USING FICTION IN PHYSICS' LABORATORIES TO ENGAGE UNDERGRAD STUDENTS

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Learning experimental physics is often perceived as being poorly engaging by students, especially at the university level. We wanted to test whether an immersive format could increase students' engagement in experimental physics. Forty-six second- and third-year university students (18 females, 28 males) were immersed into a fictional scenario. The learning goals were centered on experimental methodology and transversal skills, such as teamwork. They were all given a role in a story that unfolds during the class (not unlike a live-action role play). All of them had to perform physical measurements, not because their teacher asked for it but because the scenario they were going through required it. For 28 students we could measure the impact of the fictional scenario on their behavioral, emotional and cognitive engagement by comparing with teaching as usual. The results show that students' emotional engagement was higher in the context of immersion ($p<0.001$). No behavioral or cognitive effects were found. Student transcripts confirmed that they enjoyed the use of fiction, and that the learning goals were achieved. We were concerned that fictional scenarios could result in differentiated effects among gamers; in the population of all students who followed this new teaching, we found no correlation between the students' gaming habits and any engagement scores. No gender effect was found for students' engagement. It would be interesting to test the use of an immersive scenario in other contexts where engagement is known to be poor.

Keywords: Engagement, Emotion, Physics, Context-based learning

INTRODUCTION

A central objective of physics education is to foster experimental abilities such as modeling, designing experiments, and analyzing data (Kozminski et al., 2014). Physics labs are important in physics education, and can have different goals: develop practical skills, develop conceptual understanding, promote the scientific method, develop creative thinking, and also to arouse and maintain interest (Tamir 1974, Hofstein 1982).

However, students do not always appreciate physics' labs (Deacon 2011, Solokoff 2007), particularly in the case of cookbook laboratories where students follow a precise protocol with no margin for autonomy. As physics teachers, we became interested in the question of student engagement, and how to adapt our practices to increase it. We wanted to test whether the use of an immersive approach with a fiction scenario had an impact on the engagement of our students. To do so, we developed a new course in which all participants (students and teachers) play a role and must act accordingly. The students perform physics experiments in response to the story they are immersed in.

CONCEPTUAL CONSIDERATIONS

Engagement is a multi-dimensional construct that can describe student's actions and emotions (Fredericks et al., 2004). Engagement is a very malleable notion, and different dimensions have been attached to this concept (Alrashidi 2016). Frederick and colleagues (2004) put forward a model based on three dimensions: behavioral, emotional, and cognitive engagement. Behavioral engagement encompasses student participation in class activities and outside activities; it refers to how involved the student is in the learning activity. Emotional engagement encompasses emotions and feelings related to the educational environment; it refers to the presence of positive emotions during task involvement and to the absence of negative emotions. Cognitive engagement encompasses the learning practices and strategies; it refers to the strategic use of sophisticated rather than superficial learning strategies. It is worth noting that student engagement defined as such can evolve in time and differ between different topic.

This new course ("immersive teaching"), described below, presents some clear features of gamification, a process that has been used and studied in higher education. Gamification is known to increase engagement (Hamari et al., 2014; Riemer 2015). It should be notice that students' response could depend on their gender (Bonanno 2008; Riemer 2015) and their gaming attitude (Bonanno 2008). Women underrepresentation in physics at university level is well known and has been addressed many times in the literature (for example, see Allaire-Duquette 2014). The effect of active engagement activities on this gender gap is debated (for more details, see for example Karim 2018). The issue that our research is addressing is the impact of an immersive pedagogical learning device involving fiction (the immersive teaching) on a typical second – and third- year university physics students' sample.

MATERIAL AND METHODS

Participants

The work presented here was carried out in January 2020, before the COVID pandemic, both in Paris-Saclay University ("Paris") and in Bordeaux University ("Bordeaux"). In both universities, a two-day long immersive teaching following the principles presented below was proposed to students, using a different scenario and with different teachers.

In Bordeaux, 18 second-year science students (M ± SD = 19.4 ± 1.2 year-old; 9 females, 9 males) followed the immersive teaching, under the supervision of two physics teachers. In Paris, 31 third-year science students (M ± SD = 20.6 ± 1.4 year-old; 9 females, 22 males) followed the immersive teaching, under the supervision of two physics teachers. The same 31 students from Paris also followed a second course with very similar pedagogical objectives, also using active pedagogy but without any immersion, and with two different physics teachers.

Description of the immersive teaching

The pedagogical objectives are to let students work on their experimental skills, in particular by letting them build experimental devices designed by them. In addition, this teaching includes transversal objectives such as teamwork, resolution of open-ended problems, and finally pleasure of doing physics.

This new teaching was developed jointly between the Paris-Saclay University and Bordeaux University. Its core principle is that students are immersed in a scenario that will encourage them to perform some physics experiments. As in a life-action role-play (LARP), all participants (students and teachers) play a role and must act accordingly. However, in contrast to LARP, students have no specific back story or different set of agendas. They behave as they would naturally and try to solve the different problems that arise. Their roles are generic and similar: they play the role of young scientists, (e.g. an engineering team), who provide technical support for people in difficulty (e.g. spies, astronauts, …). An unforeseen crisis forces them to quickly work on a series of experimental devices needed by non-player characters. The teachers are characters that have no particular physics knowledge but which are responsible for the organization (human relation managers for example): this allows them to keep the responsibility of the schedule while justifying their inability to help the students in the scientific tasks, giving students a large autonomy in their organization and production. Teachers can occasionally switch character if the scenario requires it. A typical example is when a scientific expert is needed: changing a nametag and a piece of clothing is enough to do so. For the immersion to work, teachers must play their roles seriously, as if it was real, but there is no need for good acting skills: they benefit from the students' willing suspension of disbelief (Muckler 2017). This concept, which describes the fact that one is willing to accept a story in order to enjoy it, allows, for example, to seriously consider the different ways to interact with extraterrestrials. Small details (e.g. nametags, graphical charter of all documents, some small accessories …) help with this. Interactions with non-player characters and progress in the scenario are conducted through webchats or mails (which are controlled by the teachers), and also through audio and video messages that have been prepared in advance.

From a practical point of view, this teaching is given to science students in their second or third year of university studies in Paris (~30 students / year) and in Bordeaux (~30 students / year). In both universities, this teaching takes up two consecutive full days and is supervised by two physics teachers. Prior to these two days, the students are made aware of the objectives and principles of this teaching during a short briefing meeting.

The fiction begins with a convocation letter that is sent to the students, with the date and location. This letter marks the beginning of the fiction, since it is addressed to the characters the students are playing. The location is not one of their usual classrooms, but one from another section of the university, away from their usual grounds. At the beginning of these two days an icebreaking activity is organized, but the given reason for the convocation is an excuse: very rapidly after the icebreaker a crisis is triggered which requires the team to respond to an external demand for technical assistance (for example, a very secret space mission is about to land on an unknown planet and needs help). The story is organized around a series of scientific activities, each activity advancing the scenario, and leading to the next activity. We typically plan for four activities, of about half a day each. These activities are open problems that do not have unique solutions, but require students to build, test, and often document experimental devices. The physics involved is rarely complicated (mainly mechanics and small electronics), and the equipment available is not very advanced. For example, students must design a device to send a camera as far as possible without damaging it (see Figure 1). The difficulties for the students are often to organize themselves, and to fully carry out the realization of the requested device, including testing and comparing their results. The scenario sometimes allows for some different outcomes depending on the quality of students' work, but generally the scenario is constructed to avoid complete failure in order to ensure a better experience for the students.

The fiction closes with an end credits (often literally, with the students' names projected on a wall with music), which allows everyone to get back their own identity. A collective debriefing is then organized in order to recontextualize the teaching, to listen to the students' feedback, and to give them feedback on their work.

Figure 1. Students, during the immersion teaching, working on a prototype to help stranded astronauts.

In Paris, the same students also followed a second lab course; in the rest of this article, "Immersion" will point to the first teaching (either in Paris or Bordeaux), and "teaching as usual" to the second (in Paris only). This second course, "teaching as usual", also used an active pedagogy; during two non-consecutive days, supervised by other physics teachers, the students had to build up from scratch an experimental setup to study a physics phenomenon. It was close to the "immersion teaching" in format, objective and duration, with one major difference: no element of fiction was present.

Data collection and analysis

Just at the end of the course (either the immersion or the teaching as usual one), students were asked to answer an online survey aimed at measuring their engagement. We used a new version of Parent's survey was used to capture student engagement, (Parent, 2017). Parent's survey was specifically built to study the engagement of students during an active pedagogy teaching, and has been validated in French. Originally each dimension of engagement was measured by 10 questions, but we had to left out some questions that were not applicable to our situation, such as questions about the work done during the week between two classes (our teaching is held on two consecutive days). We kept 5 for behavioral engagement, 10 for emotional engagement, and 8 for cognitive engagement. To establish an engagement score we took the average of the responses, using 4-point Likert scales, 1 being the minimal, and 4 being the maximum engagement.

We were also concerned that, due to the game-like aspect of this teaching, their gaming habit could have an influence on their engagement, and we tested this parameter. To measure this effect, we adapted a survey made by Berry et al. (in press) used to study the gaming habit of the French population. These answers were transformed into a 0-100 scale gaming score, 0 denoting a student that has never played any games, 100 a student who plays often many games. The value of this score has no absolute meaning but it allows to rank students and look for correlation between gaming habits and engagement scores. This survey measures the general culture of participants, including board games, card games, …: it is not restricted to video games.

In addition, we also specifically asked the students if they had ever participated in a LARP. The immersion teaching has many common features with LARP, and we tested if there were significant differences in the engagement between the students who had already participated in a LARP and those who didn't.

This survey also contained open questions at the end to collect students' verbatims and impressions.

Of the 31 Paris students, 28 students (M ± SD = 20.4 ± 1.0 year-old; 9 females, 19 males) answered both surveys (after the immersive teaching and after the teaching as usual), and all students from Bordeaux answered it after their immersive teaching. Inter-groups, intra-group and regression statistical analyses presented below were carried out with R 2.9 software (http://www.r-project.org/) using 'car', 'effects', and 'Hmisc' libraries. The graphical representation was obtained with ggplot library.

Since the response to serious games was reported to be gender-dependent, we tested the effect of gender on our results.

RESULTS

Cronbach's alpha test gives 0.81, 0.40, and 0.62 for the survey questions related to emotional, behavioural, and cognitive engagement respectively.

To determine whether the immersive format added value in terms of engagement, we ran the analysis only on the Paris dataset – the only students who have followed both the immersive and the as-usual teaching. For each engagement type, a paired t-test was used to look for significant differences between these two teachings. We found a format effect on emotional engagement, ($\beta=0.36$, $F(1,27)=15.81$, $p<0.001$, PRE=0.37, IC 95%[0.17,0.55]), with students significantly more engaged during the immersion class than during the teaching as usual. No significant differences were observed for the behavioral and cognitive engagement scores (See Figure 2 and Table 1).

Table 1. Engagement scores for the 28 Paris students (mean ± standard deviation). Null engagement is 1, maximum is 4. Bottom row is the p value for the paired t-test corresponding to a significant difference between the two teachings.

Teaching	Behavioral engagement	Emotional engagement	Cognitive engagement
Immersion	3.05 ± 0.33	3.41 ± 0.34	3.22 ± 0.39
Teaching as usual	3.02 ± 0.44	3.04 ± 0.4	3.10 ± 0.37
p value	> 0.1	< 0.001	0.067

We now focus on the immersion teaching only. We looked for an effect on the students' engagement during the immersion of their gender, their gaming score, and also of whether they had already participated to a live-action role play. For this study, we considered all the students who experienced this teaching, in Paris and Bordeaux. We pooled both datasets: the results below were obtained on a population of 46 students, 18 females, 28 males.

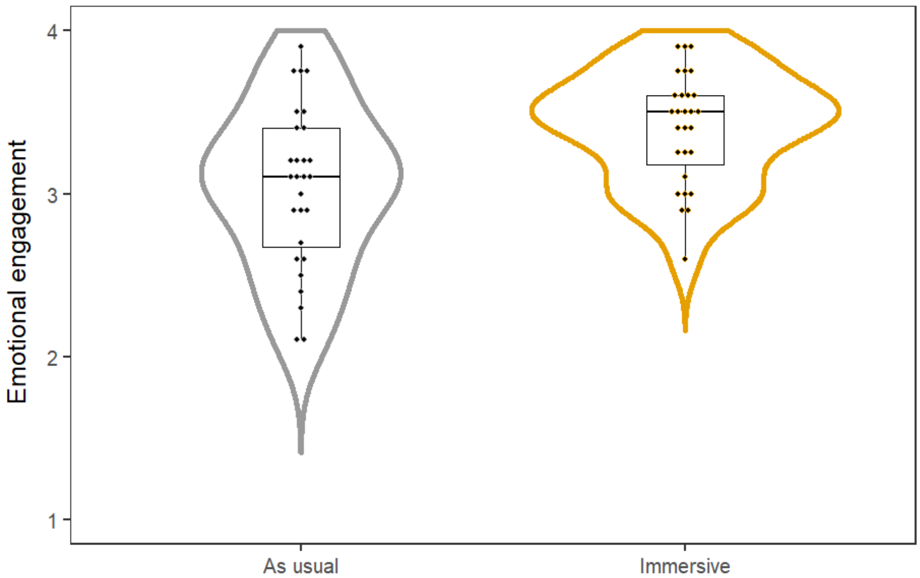

Figure 2. Students' emotional engagement during the immersion and during the teaching as usual, on a scale from 1 to 4, 4 being the most engaged.

Concerning a gender effect, Table 2 presents the value of engagement during the immersion teaching for the female and male students separately. For each engagement type, no gender effect was found using an independent t-test. All the same, we noted a gender effect on the gaming score, with male students scoring higher than females ($\beta=18.52$, $F(1,44)=6.2$, $p=0.02$, PRE=0.12, IC 95%[3.53,33.50]).

Concerning the gaming score, the average for students' population is 39.9 ± 13.0, with 0 indicating a student who has never played any games, and 100 a student who plays various games a lot (this scale is arbitrary and not linear). The correlation coefficients between this gaming score and the engagement scores are not significant for emotional and cognitive engagement. A significant correlation was found for the behavioural engagement ($\beta=0.008$, $F(1,44)=7.39$, $p=0.009$, PRE=0.14, IC 95%[0.002,0.01]).

Concerning the effect of having already participated to a live-action role play, 20 students among 46 answered that they had already done so. However, we found no significant effect of this experience neither on emotional nor behavioral or cognitive engagement.

Table 2. Engagement and gaming scores (mean ± standard deviation) for the immersion teaching pooling Paris and Bordeaux datasets, by gender (18 females, 28 males). Null engagement is 1, maximum is 4. Bottom row is the p value for the paired t-test corresponding to a significant difference between the two teachings.

	Behavioral engagement	Emotional engagement	Cognitive engagement	Gaming score
Female students	3.0 ± 0.3	3.6 ± 0.2	3.4 ± 0.4	34.3 ± 11.4
Male students	3.1 ± 0.3	3.4 ± 0.4	3.2 ± 0.3	43.5 ± 12.8
p value	> 0.10	> 0.10	> 0.10	0.02

The students' transcripts from the survey open questions contain many answers where the fiction was mentioned in relation to their emotional engagement. The role of teamworking was also often mentioned (translated):

- *"[fiction] It motivated us more to do the different tasks";*
- *"I loved that the teachers were fully in their roles until the end, it pushed us to play the role, and it made the experience unique and very interesting, it's a great way to introduce people to science";*
- *"An amazing experience";*
- *"[fiction], it allowed us to get out of school and work in a good atmosphere. [I learned] mainly to work in a group, to integrate myself, to impose my point of view while knowing how to listen to that of others, to make compromises ..."*

DISCUSSION

The Cronbach's alpha test performed on our survey shows that it correctly measures emotional and cognitive engagement; the measurement of behavioral engagement is not as good

(Nunnally, 1978). The original survey has been validated but the part measuring the behavioral dimension of the engagement is the part that we reduced the most (only five of the ten questions were kept), which could explain this difference.

The main result is that the students' emotional engagement was significantly higher during the immersive teaching than during the teaching as usual ($p < 0.001$, see Figure 2), without the other forms of engagement being significantly modified in one way or another. Both teachings had the same duration, the same pedagogical objectives (experimental practice in physics in the broad sense), both used an active pedagogy, with open problems of physics and with large student autonomy: the most likely cause for this increase of students' positive emotions is the use of fiction during the immersion teaching. Another important result is that this increase did not happened at the expense of the other dimensions of engagement, cognitively or behaviorally. It is however impossible to refute the existence of other biases between the two teachings. We tried to minimize these biases as much as possible. The students' transcripts provide support for the idea that using fiction was a crucial point as it was often mentioned in a positive manner. However, some important differences in the organisation could not be avoided and may have also play a role: the teaching-as-usual course was during two non-consecutive days (instead of two consecutive days for the immersion) and the teachers were different. Teachers are a known bias toward positive results in education studies (Hattie 2008).

These results can be linked to reports that gamification in education generally increases engagement (Hamari et al., 2014). No correlation was observed between the emotional engagement scores and the gaming scores of our students, nor with whether they had already participated to a LARP or not. This result is obtained by pooling Paris and Bordeaux datasets, making it more robust size-wise. The only significant effect we measured was on the behavioral engagement. However, this is the dimension of engagement with the lowest Cronbach alpha test value and can be treated as a solid result. We conclude that the use of fiction did not create any noticeable differences between our students.

The fact that the gaming habit does not correlate with the engagement score is surprising at first sight. However, our population (young science students) possesses a higher game culture than the rest of the general population (Berry et al., in press) and is likely to be homogeneous with regard to gaming habits. It is possible that differences could be observed on more heterogenous populations.

No gender difference was observed in the engagement scores, which is an important result for us since stem studies are traditionally less engaging for female students. There seems to be a slight tendency for a better emotional engagement in the female population (Likert score: 3.6 ± 0.2) compared to the male one (Likert score: 3.4 ± 0.4), even though it remains below the significance threshold. At the very least the immersion teaching did not produce a negative bias among the female population. The gaming scores shows that the female students have a lower gaming habit than the male students; this bias is not correlated with the engagement scores, and even though this difference is significant, the gaming habit of the female students remains high compared to the general population as previously noted.

CONCLUSION

The use of fiction in our teaching increased the emotional engagement of students. This occurred independently of our students' game culture, measured in two different ways. No significant differences could be observed in relation to the students' gender. In addition, the transcripts show that our educational objectives were achieved according to the students. However, the statistical power could be increased with larger-population studies. The principle of using a scenario is not restricted a priori to experimental physics and could be applied to other teachings. Proposing different and original teaching formats, complementary to standard teaching, seems an effective way to break the monotony of yearlong training and to offer students a teaching experience that affects them emotionally. This is undoubtedly all the more important these recent years when many teachings have been done remotely with very little direct human contact. During lockdown conditions we could propose our students a remote version of the immersion teaching.

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APPENDIX – ENGAGEMENT SURVEY

This survey, in French, is adapted from Parent (2017). The Likert scale was inverted during the analysis, so that 1 represents no engagement, and 4 a maximum engagement.

Sur une échelle de 1 à 4, commentez les affirmations suivantes :

J’ai posé des questions aux enseignants pendant cet enseignement.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai posé des questions à des collègues pendant cet enseignement.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai organisé mon temps efficacement.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai donné des explications à un autre étudiant.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai fait preuve de leadership.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai eu du plaisir lors de cet enseignement.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

Cet enseignement m’a permis de donner le meilleur de moi-même.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

Je ne voulais pas arrêter de travailler à la fin d’une activité.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

Je suis intéressé(e) par ce que nous avons appris dans cet enseignement.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

Cet enseignement a représenté un défi pour moi.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

Je crois que ce que j'ai appris dans cet enseignement m'aidera à atteindre mes objectifs personnels et professionnels.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J'ai lié des idées de cet enseignement avec ce que j'ai appris ou vécu auparavant.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J'ai l'impression que ce que j'ai appris dans cet enseignement me sera utile dans mon parcours scolaire.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J'apprécie ce que nous avons fait dans cet enseignement.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J'ai des relations amicales avec des étudiants dans mon groupe pendant cet enseignement.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J'ai pensé de façon créative pour améliorer quelque chose ou produire de nouvelles choses.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J'ai discuté d'un problème pour développer une meilleure solution.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J'ai fait valoir un point de vue en m'appuyant sur des raisonnements et des preuves.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai appris quelque chose qui a changé la manière dont je comprends un problème ou un concept.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai évalué les forces et les faiblesses de mes propres points de vue sur un sujet.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai réfléchi sur ma façon d’apprendre.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai évalué plusieurs solutions à un problème.

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais

J’ai vécu une situation qui impliquait de m’adapter au changement (par exemple, une nouvelle technologie, un nouveau contexte, un nouveau point de vue).

1 Souvent – 2 Parfois – 3 Rarement – 4 Jamais