The effect of using games in teaching conservation

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Games are an increasingly popular approach for conservation teaching. However, we know little about the effectiveness of the games on conservation teaching. Current games are mainly supplemental games (SG) that have no meaningful interaction with the subject matter. We adapted the experiential gaming (EG) model where students were immersed in goal-orientated tasks reflected in real-life situations, and they tackled questions to complete actions for their main task. Classroom-based games were created for 8 different conservation topics for an annual Wildlife Conservation Course and an annual Diploma in International Wildlife Conservation Practice. Data were collected over two cycles, a total sample size of 55 multinational students. We used a combination of repeated-measures design and counterbalanced design: each student was subjected at least twice to each of the EG and didactic instruction (DI) treatments, and at least once to the SG approach. We compared students' perception, learning and behavioral responses to the treatments, including measures of student personality types and learning styles as mediators. Findings revealed multiple benefits of the classroom EG compared to the DI approach, such as increased attention retention, increased engagement and added intrinsic motivation. The improved level of intrinsic motivation was mainly facilitated by increased social bonding between participants. Further, we show that this experiential gaming approach appeals to a wide range of learning styles and personalities. The performance of SG was generally intermediate between that of EG and DI. We propose EG as a beneficial complement to traditional classroom teaching and current gamified classes for conservation education.

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Abstract

Games are an increasingly popular approach for conservation teaching. However, we know little about the effectiveness of the games on conservation teaching. Current games are mainly supplemental games (SG) that have no meaningful interaction with the subject matter. We adapted the experiential gaming (EG) model where students were immersed in goal-orientated tasks reflected in real-life situations, and they tackled questions to complete actions for their main task. Classroom-based games were created for 8 different conservation topics for an annual Wildlife Conservation Course and an annual Diploma in International Wildlife Conservation Practice. Data were collected over two cycles, a total sample size of 55 multinational students. We used a combination of repeated-measures design and counterbalanced design: each student was subjected at least twice to each of the EG and didactic instruction (DI) treatments, and at least once to the SG approach. We compared students' perception, learning and behavioral responses to the treatments, including measures of student personality types and learning styles as mediators. Findings revealed multiple benefits of the classroom EG compared to the DI approach, such as increased attention retention, increased engagement and added intrinsic motivation. The improved level of intrinsic motivation was mainly facilitated by increased social bonding between participants. Further, we show that this experiential gaming approach appeals to a wide range of learning styles and personalities. The performance of SG was generally intermediate between that of EG and DI. We propose EG as a beneficial complement to traditional classroom teaching and current gamified classes for conservation education.

Keywords: Conservation education, conservation games, intrinsic motivation, personality, learning style

Introduction

Effective conservation of biodiversity depends on people's knowledge and actions. Conservation education aims at developing lifelong knowledge and skills relevant for conservation action (Hungerford & Volk 1990). As the human population continues to increase, intensifying the demand for natural resources, there is an increasing need for improved education and outreach methods to effect attitude and behavioural change. In recent years, many techniques have emerged to bring conservation education to life. These techniques integrate the conservation message with a form of delivery that immerse learners in different perspectives. Some of these exciting delivery methods include hands-on activities, role-play and games (Jacobson et al. 2015).

Gamification, the application of game elements in a non-game context (Deterding et al. 2011) has become a trending topic over the past decade. Games are increasingly popular for serious or social purposes in a wide range of fields, including conservation education (Sandbrook et al. 2015). Given the potential to enhance engagement and motivation, environmental educators have utilised games as a way to teach and learn (e.g. Hewitt 1997; Bromley 2000). Conservation often involves hard choices, compromises, and even conflict (Redpath et al. 2013), both of which are rich source material for game creation. By incorporating active learning principles, games can also empower pupils to exercise responsibility for their own lives and for the environment (Tilbury 1995). Thus, games can be a powerful tool for demonstrating and teaching conservation concepts to both children and adults (e.g. Project WILD 2007). However, despite its increasing popularity in conservation education (Bång et al. 2009), there is no empirical evidence on the effectiveness of conservation games. Additionally, when examining the effects of non-conservation games on education, while some studies have demonstrated benefits (Brunsell &

Horejsi 2011; Muntean 2011), others have shown negative effects on motivation and performance (Christy & Fox 2014; Hanus & Fox 2015). This inconsistency in effects could be attributed to a variety of reasons, from the different game types to the different personalities and learning styles of the students (Codish & Ravid 2014b; Hamari et al. 2014b).

Game types comprise of two major forms: supplemental and experiential games. The majority of games in classrooms are supplemental games which use points, badges and leaderboards as a way to motivate and increase engagement amongst students ranging from primary school students to undergraduates (Hamari et al. 2014a; Hanus & Fox 2015). Such gaming mechanisms have been criticized because they offer tangible, expected incentives to students who are already interested in a topic and as a result they may shift motivations from intrinsic (i.e., because they wanted to) to extrinsic (i.e., because they want to achieve the reward; (Deci et al. 2001). However, there is also evidence of incentives given for undertaking tedious tasks actually increasing intrinsic motivation (Lepper et al. 1973) by distracting students from the tedious task, and making the situation more interesting and engaging. This suggests that the points, badge and leaderboards system can be either beneficial or disadvantageous depending on circumstances. An example of a supplemental conservation game is the ‘Freshwater Board Game’ where players move around a board and face ecological events that help them advance or move backwards (School 2013). Players learn about freshwater ecosystem but they have no control over their actions or movements which are mainly determined by the dice roll. The second form of gaming, experiential gaming, differs from supplemental gaming in that players learn about the subject matter while doing other, related tasks. Importantly, experiential gaming advocates immediate feedback on players’ actions, giving the players relevant challenges while they work towards a goal (Kiili 2005). Such a model integrates educational theories and game design to facilitate understanding and optimal learning for participants (Kiili 2005). For example, in the board game 'Conservation Crisis', players manage a wildlife reserve in crisis with a species on the verge of extinction (Gilhead & Milburn 2016). They must thrive to protect their wildlife and mitigate conservation challenges. Hence, players learn about challenges faced by conservationists and the measures needed to protect wildlife. This type of game emphasises on the application of knowledge and students learn about the consequences their actions. Therefore, they are ideal for teaching cause-and-effect systems like conservation biology.

The different game types might also interact with the learning styles and personality traits of learners to give rise to differential responses. Previous studies have demonstrated that an individual's performance is an outcome of an interplay between the educational method, learning style and personality attributes (Chamorro-Premuzic et al. 2008; Richardson et al. 2012). For example, students with high agreeableness and low neuroticism have been shown to prefer more interactive lessons such as group work and practical teaching (Chamorro-Premuzic et al. 2007b). In another study, achievement motivation was positively correlated with the meaning, reproduction and the application-directed learning style, and negatively correlated with the undirected learning style (Busato et al. 1998). Yet, there have been few studies investigating the interplay between these personal factors and an individual's affinity for the different types of games (Codish & Ravid 2014a). This is pertinent especially in the context of conservation education which is usually aimed at a range of large and diverse audiences. Our study aims to address this, examining the appeal and effectiveness of the different gaming approaches to individuals of different learning styles as well as personality traits.

There is a need for research in this area to establish to what extent games really can contribute to conservation teaching. Here, we tested the effectiveness of different game types

(SG and EG) and compared these with the conventional approach of didactic instruction when teaching conservation. We quantified perception with questionnaires, learning effectiveness with quizzes and behaviour via observations and video-recording. Additionally, we assessed whether these responses to different lesson types were affected by the students' personality types and learning styles.

Material Methods

Participants and course details

Our study was conducted on 55 early-career conservation biologists from two courses: a Wildlife Conservation Course in Malaysia and the Recanati-Kaplan Centre Postgraduate Diploma in International Wildlife Conservation Practice in Oxford, United Kingdom.

21 conservation biologists from different countries in Southeast Asia were selected to attend the Wildlife Conservation Course that took place between 19th and 30th January 2015. In 2016, the same course was held again on 4th to 15th January for 16 other participants. This course was held in the University of Nottingham Malaysia Campus (UNMC) and was jointly organized by the Wildlife Conservation Research Unit (WildCRU, University of Oxford) and UNMC. It comprised eight topics (Table 1), ranging from concepts in conservation biology, to transferrable and practical skills. A game was developed for each topic, whereby students were divided into teams competing with one another on the tasks given. All topics were taught by the same tutor, irrespective of the teaching method. This study was approved by the University of Nottingham Malaysia Campus Ethics Committee and participants involved willingly signed an agreement form prior to the lessons.

Another set of participants comprised of sixteen international students (eight each for year 2015 and 2016) attending the 7-month Recanati-Kaplan Centre Postgraduate Diploma in International Wildlife Conservation Practice directed by the Wildlife Conservation Research Unit, University of Oxford. Individuals who were existing conservation biologists were chosen via an interview process by a panel not involving the tutor leading this study. There were 4 males and 4 females in both years. The taught Diploma covered a range of subjects in conservation biology but only in 3-4 topics were the participants subjected to different lesson types (treatment) and had data collected for this study. On two occasions, two PhD students from the Wildlife Conservation Research Unit joined in the lessons and they were included in the study. This study was approved by the University of Oxford Central University Research Ethics Committee and participants involved willingly signed an agreement form prior to the lessons.

Personality and learning style questionnaires

Prior to the start of the course, questionnaires were administered to participants to assess their personality traits and learning styles. The Five Personality Factor test, 5PFT" (five personality factors test) is the first published personality questionnaire specifically created to measure the personality traits now known as the big five (Elshout & Akkerman 1975): agreeableness, conscientiousness, extroversion, neuroticism and openness. The learning styles were measured via the Inventory of Learning Styles (ILS) (Vermunt 1994). Scores were subsequently calculated for each component of Vermunt's four learning styles: undirected, reproduction-directed, application-directed and meaning-directed. Details on the definition of each category of personality and learning style are provided in Supplementary Method S1.

Experimental design

We employed three lesson types: Didactic Instruction (DI), supplemental game (SG) or experiential game (EG) for our classes. The guidelines used to create the games are explained in Supplementary Method S1. We adopted two experimental designs to examine the differences between lesson types: repeated-measures design or counterbalanced design. In a repeated-measures design, a single group of students was taught the first session with one lesson type and then the second session with another lesson type. In a counterbalanced design, the class was divided into two groups and both were taught a two-session lesson. During the first session, one group was taught using one lesson type and the other was taught using the other lesson. In the second session, the treatments were swapped and thus each group experienced both types of lesson in a balanced ordered manner.

The design used was dependent on the number of students and the time available. The counterbalanced approach utilized twice the amount of time and half the number of students each time as compared to the repeated-measures design. Therefore, this design would be limited to situations with more time and with larger groups of students (i.e. student for the Wildlife Conservation Course) because most of the games required a minimum of 8 players (for 4 teams with at least 2 persons each). However, we recognize that the repeated-measures design has a limitation in which students' response to the second session depended on the lesson type of the first session, i.e. order effect. Therefore, where possible, we alternated the order of the lesson type for different topics and different groups of students. Details of the experimental design and order utilized for the different groups of students are provided in Table 1.

Assessment

Participants were assessed in three ways: (1) perception: via questionnaires administered to participants, collecting data of individual perceptions of each lesson (Supplementary Information S1); (2) learning: via quizzes pre and post-session to examine the knowledge acquired by each individual. In 2016, a third quiz was conducted one week after the lesson to quantify long-term knowledge acquisition; and (3) behaviour: via observational surveys and video recording during the classroom sessions.

The questionnaire designed to test students' perceptions was divided into three sections. In the first section, students were asked to compare the lesson to that of a traditional teaching method experienced previously (not during the course) and rate each statement (e.g. teaches me more content) according to whether they strongly disagreed (1 point), disagreed (2 points), no difference (3 points), agreed (4 points) and strongly agreed (5 points) (Supplementary Information S1). The first section of the questionnaire differed slightly between courses and years in terms of the questions asked (statements of 'Encouragement to ask questions', 'Learning from peers' and 'Connection with peers' were not asked of participants of the Wildlife Conservation Course 2015 and statements of 'appreciation of application' were not asked of students in 2015). Sections 2 and 3 of the questionnaire were only administered to students of 2016. The second section of the questionnaire focused on the degree of intrinsic motivation and its predictors: perceived choice, perceived competence, pressure/tension and social bonding (see Supplementary Method S1 for details).

Quizzes consisted of questions asking facts, meaning or application of topic to a real-world situation. Therefore, a question could be categorised as reproduction-, meaning- or application-based question type. They were in a multiple-choice format with 4 options, only 1 of which was right. There were 10 questions for each quiz, comprising of a mixture of question types. Quiz questions based on the questioning or gaming step were a derivative of the questions asked during these steps, not an exact repeat.

We noted the frequency of joyful behaviour (smiling, laughing, clapping, cheering), distracted behaviour (yawning, falling asleep expressions, looking at phones), asking questions, and answering questions. Due to logistical constraints, we did not record behaviour for the R analysis lessons in the Wildlife Conservation Course 2015. Behaviours that occurred for a duration of more than a minute were considered as multiple counts if there was at least a 10-sec interval between the behaviours. During the DI lessons, the same questions used in the gaming lesson were asked verbally and the tutor waited for answers from the participants.

Statistical analysis

All analyses were conducted using R 3.0.2. For the questionnaire, we examined the effects of lesson type (DI, SG or EG) on students' perceptions using a multinomial model with level of agreement as the response, lesson type as the fixed factor, and student and topic as random factors. Year, course (Wildlife Conservation Course or Diploma), age, gender, teaching experience (yes or no), formal teaching training (yes or no) were included as covariates. We used one model for each statement.

We analysed the variation in each behaviour (joyful, distracted, question-asking and question-answering) with two analyses: (i) a Generalised Linear Mixed Model (GLMM) with a binomial error distribution, the 'probability of performing the behaviour' as a response variable, and (ii) a Linear Mixed Model (LMM) with a normal error distribution and the 'rate of behaviour per hour' as the response variable, omitting zeros.

To examine whether learning effectiveness differed with lesson type for the three topics, we entered in a Generalised Linear Mixed Model, with binomial error distribution, correctness as a response (1 = correct; 0 = wrong), lesson type and period (before or after or long-term post lesson (for 2016 only)) and their interaction as fixed factors, and topic and student as random variables. Details on checking for assumption violations, and fixed factors and random factors entered for each analysis are provided in Supplementary Method S1.

Results

Students' perception

Students scored EG and SG significantly higher than DI in the following questionnaire statements: 'remembrance of content', 'motivation to learn after lesson', 'broadens perspective', 'nurtures creativity', 'challenging', 'attention retention, 'engagement with tutor' and 'engagement with student' (Fig. 1A-C; Table S1 & S2). For the statements 'learning from peers' and 'appreciation of application', only EG was scored significantly higher than the DI method, SG attained an intermediate score between EG and DI (Fig. 1A-C; Table S1). EG was scored significantly higher than SG and DI in the questionnaire statements 'connection with peers' (only for 2015 students; Fig. 1C). SG was scored significantly higher than DI in the questionnaire statement 'better understanding'. Lastly, for statements 'amount of content' and 'encouragement to ask questions', no significant differences were found among the lesson types (Fig. 1A & C; Table S1 & S2).

Intrinsic motivation parameters measured only for 2016 students revealed significantly higher scores of 'interest / enjoyment' for EG than for DI (SG attained an intermediate score; Fig. 1D). This self-report measure of intrinsic motivation was not explained by 'perceived competence', 'perceived choice' nor 'pressure or tension' which are predictors of intrinsic motivation (Fig. 1D). Bondedness rating with peers within team, considered a positive predictor of the intrinsic motivation, was significantly higher for EG than for DI (Fig. 1E).

When examining whether the overall rating was affected by personality and learning styles, all except 'Undirected learning style' had non-significant interactions with lesson type on overall rating (Undirected learning score*lesson type: $\chi^2_1 = 7.29$, $p = 0.026$; Table S1). The correlation between overall rating and 'Undirected learning' scores was negligible for EG, and positive for DI and SG (Fig. S1).

Behavioural response

There was a significant difference in the probability of 'asking question', 'joyful behaviour' and 'distraction' occurring among lesson types: students displayed a higher probability of question-asking for EG lessons compared to DI and SG lessons, higher probability of joyful behaviour in EG and SG lessons than in DI lessons and higher probability of distracted behaviour in DI than in SG and EG lessons (Fig. 2A; Table S3 & S4). The frequency of 'joyful' behaviour per unit time was significantly higher in EG compared to SG and DI lessons and the frequency of 'distracted' behaviour per unit time was significantly lower in EG compared to DI lessons (Fig. 2B; Table S3 & S4).

Learning

Overall, students scored higher in quizzes after the lesson than before the lesson. Long-term quiz scores varied (only 2016 students), depending on lesson type. The average long-term quiz scores were similar to that of the after-lesson quiz.

When analyzing all quiz questions, there was no significant difference in learning effectiveness among lesson types (DI *versus* SG *versus* EG), as shown by the lack of interaction between lesson type and period (before or after) on the proportion of quiz answers being correct ($\chi^2_1 = 5.18$, $p = 0.075$; Fig. 3Ai). This lack of significance of lesson type was consistent across both years (Fig. 3Aii and Aiii; Table S5). However, when examining only reproduction-type questions, there was a significant interaction between lesson type and period on the proportion of quiz answers being correct ($\chi^2_1 = 30.0$, $p < 0.001$): the proportional increase in quiz score was higher for DI and EG than for SG (Fig. 3Bsi). This effect was largely attributed to the quiz performance of 2015 students (Fig. 3Bii and Biii). When analyzing meaning-directed and application-directed question scores separately, the non-significant interaction between lesson type and period indicate that students performed equally well in these questions despite the lesson type (Fig. 3C and 3D: Table S5).

Discussion

We have adapted the experiential gaming model to conservation teaching and our results demonstrated multiple benefits of experiential gaming (EG). Based on our behavioural observations and perception data, EGs performed better than DI control in retaining the students' attention, increasing their interactions with other students and the tutor, improving intrinsic motivation via social bonding and motivating students to learn more after the lesson. Additionally, these positive effects of EGs were mostly consistent across personalities and learning styles. SGs performed better than DI in a few perception parameters (e.g. motivation to learn more after lesson), was mostly on par with DI, but fared worse than DI with

'Conscientious' persons and in reproduction-directed learning scores. EG was as effective as DI in learning rate.

Supplemental games have the potential to increase engagement and fun in conservation teaching but they offer extrinsic rewards (points, badges, or token movements) for the participants without providing control over the outcome nor role-immersion (e.g. (School 2013). Cognitive evaluation theory proposes that when an incentive system is perceived as controlling, it can cause one to feel restrained and less competent, which in turn hinders intrinsic motivation (Deci et al. 1975). As such, these game mechanisms can lower students' satisfaction and confidence. In contrast, a student-focused environment for learning like EG, could develop intrinsic motivation (Entwistle et al. 2002) and improve the motivation to study and reach success (Diseth & Martinsen 2003). Our study supports this idea: EG fared better than DI in improving intrinsic motivation and the effect of SG was intermediate between that of EG and DI. Increased intrinsic motivation may in turn encourage students to adopt a deeper approach towards learning, which is associated with intentions to understand rather than to reproduce the material. Moreover, if students prefer teaching methods that are interactive (Chamorro-Premuzic et al. 2007a), or facilitate understanding of relevance (Entwistle & Tait 1990), they are more inclined to use a deep approach. This is especially beneficial for practical conservation like population management and conflict resolution. It would thus be interesting to examine if the learning direction of students change after being subjected to experiential gaming.

EGs are particularly suited to conservation teaching for many reasons. Commercially available EGs such as task-based simulations (e.g. The Sims (Electronic Art 2009)) give players a goal or a choice of multiple aims, and players must act consistently in character to achieve it. The beauty of this open-ended concept is that participants can experiment and fail gently. Similar educational EGs such as a jigsaw puzzle to teach Photoshop skills (Dong et al. 2012) and calibration games to teach calibration (Flatla et al. 2011) work on the same principles of task-based simulation and role-play. They allow for users to experience the process of reaching a set target whilst learning. Indeed, all of these studies demonstrated positive effects in terms of students' perception (Flatla et al. 2011; Smith & Baker 2011; Dong et al. 2012), and behaviour (Halan et al. 2010; Dong et al. 2012), similar to our findings. The potential role of digital EGs in conservation education has also been recognized for at uleast 10 years (Brewer 2003). However, research into the influence of EGs (or games in general) on conservation behaviour is lacking. Moreover, seldom are these games designed specifically for the classroom, that is, they are computer-based games which in turn requires a software developer and may also lack real-time interactive feedback from the teacher/peers. Our study demonstrated that the elevated level of intrinsic motivation when playing experiential conservation games (relative to DI lessons) was largely attributed to increased social bonding with peers. This suggests that EGs might be more beneficial when played in the classroom than on the computer.

EGs create opportunities for experiential learning, which is considered more effective than traditional didactic teaching (Garris et al. 2002). Experiential learning is student-centered and allows for constant feedback from the students to the tutor. A DI lesson focuses on one-directional fact learning in which meaning or application of the knowledge content may not be effectively assimilated by students. However, we found that EG is at least as good as DI in improving learning, be it reproduction, meaning or application. This is in contrast with other studies that have demonstrated positive effects of experiential gaming on learning (Flatla et al. 2011; Smith & Baker 2011; Dong et al. 2012). In these studies, learning was assessed in terms of whether learners were able to perform the task after the lesson (e.g. using a software), while ours was based on multiple-choice questions which was perhaps more suitable for conceptual (rather than software) learning. Nevertheless, perhaps future works could evaluate the differences in assimilation of the process versus concept.

Our results demonstrated that students underperformed in reproduction-based quiz questions during SG classes relative to EG and DI classes. SGs can be considered a distraction from the content such as ones encouraging competition and jeopardise the recall capacity of the students. Similarly, another study propose that the controlling game mechanics of SG can decrease intrinsic motivation and hence reduce exam scores (Hanus & Fox 2015).

While some of the differences in results as reported by past studies can be explained by game type, there are differences in how individuals are affected by gamification which can be explained by personality differences (Hamari 2013; Hamari et al. 2014b). In our study, there are a couple of interesting results on the effects of personality and learning styles on the appeal of games. Importantly, the lack of interaction between personality scores and lesson type on questionnaire scores suggests that the preference of EG over DI is universal across different personality types. These results are contrary to a study showing that agreeableness and neuroticism were positively and negatively associated (respectively) with preference for interactive lessons such as group work and practical teaching (Chamorro-Premuzic et al. 2007a). Perhaps the EG approach is both interactive and fun, which might appeal better to people with low agreeableness (cynical of the world around them) and high neuroticism (tendency to experience negative emotions very intensely). The undirected learning approach is characterised by a lack of discipline and of interest (Tait & Entwistle 1996) and has been shown to be associated with poor academic performance (Boyle et al. 2003; Kimatian et al. 2017). Hence, the preference for EG over SG and DI for students with low undirected scores was not unexpected. SG could be perceived as spontaneous and disorganised and DI could be seen as dry, in contrast to EG where the game is relevant to the topic and students are centre to the learning process.

The EG educational approach does not come without caveats. Creating a game aligned with the topic and obtaining its various components requires more time than preparing a DI lesson. Additionally, the duration of an EG lesson is on average twice the time of a typical DI classroom. We suggest ways of minimizing time expenditure in preparing and teaching EG lessons. First, give students time limit for answering the questions (usually 1 minute) and this would enable the lesson to be time-regulated. Second, instead of regurgitating a lot of knowledge as in DI, focus on teaching important concepts and then provide Supplementary Method for the motivated students to learn after the class. Nevertheless, when there is large volume of content to be covered as dictated by a syllabus and when time is limited, the approach of EG or any form of gamification alone might not be suitable. Further, in developing countries where students might not have access to comprehensive libraries or online access to academic material, the content would have to be provided and explained by the teacher.

To the best of our knowledge, this is the first study to examine the effects of games on conservation teaching. There is scope for many further studies. The effects of the EG approach could be tested on the general public which might have less interest for the work (in this case biodiversity conservation) to examine if the EG approach is able to increase intrinsic motivation in non-conservationists, and cultivate people's minds to be more aware and involved in conservation issues. Further, it would be interesting to examine the effects of personality on group dynamics in an EG environment to better understand the interaction between individual traits and group performances (Kramer et al. 2014). Future work should also investigate the long-term effect of the training such as students' application of the acquired skills and friendship bonds.

Conclusions

EG provides a novel approach to first-hand conservation teaching. Despite the extra time needed for the tutor and for the lesson, our findings demonstrate the many benefits for the students as compared to the traditional DI. The focus shifts from the teacher to the learners, acknowledging the students' voice as central to the learning experience. Educational reforms and pedagogical research are current hot topics (Swallow 2012; Wadner & Compton 2015). The aims are to shift from memory-based learning to meaning- and application-focused education, creating innovative thinkers and developing team-players. Experiential gaming is one approach that could cater to these objectives. Conservation games, if used appropriately, can play an important role in making conservation more immersive, fun and appealing. In particular, EG could be an educational approach towards engaging multinational citizens and professionals with biodiversity conservation and building capacity among conservationists in both NGOs and governmental organizations.

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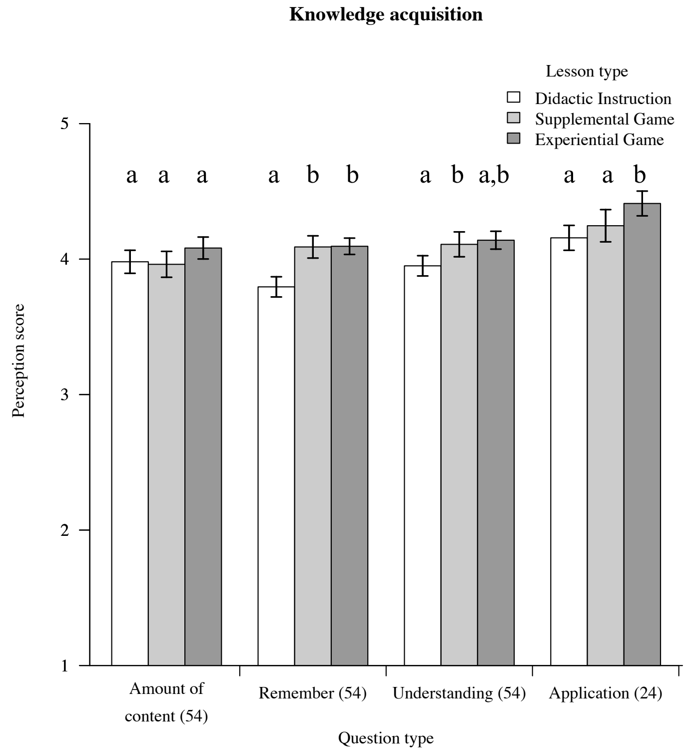
Figure 1 (on next page)

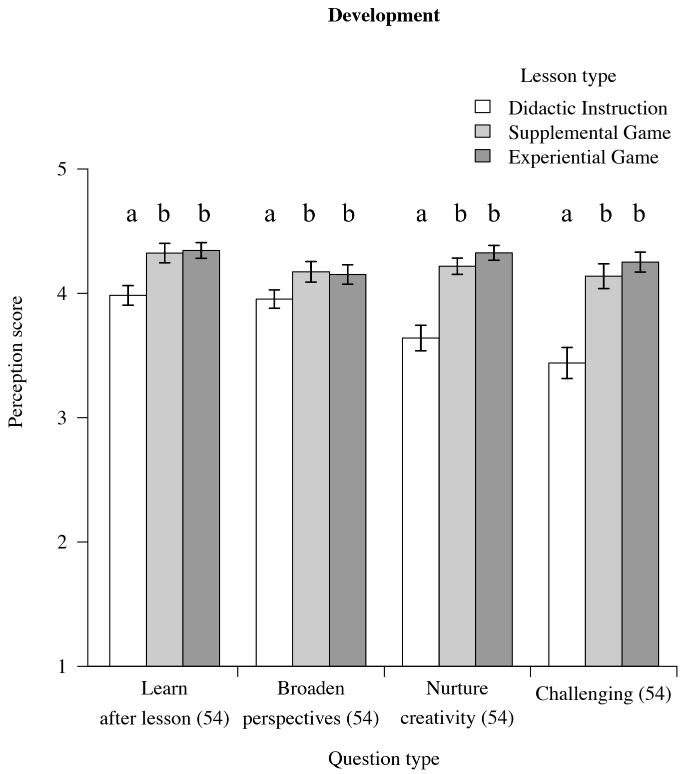
Perception

Figure 1. Students' perception of the different teaching approaches. (A) Knowledge acquisition parameters; (B) Development parameters; (C) Class dynamics parameters; (D) Intrinsic motivation parameters, 'interest or enjoyment' is considered the self-report measure of intrinsic motivation, 'perceived competence', 'perceived choice' are positive predictors of intrinsic motivation while 'pressure or tension' is a negative predictor of intrinsic motivation. (E) Bondedness rating with peers within team, considered a positive predictor of the intrinsic motivation. Error bars denote standard errors of sample size. Sample sizes are indicated in brackets on the x-axis, sample sizes vary because the a few of the questions in the questionnaire were altered between years. Different letters above bars denote significant differences, details of results are shown in Tables S1 and S2.

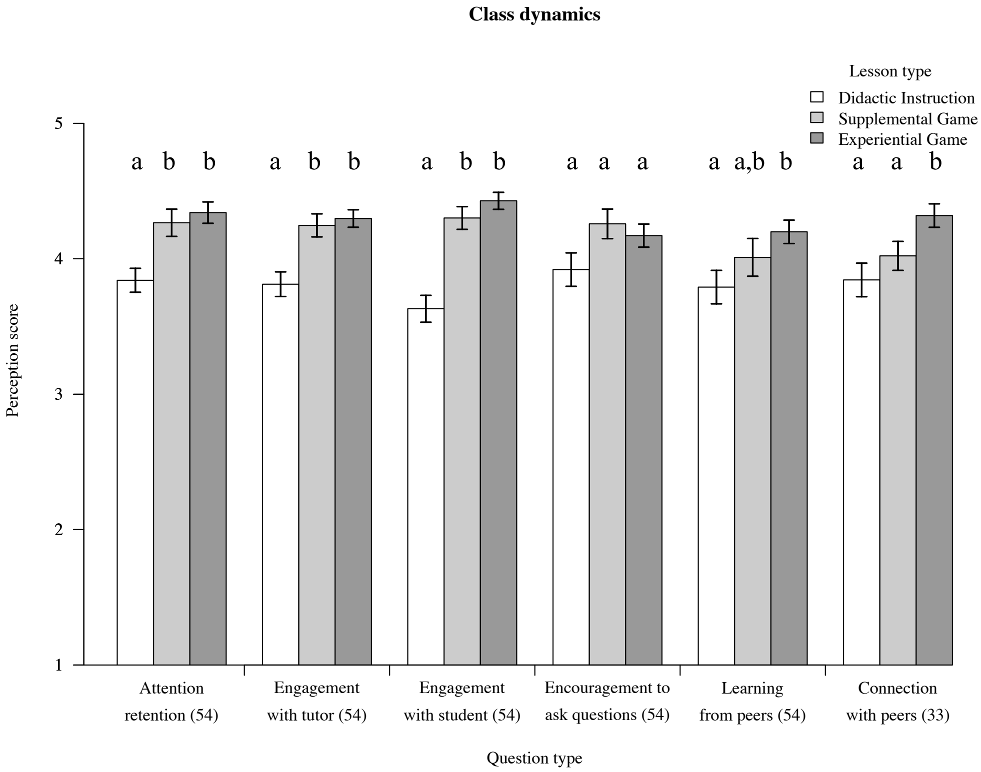
A


Knowledge acquisition
Lesson type
Didactic Instruction
Supplemental Game
Experiential Game
a a a
a b b
a b a,b
a a b
Perception score
5
4
3
2
1
Amount of content (54)
Remember (54)
Understanding (54)
Application (24)
Question type

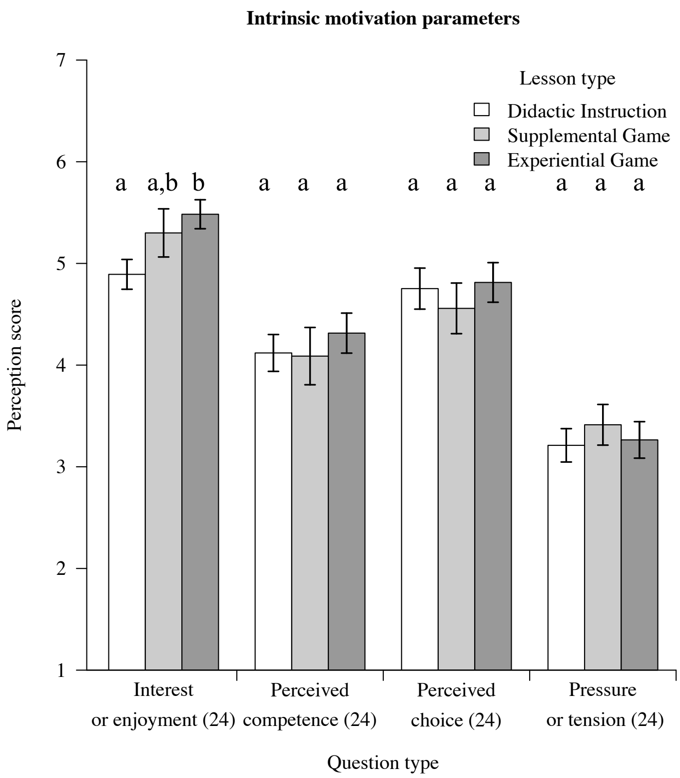
B


Development
Lesson type
Didactic Instruction
Supplemental Game
Experiential Game
a b b
a b b
a b b
a b b
Perception score
5
4
3
2
1
Learn after lesson (54)
Broaden perspectives (54)
Nurture creativity (54)
Challenging (54)
Question type

C


Class dynamics
Lesson type
Didactic Instruction
Supplemental Game
Experiential Game
Perception score
a b b a b b a b b a a a a a,b b a a b
Attention retention (54)
Engagement with tutor (54)
Engagement with student (54)
Encouragement to ask questions (54)
Learning from peers (54)
Connection with peers (33)
Question type

D


Intrinsic motivation parameters
Lesson type
Didactic Instruction
Supplemental Game
Experiential Game
Perception score
a a,b b a a a a a a a a a
Interest or enjoyment (24)
Perceived competence (24)
Perceived choice (24)
Pressure or tension (24)
Question type

E

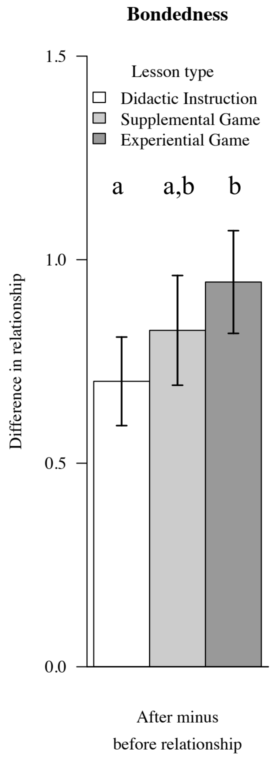
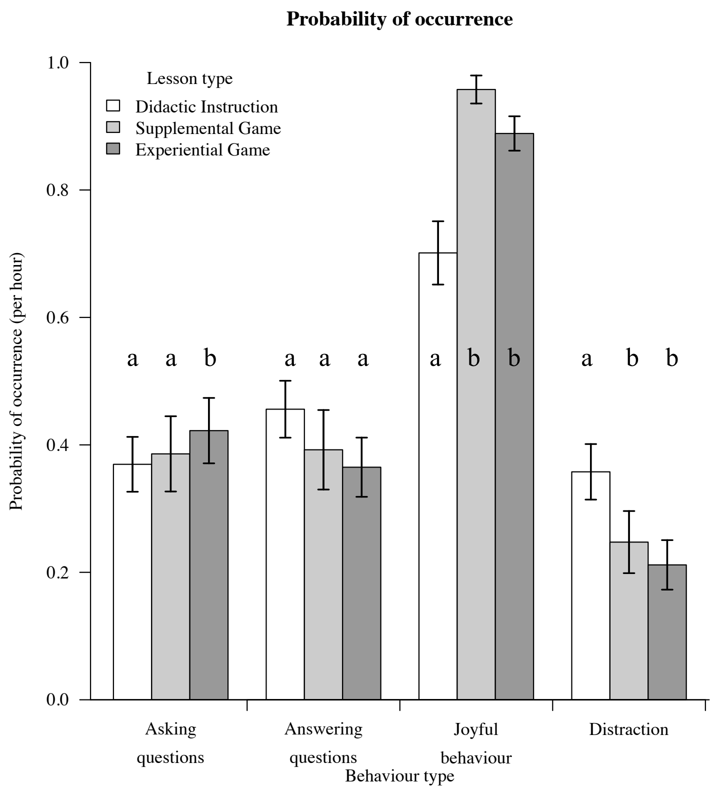

Bondedness
1.5
1.0
0.5
0.0
Lesson type
Didactic Instruction
Supplemental Game
Experiential Game
a
a,b
b
Difference in relationship
After minus
before relationship

Figure 2(on next page)

Behaviour

Figure 2. Students’ behavioural responses to the different teaching approaches. (A) Probability of behaviour occurrence; (B) Frequency of occurrence. Error bars denote standard errors of sample size (n = 54). Different letters above bars denote significant differences, details of results are shown in Tables S3 and S4.

A


Probability of occurrence
Lesson type
Didactic Instruction
Supplemental Game
Experiential Game
Probability of occurrence (per hour)
1.0
0.8
0.6
0.4
0.2
0.0
a a b
a a a
a b b
a b b
Asking questions
Answering questions
Joyful behaviour
Distraction
Behaviour type

B

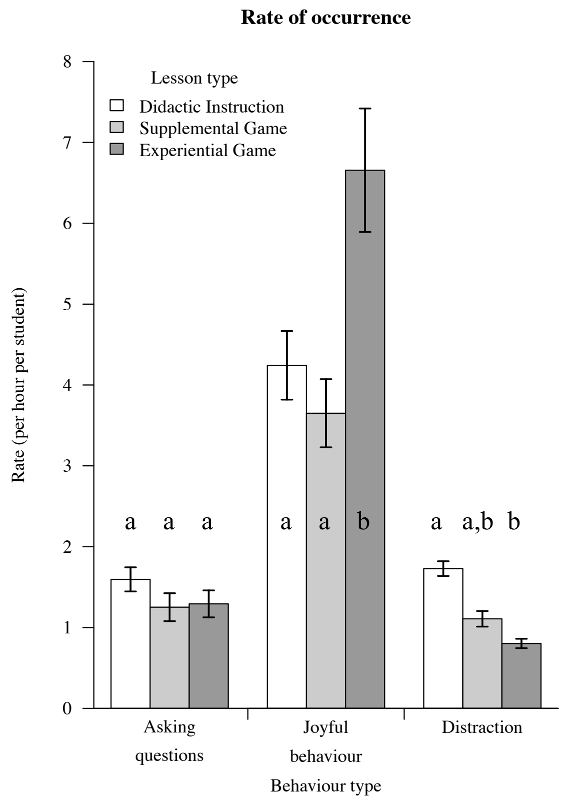
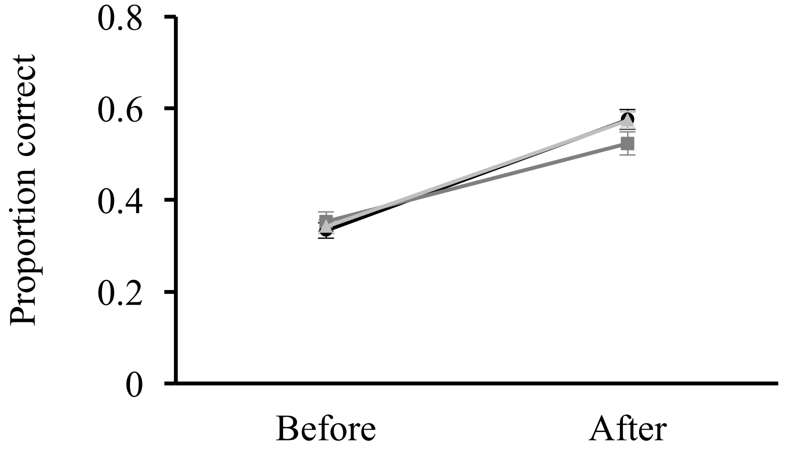

Rate of occurrence
Lesson type
Didactic Instruction
Supplemental Game
Experiential Game
Rate (per hour per student)
8
7
6
5
4
3
2
1
0
a a a
a a b
a a,b b
Asking questions
Joyful behaviour
Distraction
Behaviour type

Figure 3 (on next page)

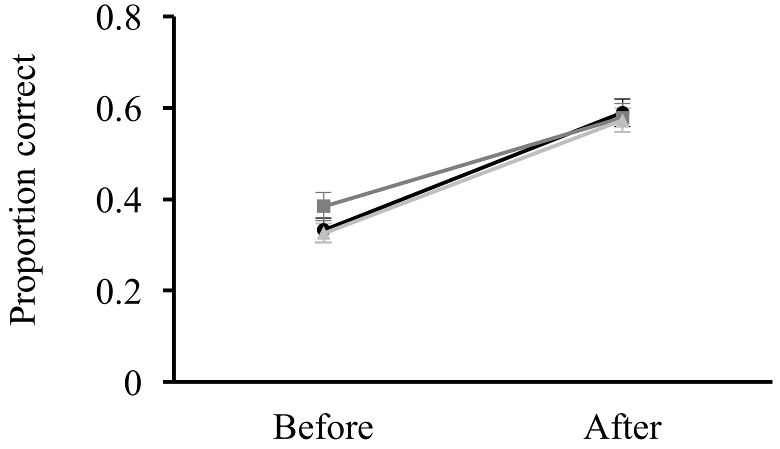
Learning

Figure 3. Learning as measured by proportion of quiz questions correct before or after lesson or long-term (LT) post-lesson. Different lines denote different teaching approaches. (A) All question types; (B) Reproduction-type questions; (C) Meaning-type questions; (D) Application-type questions. Error bars denote standard errors of sample size ($n_{both\ years}$ = 55; $n_{year\ 2015}$= 30; year 2016 = 25). Details of results are shown in Table S5. DI – Didactic Instruction; SG – Supplemental Game; EG – Experiential Game.

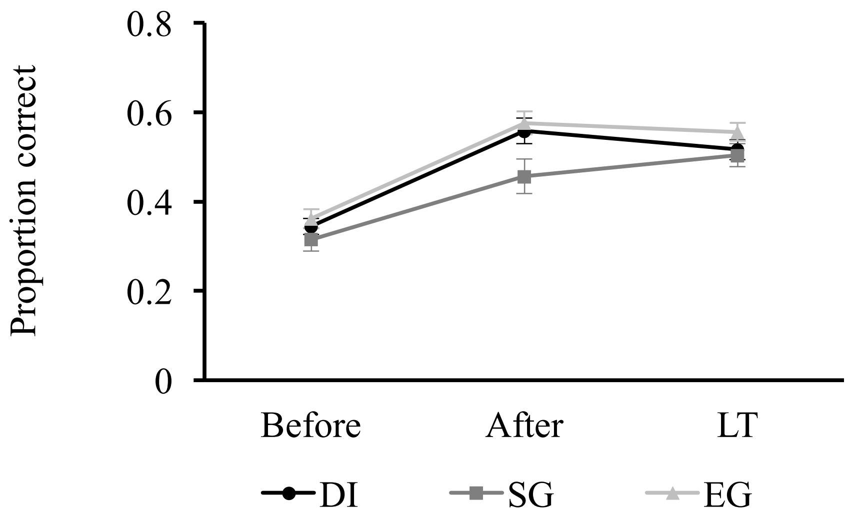
A i. Both years



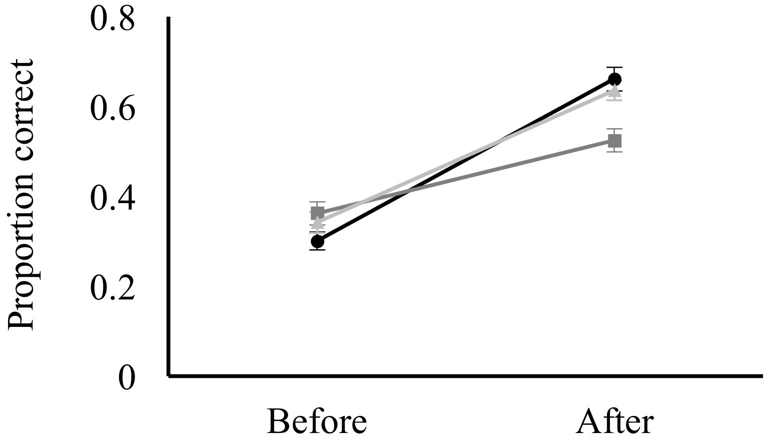
ii. Year 2015



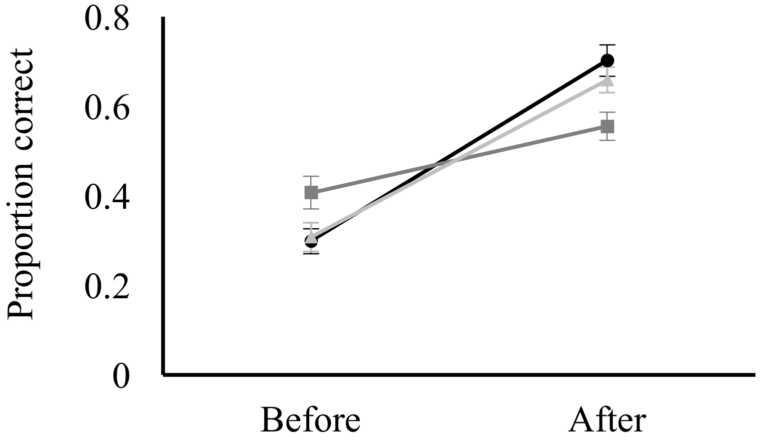
iii. Year 2016



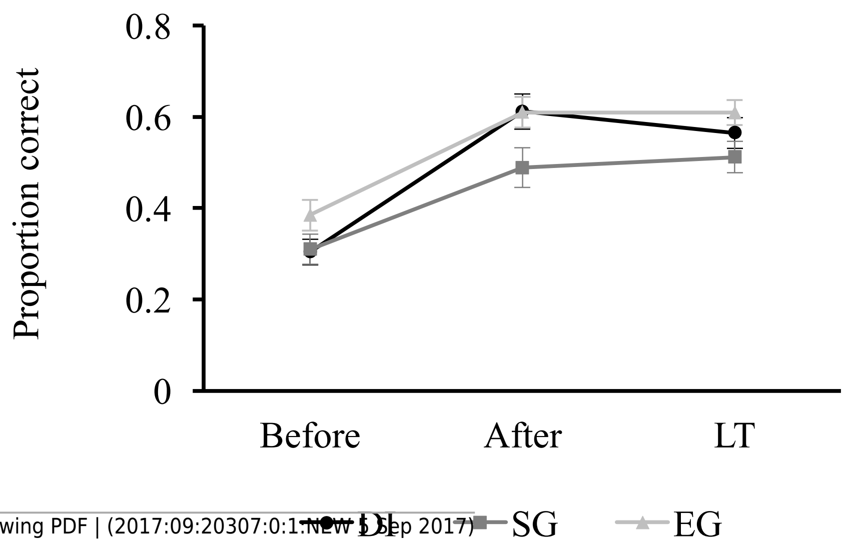
B i. Both years



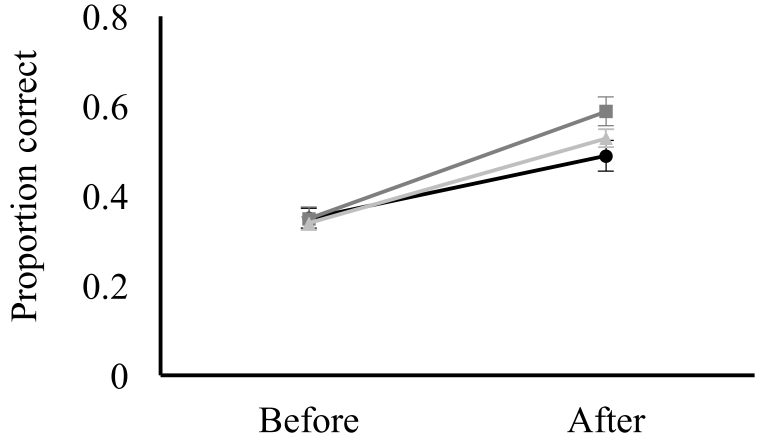
ii. Year 2015



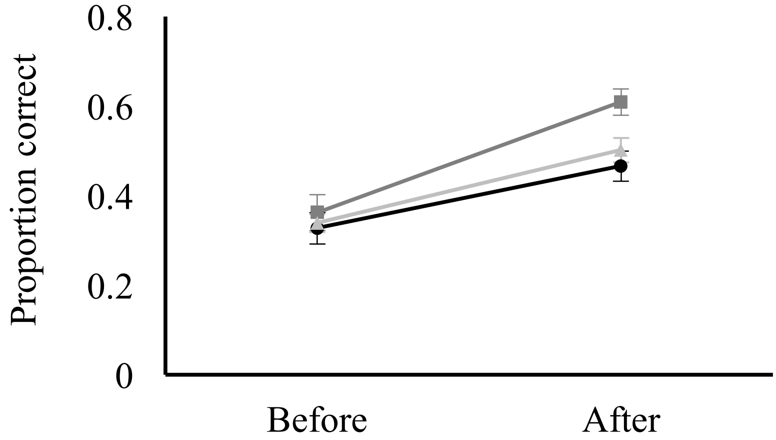
iii. Year 2016



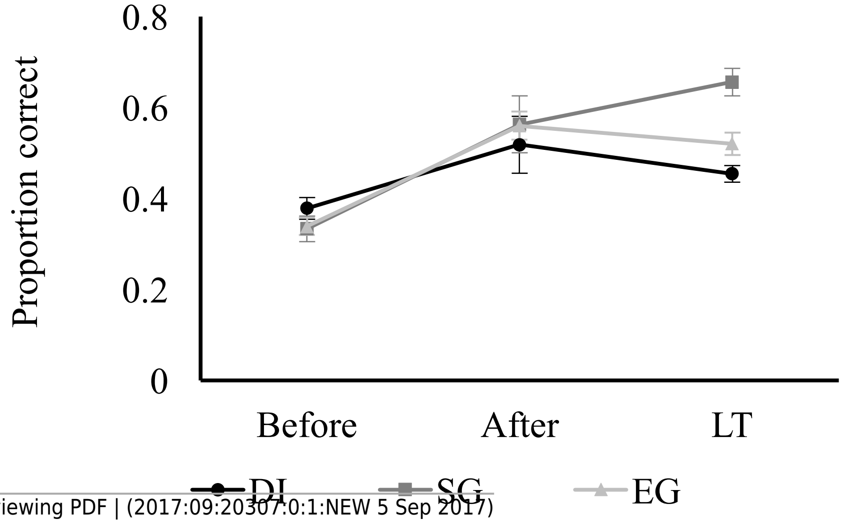
C i. Both years



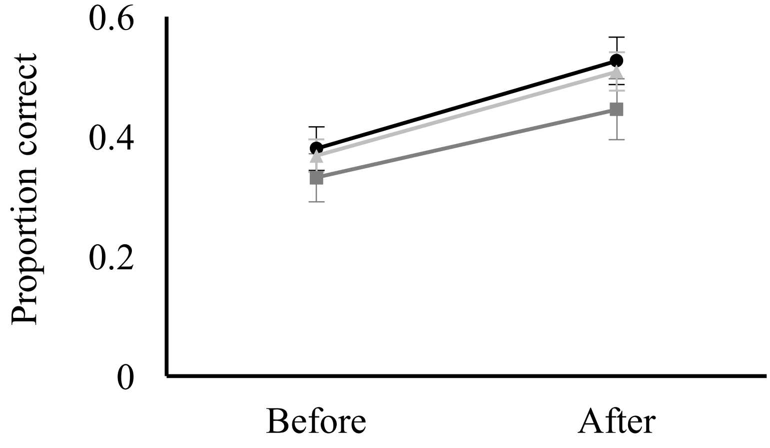
ii. Year 2015



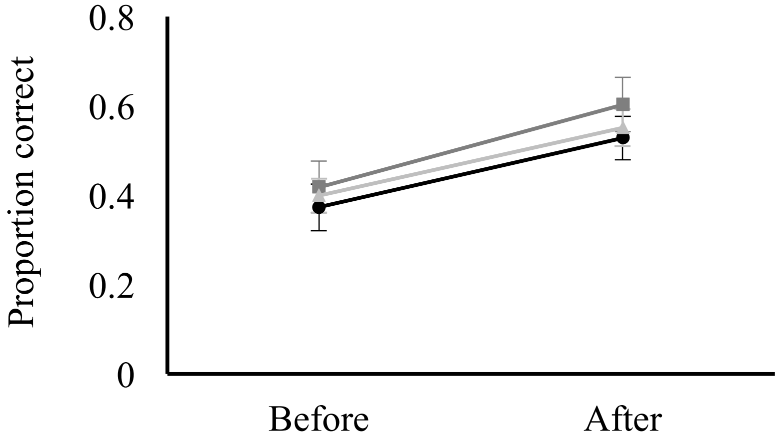
iii. Year 2016



D i. Both years



ii. Year 2015



iii. Year 2016

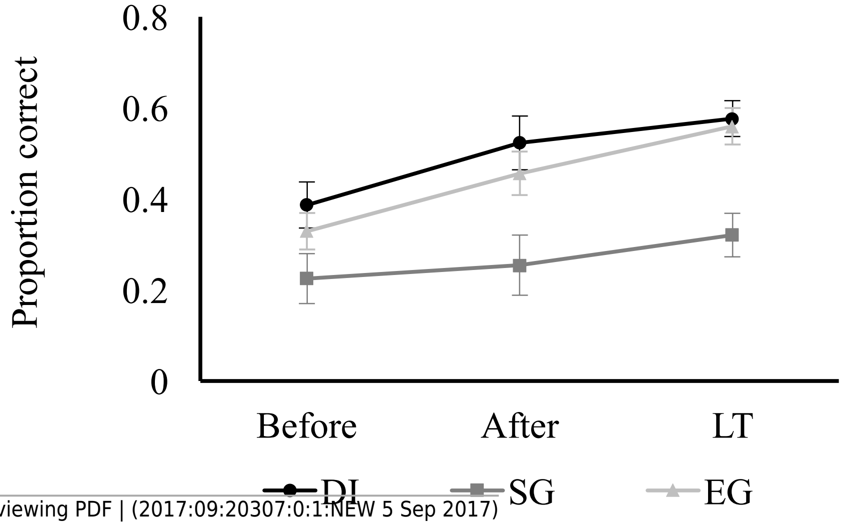


Table 1(on next page)

Topics taught during the Wildlife Conservation Course (WCC) and Diploma in International Wildlife Conservation Practice and the experimental design used

Table 1. Details on the experiential gaming (EG) task or supplemental game task (SG) assigned to the teams are provided. Repeated-measures design: a single group of students were taught the first session with one lesson type and then the second session with another lesson type. Counterbalanced design: class was divided into two groups and both were subjected to a two-session lesson. During the first session, one group underwent one lesson type and the other underwent the other lesson. In the second session, the treatments were swapped and thus each group experienced both types of lesson in a balanced ordered manner.

Table 1. Topics taught during the Wildlife Conservation Course (WCC) and Diploma in International Wildlife Conservation Practice and the experimental design used. Details on the experiential gaming (EG) task or supplemental game task (SG) assigned to the teams are provided. Repeated-measures design: a single group of students were taught the first session with one lesson type and then the second session with another lesson type. Counterbalanced design: class was divided into two groups and both were subjected to a two-session lesson. During the first session, one group underwent one lesson type and the other underwent the other lesson. In the second session, the treatments were swapped and thus each group experienced both types of lesson in a balanced ordered manner.

Topic	**Type**	**Task**	**Experimental Design**	**Course**
Behavioural Ecology	EG and DI	Teams were species of mammals interlinked via a food web and had to behave like the species to reproduce, feed or avoid being predated by other teams	Counterbalanced	WCC 2015 and 2016
			Repeated-measures (EG then DI)	Diploma 2016
Conservation genetics	EG and DI	As conservation geneticists, teams had to manage a population of coloured casino chips by betting on their answers. Different colours represented different	Repeated-measures (EG then DI)	Diploma 2015

		phenotypes. The goal is to avoid stochastic and genetic events (e.g. genetic drift) and attain a population as heterogeneous as possible.		
Human-wildlife conflict	EG and DI	Assuming the roles of government, conservation biologists, rural population or urban population, teams are given the task of managing a forest where human-wildlife conflict is prevalent	Counterbalanced	WCC 2015 and 2016
Capture-mark-recapture	EG and DI	Teams were conservation biologists tasked to buy different models of camera traps, deploy them in a forest board and subsequently analyse the collected data to reveal the density of clouded leopards	Repeated-measures (EG then DI)	Diploma 2015 and 2016, WCC 2016
Vegetation statistical analysis	SG and EG	Teams aimed to either obtain the most number of chocolates (SG) or prevent the continuous vegetation from being disconnected (EG)	Repeated-measures (SG then EG)	Diploma 2016
Spatial-temporal	EG and DI	Teams were species of mammals attempting to either avoid (as prey) or overlap (as predator) the activity of	Counterbalanced Repeated-measures	WCC 2016 Diploma 2016

patterns		other teams	(DI then EG)	
Population viability analysis	SG and DI	Teams were to obtain gummies by answering the questions correctly	Counterbalanced	WCC 2015
R analysis	SG, EG and DI	Using the software R, teams were answer questions in order to advance forward on a game board (SG) or to obtain tokens for designing an experiment (EG)	Repeated-measures (SG then EG) Repeated-measures (SG then DI then EG)	Diploma 2015, WCC 2015, 2016 Diploma 2016