Teaching PLF through "Serious Escape Games" based on 3D-imaging, accelerometer approaches and R programming

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Abstract

The spread of precision livestock farming (PLF) services in the agricultural professional field requires more training. This training involves knowledge and skills on the use and the functioning of sensors and data analysis. This is crucial for future consultant or researcher in agriculture. However, some students may be reluctant to this learning. To improve the attractiveness of PLF teaching, we developed “Serious Escape Games" (SEG) that combine the teaching of knowledge and skills with the playful characteristics of an escape game. The developed SEG use the examples of 3D-imaging and accelerometers applications in dairy cows, and a few in sows. The games run under R software, which is free of use and largely taught in universities for data analysis and visualisation. With a total duration of 2 hours, the SEG sequences include 15 min of introduction, 60 min of playing to solve 10 enigmas about PLF and data analysis, and 45 min of debriefing. The students have to mobilize their prior knowledge in R, data analysis and animal science, as well as their collaborative soft-skill to “escape” the game on time. The SEG teaches new skills and knowledge that are specific to PLF: new R procedures, animal indicators, field applications of 3D-imaging and accelerometers, and the process to develop and validate sensors. They were developed in French, but the development of a framework for SEG in English or other languages is under consideration. This will allow a wide free distribution, as well as applications of this concept to other fields and graduation levels.

Keywords: PLF, serious game, R software

Introduction

The spread of precision livestock farming (PLF) services and tools in the agricultural professional field creates new tasks which also require new skills. The skills needed and the level of expertise will vary upon the position: the provider of PLF tools needs the highest level of digital skills, the consultants and salesmen need enough skills to understand the PLF tools and applications, and the farmers need enough skills to use them. In addition, the use of artificial intelligence in PLF tools is increasing more and more, and helps to rapidly transform the raw data signal from the sensors into information that is usefull and comprehensive for companies and farmers.

Students, as future actors of the livestock value chain, need to reach a minimal (basic) level in PLF. Further knowledge and/or development will have to be taken over when students are entering the professional life. As PLF tools and solutions are continuously changing, the "*at minima*" required digital skills are hard to define precisely. Data science is already part of most academic teaching programs in agriculture. Serão et *al*. (2021) indicated that students agreed that "traditional" statistics topics (basic concept of experimental design, classical linear model, analysis on traits with normal distribution) are already well taught but the methods that are increasingly used in big data and PLF (Machine learning, Generalized models for example) analyses are rarely discussed. Besides data science knowledge, students must be able to manage big and complex datasets. Basic coding and data management are therefore requested to work within the field of PLF. Different software and programming languages allow to manipulate complex data and to perform visualization or analysis, as R or SAS software. But Grosjean & Engels (2021) noted that R language and Rstudio software are perceived by biology students as badly or mildly usable tools. Those students claim that an intensive training is needed before using them. Negative emotions such as "fear" or "repulsion" are reported when first using these softwares (Grosjean & Engels, 2021), which resulted in a significant decrease of interest in the learning process.
To overcome this reluctance to data science, education must be progressive and must include more experiential training, like collective or individual data science projects. Gamification is another possibility that is largely used to engage learners in the learning of data sciences (Legaki et *al*., 2020). Gamification is a popular leverage to engage learners in experiential learning applying game codes and mechanisms. Gamification is also spreading largely in the agricultural education. For example, the GAMAE (games for agriculture, alimentation & environment) platform identified 105 games in France, which aim to be used in training and education, therefore called serious game, in the agricultural sector (Dernat et *al*., 2021).
The aim of this project was then to use the gamification leverage to teach PLF and R programming by codesigning serious games, based on the escape game concept, which relies on solving one or several enigmas within a limited time (1h). This paper presents the methodology of conception, the two Serious Escape Games (SEGs) created and the first feedback from users.

Material and methods

Context behind the SEGs development.

This study was conducted within a course of training for Master 2 students in animal science about precision livestock farming (PLF). The course addresses both animal science and science relative to new technologies and data science. Until 2020, this course gathered lecture course, farm and PLF company visits, hands-on session and debates. Two of the hands-on activities were performed for 5 years using Excel software to analyse accelerometer data and 3D imaging data. It was then proposed to update these hands-on activities and to involve more students by making them actor of the activity. Moreover, the objective was also to improve their skills on R software for data visualisation and analysis.
In the updated hands-on activities; the objective was to find a ludic way to teach R or data science. Serious games appeared as a possible solution, since the student learns while he

is playing. As duration of each of the two hands-on activity was limited, we also chose the escape game option. Indeed, an escape game is a game which involves a team of players that has to escape from a room or a game, by solving a major enigma thanks to specific clues, tools, puzzles within a limited time. It was then possible to include it in an educational sequence of a maximum of 2 hours. The two SEGs developed in this study were originally developed as a "crash test" to test ways to update teaching precision livestock farming to Master 2 students. The success of this "crash-test" led to the current project, aiming at properly develop 2 escape games by including relevant partners and exchanging with an escape game designer on rules of design and conduct.

A collective process to develop the methodology.

The SEGs were developed from January 2020 to January 2021, and were first tested in real conditions with a group of students involved in animal science during spring 2021. Other complementary tests, with different groups of students in different graduate schools and universities, were performed from summer 2021 to winter 2021. This means that the validation phases started in November 2021 and are still under process.
In September 2020, a steering committee was established and gathered researchers, engineers, associate professors, and students. Their background was either in animal science or data science, or both. This group was based on persons who already knew each other and already collaborated in several projects. The first step consisted of defining precisely the target audience, the objectives and the educational sequences for each game. The key point is to gather both the future end-up user, i.e., students and teachers, as well as experts in animal science, PLF, data science and programming. To better define the two SEGs and be sure that we could call it "escape game", the group did an escape game together ("Le Manoir d'Ernestine", see https://escapeyourselfrennes.fr/escape-game-room/manoir-ernestine/ for information). The group then discussed afterwards with the designer to get the rules and specifications of an escape game as well as to have his feedback about making a serious escape game.
Both games were developed simultaneously, by two different groups: "Rscape the office" was developed by researchers and "Panic on the farm" was developed by Master 2-students as their M2-group project, with the supervision of the first group. Exchanges and testing of multiple options, whether or not they were retained in the end, were then possible between the two groups.

Development of the games.

- The application hosting the game

The numeric SEGs were developed with the R software, using its ecosystem of packages, to demonstrate to students that "R is more than only a statistical tool". We specifically developed the games' interfaces as R tutorials using the {learnr} package (Schloerke et *al*., 2020). The syntax of {learnr} is based on {Rmarkdown}, a package largely used by R users, and easily learnable by anyone that might reuse the code for developing another serious game. As a Rmarkdown report, a learnr tutorial allows to combine texts, images, videos, and R outputs paired with their computing codes but also frameworks to easily add various types of questions, code exercises and independent interactive shiny components (buttons, chronometers etc.). For the player, once the game repository was downloaded, and R, Rstudio (an R IDE) and some selected packages installed, the learnr

package allows to leave R studio in one click to a user-friendly HTML interface loaded in a web browser.

- Technical content

The SEG A “Panic on the farm” is based on the use of accelerometers to monitor cow’s health and behavior. The learners investigate the functioning of the accelerometer in a simple use case: the use of the Lifecorder +® (Suzuken Co. Ltd., Nagoya, Japan) to monitor grazing time as described by Delagarde & Lamberton (2015). It is a one-dimension accelerometer which provides a pre-processed activity signal. Learners have to define a threshold to discriminate the grazing activity from the other activities, and check the consequences on the predictive performance of the algorithm. To do this, they have access to accelerometer data and grazing time kinetics, recorded by visual observation on dairy cows in the INRAE experimental farm of Mejusseaume (Delagarde & Lamberton, 2015). Some kinetics have been modified for educational purposes.
The SEG B “Rscape the office” aims to make the player to be able to validate a 3D imaging device, as an accurate technology for estimating the body weight of dairy cows. This is based on the device “Morpho 3D” described by Le Cozler et *al*. (2019) and its interest for the estimation and monitoring of body weight. Two datasets are needed for the game to allow learners to experience a complete validation approach. One dataset gathers morphological indicators of 28 Holstein cows measured on 3D images from the Morpho 3D device. Because no perfect dataset was available to show examples of all indicators targeted in the pedagogical objectives, the original dataset was enriched by data created by experts for the pedagogical purpose only. During the game, students have to study the repeatability and reproducibility of the collection of the morphological indicators from 3D images, as well as to estimate body weight based on 3D indicators. A second dataset (created for this purpose) gathered repeated measures of 3 operators on 2 morphological indicators. The Morpho3D device also provided 3D images used as illustrations in the game.

- Media content

Different media were used to build an escape game atmosphere. Teasers videos were realized for both SEGs. Royalty free music from www.bensound.com was used. In the SEG A, videos and photos were collected on a farm, puzzles were built, soundtracks were recorded. In the SEG B, computer screenshots and 3D images were used.

Games validation

A preliminary game validation phase was implemented to: i) evaluate the ease of the game installation, ii) assess the time needed for the completion of the game and the whole educational sequence, iii) identify technical issues iv) check the matching between the difficulty of the SEGs and the level of the learners. This preliminary evaluation was performed in 2 steps. In November 2020, a first evaluation of the SEG B was performed through videoconferences in an agricultural engineering school, UniLaSalle Beauvais, with M2 students. In January 2021, both SEGs were tested in-person with M2 students from another agricultural engineering school, L’Institut Agro Rennes-Angers. During these tests, the game developers investigated learners’ behaviours and recorded all technical issues (installation, application bug…). Learners’ feedbacks and satisfaction were collected at the end of the educational sequences, both orally and through a survey.

Subsequent tests were performed in other schools and universities in the second semester of 2021 and 2022, with updated versions of the two SEGs.

Results and Discussion

A framework of educational sequence

The expert college defined a common framework for the SEGs' educational sequence: a presentation phase (15 min), a performance phase (e.g., the SEG itself, 60 min), a break (10 min) and a knowledge "anchoring phase" to ensure that the key messages were clearly identified by the students. Educational materials support the presentation and anchoring phases for both trainers and learners. Guidelines for the installation of the games and its requirements are also provided. During the game phases, each learner is in front of its computer and a game master is driving the game.
The educational sequence seems appropriate for being implemented in most of the animal science courses in France. At this point, the SEGs were always moderated by the game's developers. More guidelines are needed for other teachers to adopt the SEGs and moderate them as efficient game masters.

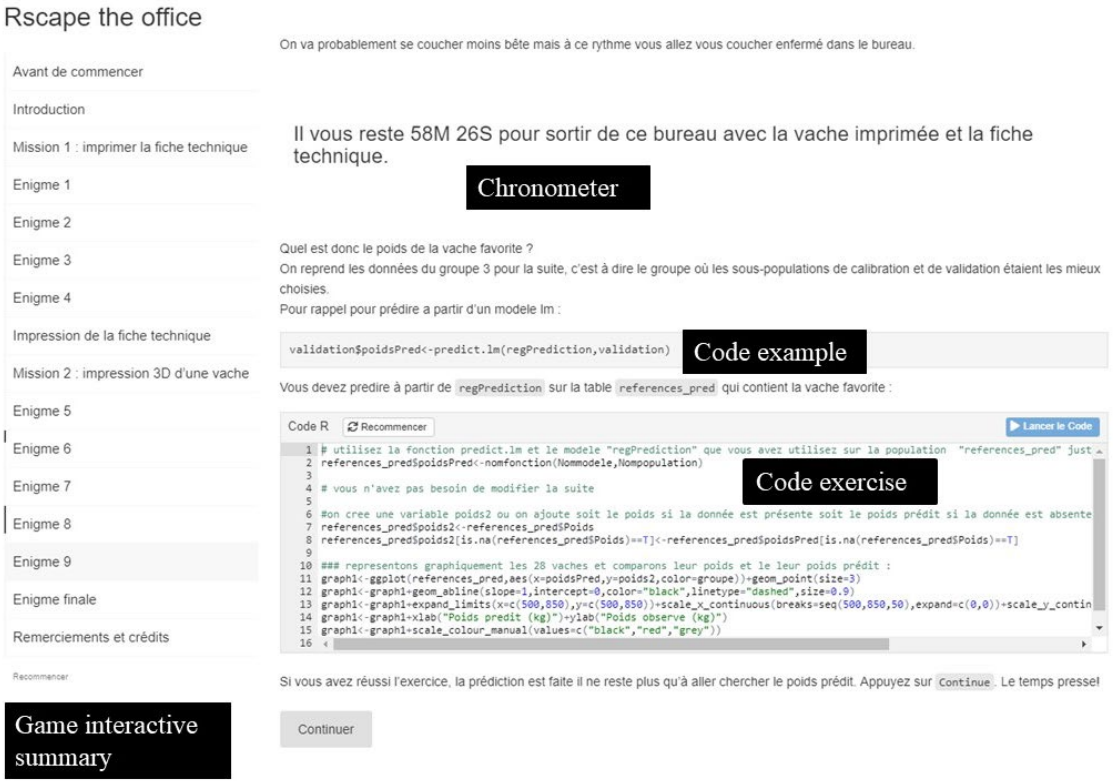

Figure 1: Screenshot of the game interface of the SEG B "Rscape the office" and examples of code exercise component, code example, interactive widgets (summary, chronometer).

A framework of numeric interface

The game interface is a {learnr} tutorial that can be personalized with .css code (figure 1). Learners are progressing in the game from one enigma to another. Different media

and/or data visualizations support the students to solve the enigma. Questions and code exercises are included to check the solving of the enigma and the understanding of the notions (figure 1). Whenever they want, learners can step back easily with the interactive summary (on the left in the figure 1). Learners can also reopen and replay the game whenever they want.

Two SEGs with their own objectives and targets

- The SEG A "Panic on the farm" is intended for Licence 3 (bachelor) level students, with no special knowledge in R programming. The games' mission is to save the cows from a nutrition issue following a malicious act on the farm. To achieve this, the necessary knowledge in animal sciences is mainly related to identification (French context) and animal behaviour. For the "sensors" part, the notions of sensitivity, specificity, ROC curve are mainly put forward, as well as the need to have reference values to validate a sensor in general (Table 1).
- The SEG B "Rscape the Office" is intended for students at Master 2 level who have a basic knowledge in R programming. The mission is to get a 3D print of a cow before the other competitors. Based on 3D imagery, the students will learn references in morphological traits usually used (body weight, heart girth, height), but also, in more original ones (surface area, volume). This escape game also addresses the key notions of repeatability and reproducibility. To be successful in the enigmas, learners have to code in R to achieve different operations (Table 1). An original feature of this second escape game is the need to work in a collaborative manner: given the time, the game can only be won if the students work together.

Feedbacks of their uses

In January 2021, both SEGs were evaluated with a general appreciation level (1 very bad, 5 very good) and a difficulty level (1 very easy, 5 very hard) by 19 learners. Marks of 4.9 and 4.4 were given to SEG A and SEG B, respectively. They were judged mildly difficult with marks of 2.8 for the SEG A and 3.3 for the SEG B. The gamification leverage was convenient for most of the learners but some of them felt the atmosphere "too stressful" and the game rhythm "too intense". The interface was appreciated in the SEG B. Some of the learners understood the opportunity to reuse the codes presented in the SEG B for their master thesis analysis. The anchoring phases of the SEG A allowed to resolve 68% of the misunderstandings. The installation was the hardest part for the learners. In every test, most of the students achieved to finish the game phases in less than 1 hour. However, doing both SEGs' sequences in one half day seemed too much engagement needed from the learners.

Table 1: Summary of the educational objectives of both SEGs

Enigma number	SEB A "Panic on the farm"		SEG B "Rscape the office"	
	Education objectives	Expected Acquisition level	Education objectives	Expected Acquisition level
1	Bovine identification system	Learning the notions	Data visualization with tables	Ability to make a variety of tables with available resources
2	Visual appreciation of cow's behaviours	Learning the notions	Data visualization with graphs	Ability to make a variety of graphs with available resources
3	Ethograms and time budgets of different species	Learning the notions	Correlation analysis between 2 variables	Ability to analyse correlations between variables
4	Functioning of an accelerometer	Understanding the notions	Repeatability and reproducibility analysis	Understanding the notions and ability to reproduce the script
5	Abnormal grazing time kinetics regarding sensors' connectivity issues	Awareness raising	Extract the mean of variables	Ability to pick a variable of interest and summarize it
6	Definition of a threshold on the activity signal to discriminate the cow grazing behavior	Understanding the notion	Understand morphological indicators	Knowledge on the dairy cow morphology
7	Sensibility and specificity of a classificatory	Learning the notions	Machine learning methodology: choice of a gold standard and performance metrics	Understanding the notions
8	Roc curves	Understanding the notion	Calibration and Validation of body weight prediction from 3D volume	Understanding the notions
9	Identification of health issues with inter-cows and intra-cow grazing time kinetics	Understanding the notion	Impact of the definition of the calibration and validation population on prediction's performances	Awareness raising
10			Predict the weight of an animal with the identified model	Ability to reuse an existing model

A rigorous evaluation of knowledge and skills acquisition is still necessary. It can be done with classical methods or by recording the responses and the progress of every learner of the questions and exercises, as described by Grosjean & Engels (2021). However, that

last method requires to deploy the game on virtual machines and several modifications of the interface are needed.

Conclusions

The use of the gamification leverage through serious escape games seems promising to train students to PLF and the underlying required data science. Learners are fully committed in the SEG and enjoy the educational sequences. The SEGs are still facing some issues, the major being its installation. Nevertheless, this will be improved or avoided by an online publishing. The acquisition of the educational objectives has not been investigated at this stage and will be rigorously investigated in the next steps. The open-source framework of the SEG based on the open-source R language opens the opportunity to adapt the SEGs to other educational context and objectives.

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