 2006; Ke, 2008; Miller et al., 2011; Buur et al., 2013; Ke & Abras, 2013;
Therefore, our findings further challenge the primacy of rigid, lecture-based teaching approaches, as have previous studies encompassing diverse areas (Bochennek et al., 2007; Liu & Chen, 2013; Hwang et al., 2016; Karbownik et al., 2016). Contemporary constructivism defines teaching as “a basic biological capacity, which allows us to change and is not solely due to biological maturation or aging. It always comprises the integration of three dimensions: content dimension (i.e., cognitive, skill, knowledge); incentive dimension (i.e., engagement, interest, and motivation); and interaction dimension (i.e., social)” (Illeris, 2018a, b). These dimensions can easily be integrated in a game dynamic. Here, the constructivist aspect was based on the students’ potential for making interactions among the card types, as well as using the knowledge provided by the cards (i.e., content assimilation) to establish relationships among entomological subjects. Within the context of this study, we expected that a strategy exhibiting more interrelations among card types would reflect the player’s previous knowledge of entomology, since the interconnection of card types improves performance in the game. However, we found that the relationship between the card interaction index and the pretest knowledge scores was not significant ($F_{1,79} = 0.13; R^2 = 0.002; P = 0.71$; Figure 4), indicating that students’ previous acquaintance with entomology did not play a significant role in their development of game strategy during the activity. This result suggests that the students were able to create a suitable game strategy with the information provided in the game, without the need to rely on previously acquired information. It could also suggest that the learning outcomes measured were only loosely connected to the actual subject, but the improved posttest performance observed rejects this hypothesis. Thus, following Piaget’s constructivism (Piaget, 1952), the game playing allowed the students to correlate previous experience and thus broaden their knowledge, resulting in learning, which can be observed in the learning outcome evidenced by the posttest.

In summary, the Insect World game proved to be an effective classroom tool, a didactic activity that encourages creativity and healthy competition among students. Furthermore, the game is a relevant source of learning, exposing students to content knowledge and engaging their minds in a ludic and innovative way. Therefore, we conclude that game-based approaches like this are worthy of incorporation in classrooms as an integrative and dynamic teaching mode, warranting a shift away from traditional learning methods and toward expanding opportunities for creativity and involvement of students. Furthermore, this initiative can be expanded to other public audiences, further benefiting the popularization of science.

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