Extreme Apprenticeship Meets Playful Design at Operating Systems Labs: A Case Study

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Abstract. The extreme apprenticeship instructional methodology, recently born in Scandinavia, serves to organise education in formal contexts, such as university courses. The fundamental idea is that a new task is learned by apprentices by looking at the master who is performing it, and then repeating the task under his or her guidance. Continuous feedback and learning by doing are key principles of extreme apprenticeship. However, in e-learning contexts, the direct contact with the master may be missing. Then engagement of students with learning material becomes a challenging goal to achieve when designing the material. In this paper, we see how extreme apprenticeship and playful design were combined for designing the learning material of the laboratories of a 'boring' university course, namely, operating systems. A preliminary analytic evaluation concludes the paper showing the viability of the blended approach.

Keywords: Technology Enhanced Learning; Methodologies for Gamified or Game-based Learning; eXtreme Apprenticeship; Playful Interface Design; Interface Design for Learning.

1 Introduction

The fundamental idea of the *eXtreme Apprenticeship* (XA) instructional methodology is that apprentices learn by looking at the master performing tasks, and trying them over and over, in small chunks, under the master constant guidance. XA has been successfully applied in science curricula and, more recently, in computer science curricula in Finland, where it was born, and elsewhere. However, in e-learning contexts, XA instructors are not necessarily present. Then instructors face a challenging problem: how to engage learners with learning material, if they cannot watch instructors practicing it. *Playful design* (PD), borrowing elements from game design, can help XA instructors in designing engaging material for e-learning contexts. This paper purports the idea of blending XA and PD in such a context. It does so by showing how the learning material of the labs of a "boring" course was organised using XA principles, and how the interface of the material, made of videos, was designed with PD principles in mind. The paper starts by providing the necessary background concepts. It moves on presenting how XA and PD were applied for designing the lab material and its interface. The paper ends by showing results from a preliminary evaluation of the interface with inspection methods, providing novel ideas for future work.

2 Background

This section provides the reader with background information concerning XA, for organising learning material, and PD, for designing their interface.

2.1 Extreme Apprenticeship

Recently a new approach to teaching introductory programming courses has received much attention, namely XA. It has originally been developed at the University of Helsinki, from where it has started to spread around [1,2,3]. XA is a comprehensive approach for organising education in formal contexts, and it is based on Cognitive Apprenticeship (CA)[4]. In CA, a new task is learned by apprentices, looking at the master who is performing it, and then repeating the task under his or her guidance. So far, XA has been applied to teaching Mathematic topics such as Linear Algebra and Logic [5], as well as Computer Science subjects such as Introduction to Programming, Algorithms, and Operating Systems [6]. Basic principles of CA are:

1. *learning by doing:* the craft can only be mastered by actually practicing it, as long as it is necessary. So, students must do many exercises, which have been designed to simultaneously build both skills and knowledge;
2. *formative assessment via bidirectional feedback:* the learning process is effective by means of continuous, bidirectional feedback. Teachers must be aware of successes and challenges of learners, giving them, as frequently as possible, even small signals of encouragement.

Results achieved so far by adopting XA are impressive, reducing drop-out rate, increasing exam grades, and achieving high retention of learned skills. Such achievements rely upon flexible arrangement, in the spirit of Extreme Programming, of tutoring on-demand. Guidance to students in XA is based on Vygotsky's idea of scaffolding [7]: students are given just enough hints to proceed, boosting in this way their ability to solve the proposed task. Scaffolding progressively fades over time, as the students begin mastering themselves the task.

Much emphasis is given by CA (and XA) on the role of exercises. They are conceived for "teaching the same material (as lectures) but in an exploratory fashion" [8]. This exploratory approach fosters intrinsic student motivation, which in turn improves student performance. XA is aware that difficulties in an assignment may result in killing the motivation of the average-to-weak students, resulting in them dropping out. By providing students with many weekly exercises, each of them requiring to master a minimum amount of new material on top of previous exercises, students acquire new skills by confronting themselves with a measurable amount of work to be done.

Another crucial factor to students achievement is the level of comfort, which is based on self-esteem and self-efficiency [9]. Students in XA-based courses assess their own self-efficiency by looking at the amount of daily work performed,

in terms of number of solved exercises. Scaffolding contributes mostly to self-esteem, where expert's feedback always provides some means to improve students' perception of self. As an example of the latter, a positive feedback must contain a sufficient grade, but quite often there is also some word of encouragement ("Well done!") or just a smiley ("☺").

2.2 Playful Design for Engaging Learners

When it comes to preparing learning material to be consumed online, e.g., on e-learning platforms, learner experience design comes into play. This requires, first of all, to treat learners as users of learning products, and hence to design for their *User eXperience* (UX). A modern trend in UX design sees products designed like games, that is, "gamified" [10]. In its most common acceptation, *gamification* means properly using game-based elements for a non-game product and in a non-game context in order to engage people in the product itself.

Despite its variety of meanings and applications, gamification in UX design always requires playful engagement as key goal [11,12,13]: as Kumar and Herger point out in [14], "while effectiveness, efficiency, and satisfaction are worthy [usability] goals, gaming and gamification extend and add increased engagement to these goals". Products get structured into missions, which in turn contain challenges and other game elements, such as rewards, that get designed according to the target types of users, conceived as players, and their motivations to play. When products are intended for learning, challenges and award-winning competitions are often added to make them less "boring rote".

However, as claimed in Ch. 5 in [15], "in each and every case, the interface design has played some part in the success or failure of the experience". For designing interfaces, one has at disposals a number of guidelines such as Nielsen heuristics [16] for promoting usability, in the sense of effectiveness, efficiency and satisfaction.

Moreover, as argued in [15], specific game mechanics and aesthetics principles for engaging learners should be added to the interface designers' toolkit: game-mechanics principles help designers to employ game elements such as rewards and progressive challenges; aesthetics principles help designers to support "clarity, communication, comprehension, and emotion" and the better the aesthetics of an interface is "the more credible users will believe the content to be".

3 XA for Operating Systems

All the learning material described in this section originates from the *Operating Systems* (OS) course at the Free University of Bozen-Bolzano. The course was offered in the Bachelor programme with the XA methodology applied to the Operating Systems labs for three academic years, from 2011 till 2013.

During those three years, the OS lab and material were organised following XA principles. Tutoring was available in labs overall 6 hours per week. Bash

scripting, covering the contents of [17], was split into many small exercises, organised into thematic weekly units, which required learners to progressively acquire specific skills. Bash exercises were distributed in plain text format.

During lab activities, however, students experienced occasional lack of concentration in reading such exercise texts, that resulted in trivial mistakes, especially when lab hours were scheduled in late afternoon. Several students could not regularly attend labs, e.g., due to overlaps with other courses. To avoid such issues, many students asked to solve exercises at home, at their most convenient times, and in a more quiet environment. They asynchronously uploaded their final solutions to the university e-learning portal, where teachers periodically downloaded and assessed them. This implied to deliver the lab in a blended fashion, scaffolding students with asynchronous feedback.

However, working alone at home may cause a lack of motivation, mainly due to the loss of synchronous interaction with peers and teachers. Our main goal thus became how to keep students engaged when working at home. This lead to the following high-level requirement: *creating more engaging self-study material.*

Moreover, the material on the e-learning portal reached a larger population of university students, including full-time workers. The second main high-level requirement for the material was then: *making online material that is usable and accessible by diverse types of university students, different in terms of background knowledge and attention span.*

For this reason, in Fall 2013 we planned to redesign the learning material, turning text exercises into videos, to be made available on the university e-learning portal, where tutors are not always available. The remainder of the paper describes how the videos were designed so as to motivate diverse university students to consume them.

4 Playful Design for Operating Systems

Videos allow us to watch things happening in motion and can arouse emotions more easily than static material. As stated in [15], "studies have shown that watching, and even just thinking about, physical things activates the same parts of the brain that are activated when we actually do those things". Videos were thus chosen for showing how the XA instructor performs with the learning material and to train learners as apprentices to that. In this section, we focus on how we designed such videos following specific design principles. In the end, we briefly sketch a preliminary analytic evaluation of the videos and its main results.

4.1 Design Choices

In designing videos for XA learning, we considered traditional usability principles such as Nielsen heuristics [16]. For instance, help for less experienced learners is provided via tips and notes as shown in Fig. 2. Navigation through the learning material is designed so as to let learners experience control and freedom in moving through the material. As Fig. 3 shows, navigation tabs at the bottom of

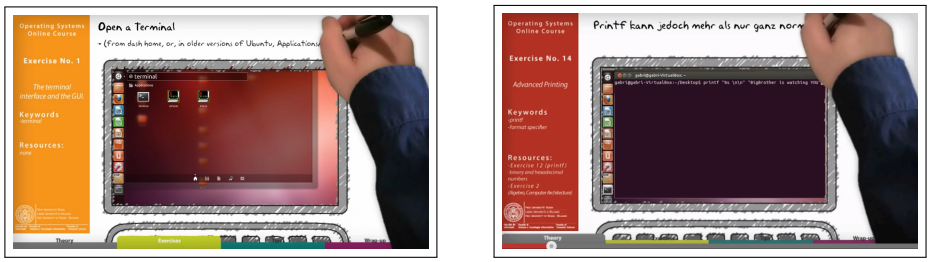

Fig. 1. Video screen-shots with tasks for learners in English (left) and German (right)

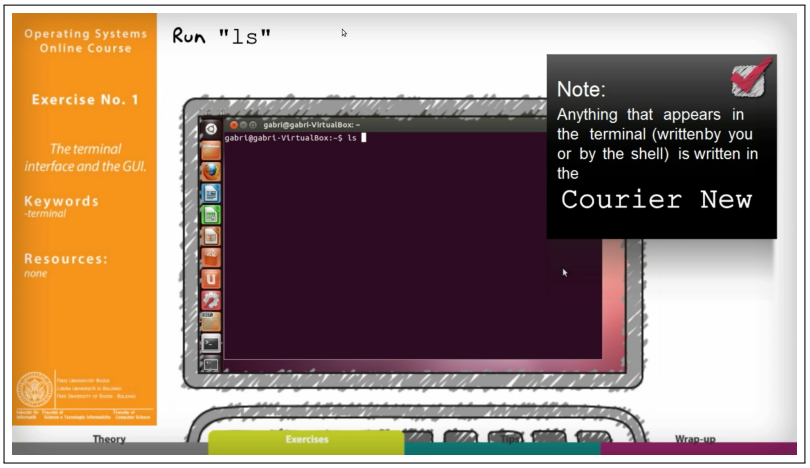

Fig. 2. A video screen-shot showing a note for less experienced learners and the usage of animation for showing learners how to run "ls"

the interface show learners what types of material the video is currently showing them, e.g., theory or exercise. The left-side of the interface, on the other hand, show learners at what point they are in their learning path by listing: the title and identifier of the video, its key concepts, its prerequisites (resources). Moreover, accessibility was a key concern and multi-modality is implemented so as to reach as many learners as possible, matching their world and metaphors. For instance, videos are both spoken and written in English, German and Italian, the three official languages of the Free University of Bozen-Bolzano. See Fig. 1. Users with reading problems can run the video in slow motion.

We concentrated in particular on aesthetics, which is deemed relevant for engaging students in learning with a positive attitude and making them perceive the learning source more creditable. As claimed by Norman [18], finding something attractive brings "a more positive mood", to the point that students become more willing to tackle problems. Aesthetic design for learning counts specific strategies [15]:

1. reducing overload, that is, striving for minimalism;

2. guiding attention to the relevant part of the interface, e.g., by positioning objects most relevant to learning in the centre of the interface as shown in all figures;
3. supporting visual perception, e.g., avoiding colour and texture faux pas;
4. implementing visual representations that promote visual learning, in particular: (1) visual cues for understanding and remembering, e.g., see Fig. 1; (2) still representations for concepts, such as the representation of the terminal as in Fig. 3; (3) animation for showing relevant tasks, such as the animation that shows how to run the "ls" command in Fig. 2, but sparingly.

Game-mechanics principles promoting engagement were also considered, such as segmenting the learning material into topic-based progressive tasks, turned into videos that last no longer than 5 minutes, so as to maintain concentration. This and the left-side navigation bar allow learners to choose topics relevant to them, and to review more easily the material, enabling shortcuts to learning. Feedback concerning exercise processing, meant for the 'entire class' [19], and discovery elements are also used to keep learners engaged, as illustrated in Fig. 4. Moreover, lab assistants are displayed as talking avatars for guiding and assisting learners through the learning material, as shown in Figg. 3 and 4.

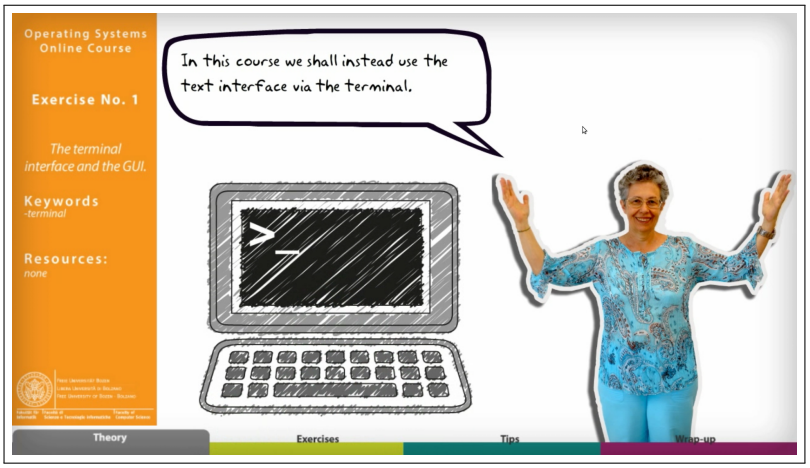

Fig. 3. A video screen-shot showing the avatar for attracting the attention towards the video learning goal, and the visual representation of a terminal, fostering recognition rather than recall

4.2 Preliminary Evaluation Results

For evaluating the video interface, we did a preliminary expert review. Reviewers were: two experts of usability and game design; two of special needs education. Results are rather uniform across reviewers. All reviewers found videos accessible

Fig. 4. A discovery element for engaging

and promoting multiple means of representation. Animations were considered relevant and not distracting from the main task.

Usability experts found room for improvement. Both noticed that visual cues were not always consistently used. For instance, the writing hand of Fig. 1 is mainly used in relation to tasks that learners should perform. At points, albeit rarely, the hand is used for other purposes. The avatar has a clear role when guiding through the learning material. That said, at points the avatar is used where the writing hand should be used to assign tasks. Moreover, juicy feedback was also perceived as crucial. According to one usability reviewer, however, learners should be more challenged to tackle exercises before watching the feedback for their resolution in the wrap-up section: adding an activity that requires a learner to stop, run an exercise and input its resolution between segments of passive information should help in keeping learners even more engaged.

5 Conclusions

This paper advocates the use of PD for designing learning material that is organised with XA principles. The paper explains the adopted XA and PD principles for engaging learners in e-learning contexts, where the XA instructor may not be present and engagement becomes critical. It does so by illustrating such principles in the context of a case study, namely, that of an operating systems lab. Lessons learnt from the study shows the viability of the approach, and pave the way for future work at the intersection of XA and PD in e-learning contexts. On the other hand, the availability of self-study engaging material allow to support other types of students such as high school ones, who would like to learn about courses offered by the local university before enrolment, and lifelong learners. In particular, we are designing contextual inquiries with high school students and teachers for testing the use of OS videos in in their specific context.

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