ADDING FICTION INTO PHYSICS' LABS 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 student engagement in experimental physics. Twenty-eight ($M \pm SD = 20.4 \pm 1.0$ year-old; 19 males) third year university science students were immersed into a fictional scenario. The learning goals were centered on experimental methodology and transverse skills, such as teamwork. They were all given a role in a story that unfold during the class (i.e. 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. We measured the impact of the fictional scenario on the students' 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 confirm that students 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; we found no correlation between the students' game culture and any engagement scores. The use of fiction in teaching experimental physics therefore appears to be beneficial for the emotional engagement of students. It would be interesting to test the use of an immersive scenario in other contexts where engagement is known to be poor.

Keywords: 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). However, students do not always appreciate physics' labs, 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 had an impact on the engagement of our students. To do so we developed a new teaching 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 immerged in.

DESCRIPTION OF THE NEW TEACHING

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

The principle of this new teaching is that students are immersed in a scenario that will encourage them to perform some physics experiments. As in a life-size 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, …) help with this. Interactions with the non-player characters and progress in the scenario are conducted through webchats or mails, and also through audio and video messages that have been prepared in advance.

From a practical point of view, this teaching takes up two consecutive full days. It is intended for third-year university students (~30 students / year) in a math / physics curriculum with a very formal approach to physics, and is supervised by two teachers. Prior to these two days, the students are made aware of the objectives and principles of this teaching.

The fiction begins with a convocation letter that is sent to the students, with the date and location (not their usual classrooms, but one from another section of the university). 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. 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 credit, 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.

CONCEPTUAL CONSIDERATIONS

Engagement is a multi-dimensional construct that can describe a student's actions and emotions (Fredericks et al., 2004). In this study, three dimensions were used: the behavioral engagement, which encompass student participation in class activities and outside activities; the emotional engagement which encompass emotions and feelings related to the educational environment; the cognitive engagement, which encompass the learning practices and strategies. It is worth noting that student engagement defined as such can evolve in time and differ between different topic.

MATERIAL AND METHODS

A new version of Parent's survey was used to capture student engagement, (Parent, 2017). Originally each dimension of engagement was measured by 10 questions; 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 the values 1 to 4 of the Likert scale, 4 being the maximum engagement.

Thirty-on students followed the immersive teaching. The same students followed a second teaching with very similar pedagogical objectives, also using active pedagogy but without any immersion. During two non-consecutive days, supervised by other teachers, students had to build up from scratch an experimental setup to study a physics phenomenon. The same engagement survey was given to the students after this class. In the rest of this article, "Immersion" will point to the first teaching, "teaching as usual" to the second. Both surveys also contained open questions at the end to collect students' verbatims and impressions. Of the 31 students, 28 students ($M \pm SD = 20.4 \pm 1.0$ year-old; 19 males) answered both surveys. The statistical analyzes were carried out by performing parametric tests after having verified that the normal distribution correctly describes the results.

We were 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 establish the game culture of the students, we adapted a survey made by Berry et al. (in press) used to measure the game culture 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 class students and look for correlation between gaming habits and engagement scores. 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.

RESULTS

Cronbach's alpha test gives 0.81, 0.40, and 0.62 for the survey questions related to affective, behavioural, and cognitive engagement respectively. The engagement scores after both teachings are presented in Table 1. For each engagement type, a paired t-test was used to look for significant differences. No significant differences were observed for the behavioral and cognitive engagement scores, but the students were significantly more engaged during the immersion class than during the teaching as usual, see Figure 1 ($\beta=0.36$, $F(1,27)=15.81$, $p<.001$, PRE=.37, IC 95%[0.17,0.55]).

Table 1. Engagement scores for our 28-student population (mean ± standard deviation). Null engagement is 1, maximum is 4.

Teaching	Behavioral engagement	Emotional engagement	Cognitive engagement
Immersion	3.05 ± 0.33	3.41 ± 0.34	3.22 ± 0.39
As usual	3.02 ± 0.44	3.04 ± 0.49	3.10 ± 0.37

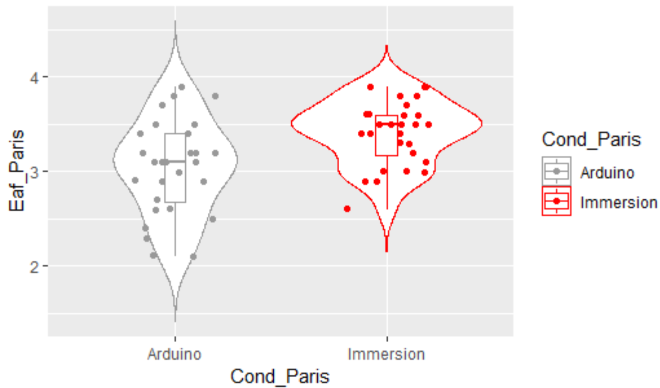

Figure 1. Students' emotional engagement during the immersion and the reference teaching, on a scale from 1 to 4, 4 being the most engaged.

The average gaming score for students is 41.1 ± 10.1, with 0 indicating a student who has never played any games, and 100 a student who plays various games a lot. The correlation coefficients between this gaming score and the engagement scores are not significant for behavioral, emotional, and cognitive engagement. Among the 28 students, 15 answered that they had already participated in a life-size role-play. However, we found no significant effect of this experience neither on emotional nor behavioral or cognitive engagement. There was no gender effect but the small sample size makes this result questionable.

The students' transcripts 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 affective 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 ($p <.001$), 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 methodology 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 positive emotions in the students 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.

These results can be linked to reports that gamification in education generally increases engagement (Hamari et al., 2014). No correlation was observed between the engagement scores and the gaming scores of our students, nor with whether they had already participated to a LARP or not. The use of fiction did not create a noticeable bias between our students. The fact that the game culture does not correlate with the engagement score is surprising. 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.

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. 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 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 this year when many teachings are done remotely with very little direct human contact.

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