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Operating Systems with Blended Extreme Apprenticeship: What Are Students' Perceptions?

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Abstract. Extreme apprenticeship, an emerging learning methodology, has been used in a blended fashion for teaching a technical subject: bash scripting for operating systems. Online learning was first supported with the Moodle platform, and then enhanced with playful videos. How did students perceive learning in such a manner? This paper reports on the design of the blended learning experience for operating systems, and then focusses on the evaluation of learners' perceptions of it.

Keywords: blended learning; online learning; extreme apprenticeship; learner experience design; learner experience evaluation; perception

1 Introduction

New learning methodologies are frequently presented as promising a breakthrough, creating high expectations. When the first enthusiasm fades away, and approaches become routinely applied, learners frequently experience deep dissatisfaction. Learners' perception of the benefits of a new learning methodology, measured towards the end of a course, is considered in this paper as a key factor for assessing how motivating the methodology is for learning. In particular, students' self-efficacy is generally regarded as a relevant predictor of students' motivation to learn and remaining in academy: "Two decades of research have clearly established the validity of self-efficacy as a predictor of students' motivation and learning", p. 89 in [23].

The methodology considered in this paper is eXtreme Apprenticeship (XA), which was first introduced at the University of Helsinki as a new educational approach in introductory programming courses at the BSc level [19]. XA is based on the Cognitive Apprenticeship (CA) approach [4], that is, on learning a task as apprentices, by observing how a master performs it. It puts an emphasis on learners, who acquire a new cognitive skill, such as programming, by doing many small exercises, under the guidance of "masters", available to give students on-demand tutoring. Tutors apply Vygotsky's idea of scaffolding [21]: students are given just sufficient hints to proceed, boosting in this way their ability to solve the proposed task. XA has shown so far impressive improvements over traditional lecture-based formats of teaching, from the point of view of increases both in grades and in percentages of successful students at the final exam [20].

The XA experience, reported in this paper, took place at the Free University of Bozen-Bolzano (UniBZ) in an Operating Systems (OS) labs at BSc level. While the principles of XA were as in Helsinki, at UniBZ some of the XA practices were adapted to the local environment. The most striking change was turning the XA feedback from in-presence guidance into a blended type of scaffolding, as in other blended teaching experiences [6,8]. Support given through a Learning management System (LMS), that is, Moodle, was crucial in providing asynchronous master-apprentice interactions and scaffolding.

In its first part, the paper describes the XA methodology and how it was used inside the OS labs for three consecutive academic years, with exercises and feedback made available via Moodle. Then it investigates students' perception with the blended XA labs: were students satisfied with the new approach? In particular, between the start and end of the course, is there a significant change in the students' perception of their efficacy in mastering OS tasks? And how did students perceive their experience with Moodle? In order to evaluate learners' perception, using XA and Moodle for learning OS, a mixed design approach was used, with different data gathering methods. The first part of the paper concludes discussing the study's major results.

In short, students were generally very satisfied with what they perceived to have learnt. However, learners that could not attend were not satisfied with their Moodle experience. Such a finding motivated more recent work, reported in the second part of this paper: the design of playful videos for self-paced online learning of OS tasks, showing how XA masters would tackle these. The evaluation of students' perceptions of videos is reported in the conclusions to this paper.

2 EXtreme Apprenticeship

XA is a comprehensive approach for organising education in formal contexts, based on CA [8]: a new task is learned by apprentices, looking at the master performing it, and then repeating the task under his or her guidance, as long as needed. XA has been applied to teaching new cognitive skills at BSc level, in several courses in Mathematics (Linear Algebra and Logic [9]), as well as Computer Science (Introduction to Programming, Algorithms, and Operating Systems [6]). Results achieved so far are impressive, e.g., reduction of drop-out rates, higher grades, higher retention. Its basic principles are two: learning by doing; formative assessment. They are analyzed in the following.

2.1 Learning By Doing

Much emphasis is given by CA and XA on the role of exercises, which serve for "teaching the same material (as lectures) but in an exploratory fashion" [14]. 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. By assigning 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. Moreover, exercises should be related to relevant topics for students, e.g., they should be connected to other course topics or issues, so as to make students perceive the intrinsic value of what they are learning.

2.2 Formative Assessment

Flexible arrangement, in the spirit of Extreme Programming, of tutoring on-demand is another key component for motivating students. Students in XA-based courses assess their own efficiency by looking at the amount of daily work performed, in terms of number of solved exercises, so as to promote self-regulation and self-efficiency [22].

Scaffolding contributes to reducing test-anxiety and building student self-esteem. Guidance to students in XA is based on Vygotsky's idea of scaffolding [21]: 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 students begin mastering tasks by themselves. More generally, expert's formative feedback gives means to improve student perception of self. Expert formative feedback can be used for correcting products or tasks, for ameliorating the processing of products or tasks, learning from mistakes, and for encouraging learners to self-evaluate their work. Praise for challenging achievements is also a key component: this can be a sufficient grade, words of encouragement ("Well done!") or just a smiley ("☺").

3 Part 1: Blending XA and Moodle

The XA methodology was applied to the OS course labs at UniBZ for three consecutive academic falls, from 2011 till 2013. During those years, the OS lab structure and its learning material were organized following XA principles. Tutoring was available in labs overall 6 hours per week. Learning material consisted in many short exercises, organized into thematic weekly units, which required learners to progressively build skills. All exercises were focused on Bash scripting, covering the contents of [2], and distributed in text format.

In particular, 54 exercises were assigned during 6 weeks, namely 3 exercises in the

Table 1. Self-efficacy survey pre (before the course) and post (after the course) items

	ID	Item
pre	Pre 1	I know how to use Linux command line.
	Pre 2	I know shell scripting.
	Pre 3	I know how to use Linux (including GUI use, editors, etc.).
post	Post 1	Now I know how to write bash scripts.
	Post 2	Now I have a better understanding on how operating systems work (because of exercises).

first week and about 10 exercises each week for the remaining 5 weeks. Students had 2 weeks to complete each set of exercises, each exercise being assessed as either passed (1) or not passed (0). Students could re-submit the same set of exercises as many times as they wished in the 2-week frame. In this period, following the XA approach, students had an opportunity to receive feedback from teachers and resubmit the wrong exercises, as many times as they wished, before the deadline expiration.

However, differently than what traditionally done in XA, exercise delivery and teacher feedback on correctness of exercises was always managed through the Moodle platform [3]. Since lab presence was not compulsory, several students preferred to come to labs only when they had problems, and they tackled the majority of exercises at home, interacting with teachers only via messaging and feedbacks on the platform. In this way the lab adopted a blended learning approach, with a mix of synchronous in-presence interactions, and asynchronous feedback messages between teachers and students [6,8]. Given the difference with respect to the traditional format for such labs, the technical demand of the bash scripting techniques, and the absence of theory lectures on bash scripting, we asked ourselves how students perceived tackling OS via XA and Moodle, especially how they perceived the efficacy of the methodology for learning. The following section reports on how the question led to a specific evaluation study, and on the major results from this.

4 Part 1: Evaluation of XA and Moodle

4.1 Goals and Objectives

The main goal of the reported study was to evaluate students' perception of XA-based learning and labs, with exercises and feedback delivered via Moodle. This goal was broken down into the following main objectives to investigate: (1) students' satisfaction with the blended XA methodology for OS; (2) student self-efficacy before and after the course; (3) students' experience with Moodle.

Table 2. Satisfaction survey items, administered after the course

Item ID	Item
1	Time between delivery and deadline of exercises was too short.
2	This lab took me more time than I expected.
3	Time spent with the teacher was too short.
4	Feedback from teacher was insufficient or not timely.
5	I needed lectures (theory) on bash.
6	I lacked some prerequisites (e.g. programming, testing).
7	I learned more than I expected (because of labs).
8	I wish other labs for other courses were organized in a similar way.

4.2 Data Gathering Methods

The evaluation of the above objectives used the same methods for gathering perception data across all 3 academic years. Observations and interviews gave qualitative data useful for all objectives. Interviews were run at the end of the course in written format, for reaching as many students as possible. Observations were done during the course. Moreover, closed-format surveys for quantitative data were also administered to students: a survey concerning satisfaction (objective 2) was administered at the end of the course; a survey concerning self-efficacy (objective 3) was administered right before and after the course.

Self-report surveys were crucial because not all students could be regularly present. The surveys were designed following course satisfaction short surveys and guidelines, e.g., [16,17]. For instance, survey items were intentionally kept simple for avoiding misunderstandings, and focused on the topic under investigation.

The self-efficacy survey is shorter and divided in two parts: one administered before the course (pre) and the other after (post). It asks students to assess their mastery of shell scripting and Linux OS in general, using a Likert scale: 1 means "totally disagree"; 5 means "totally agree". See Table 1. The satisfaction survey is longer, with 8 items, and uses the same Likert scale as the self-efficacy survey. See Table 2. It explores specific satisfaction factors. Items 1 and 2 explore the perceived timings of exercise delivery and lab activities. Items 3 and 4 explore the perceived quality of teaching and feedback. Items 5 and 6 explore the perception of the need of other resources. Items 7 and 8 explore the perceived trust in XA for learning via labs. Notice that item 8 closely resembles the Net Promoter Score question for predicting the loyalty of users to a product in user satisfaction studies, e.g., see [16].

4.3 Participants

In three academic years, 49 students of the OS course participated in the final interview, and completed both surveys (self-efficacy, satisfaction). This number represents more than 2/3 of students who completed the course. Results are recapped as follows: first the survey data for satisfaction, then the survey data for self-efficacy, finally relevant interview data. In Section 5, all results are globally discussed.

4.4 Quantitative Results for the Satisfaction Survey

In order to assess students' satisfaction with the XA method, each item of the satisfaction survey (Table 2) is considered. For each item across all 49 students, Table 3 gives: mean ratings, Standard Deviations (SDs) and 95% t-Confidence Intervals (CIs). The table inverts scales whenever needed, so as to go always from negative (1) to positive (5) ratings; items with inverted scales are labelled with "inv" in the table. Notice that a 95% CI for a sample mean gives an estimated range of values which is likely (not certain) to include the unknown population mean: should another sample from the same population be extracted 100 times, the calculated CI is likely to include the true population parameter 95 times. The t-distribution was used for computing CIs in Table 3 because, as reported in [15], p. 26, in case of satisfaction rating scales, the t-distribution better considers the sample size than the normal distribution. The computation implies a 2-sided test with $\alpha=0.05$, as both interval bounds are of interest.

Items of the survey can be aggregated and analyzed globally or per factor. Fig. 2 visualizes results for both.

Globally) We consider the mean rating of a student across all items, giving a global view on his/her satisfaction. The mean value across all students is M = 3.95 with SD = 0.51 and 95% CI[3.80, 4.1], which tends to 4.

Per factor) Instead, by aggregating items in pairs, according to the explored factor, we first compute the mean rating per factor of each student, and then the mean rating per factor across students:

- for post items 1 and 2, concerning the perceived suitability of timing of exercise delivery and lab activities in general, the mean rating across students is M = 3.67, with SD = 0.82 and 95% CI[3.43, 3.91];
- for post items 3 and 4, concerning the perceived quality of teaching and feedback from teacher in general, the mean rating across students is M = 4.2, with SD = 0.66 and 95% CI[4.01, 4.39];
- for post items 5 and 6, concerning the perception of not being in need of other resources for the courses (i.e., resources are perceived to be sufficient), the mean rating across students is M = 4.13, with SD = 0.8 and 95% CI[3.90, 4.36];
- for post items 7 and 8, concerning trust in XA, the mean rating across students is M = 3.79, with SD = 0.69 and 95% CI[3.59, 3.99].

Table 3. Satisfaction survey results per item, across students: means, standard deviations (SDs), 95% confidence intervals (CIs)

Item ID	1 inv	2 inv	3 inv	4 inv	5 inv	6 inv	7	8
Mean	4.33	3.02	4.29	4.12	3.86	4.4	3.7	3.9
SD	0.94	1.15	0.84	0.88	1.22	0.7	1.06	0.8
95% CI	[4.06,4.6]	[2.7,3.35]	[4.04,4.53]	[3.87,4.38]	[3.5,4.2]	[4.2,4.61]	[3.39,4]	[3.67,4.13]

4.5 Quantitative Results for the Self-Efficacy Survey

In order to analyze results from the self-efficacy survey (Table 1), we compare students' ratings for all pre items, and for all post items. Ratings for pre items have mean M = 2.43, SD = 1.06 and 95% CI[2.12, 2.73]. Ratings for post items have mean M = 4.06, SD = 0.68 and 95% CI[3.86, 4.25]. See Fig. 2.

Recall that the same 49 students participated both in the pre and post surveys. Let us consider the differences between pre and post ratings of each student. The mean of the differences is M = 1.63, with SD = 1.24 and 95% CI[1.27, 1.98], calculated as in Sect. 4.4.

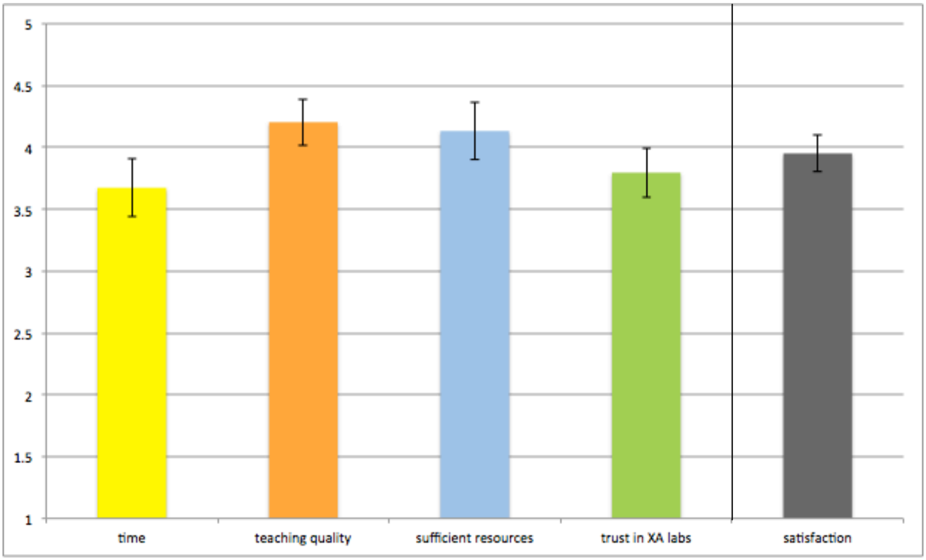

Fig. 2. Satisfaction survey means per factor (time, teaching quality, sufficient resources, trust in XA labs) and across all factors (satisfaction), with the respective CIs

This CI does not contain 0, hence there is a significant difference between pre and post ratings with 95% confidence [15]. See Fig. 2. A paired t-test for the mean difference with STATA confirms a significant difference: $t(48) = 9.2$, $p = 0.00 < 0.05$. In other words, student perception of their mastery of OS is significantly higher at the conclusion of the OS labs than before taking them.

4.6 Qualitative Results

The open-format written interview was meant for collecting comments from students, concerning their satisfaction of the XA method via Moodle and suggestions on how to improve the course in future. The most interesting ones are as follows.

Student 1 (2011–2012): “This is new way of teaching. It is very interesting. I didn’t expected from myself that, without any knowledge about bash and without any lectures, it is possible to learn so much! The text of the exercises was very clear, it was interesting to follow the procedure and to write a script. I think that other courses should be thought in similar way! Thank you!”.

Student 2 (2012–2013): “The exercises were well prepared with a good and constant elevation of difficulty. The continuous grading helped a lot to understand personal skill levels”.

Student 3 (2012–2013): "I am a worker and due to this I have not regularly attended the lessons. Despite that I can say that the course teacher and assistant gave me all the information that I need in a helpfully [sic] way".

Student 4 (2013–2014): "The entire process of writing, testing, and uploading scripts isn't a great user experience. Have you considered something like codecademy?".

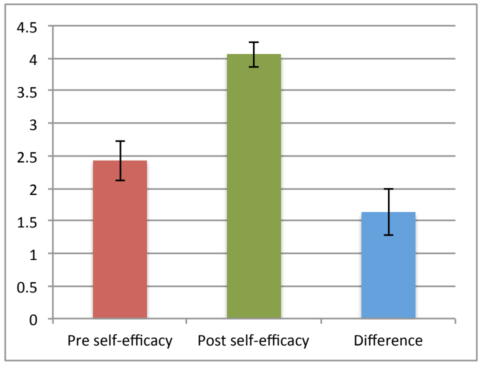

Fig. 3. Self-efficacy results: pre (red), post (green), and difference means with the respective CIs

5 Discussion

Results of the reported satisfaction survey are positive. Considering the explored factors, the suitability of timing of exercise delivery and labs is the one with an average neuter opinion, and for which we have a CI with lower bound close to 3 (neutral). All other results are extremely positive, with CI bounds that are all close to 4. In other words, one is 95% confident that students from the same population would be likely, on average, to perceive positively the quality of teaching and XA type of feedback, not to feel in need of additional resources such as more theory, and to enjoy working in XA-style again, in other courses. Similarly, given the CI bounds for the mean rate across all items and students, one is 95% confident that students from the same population are likely to be on average satisfied with the learning approach.

Results of the self-efficacy survey are also very interesting. According to the performed statistical analysis, there is a significant increase in what students, on average, perceive to master of OS before the start of the course and after taking it.

The qualitative data, resulting from observations and interviews, reinforce such findings. For instance, it is interesting to notice that even students that could not regularly attend lectures and mainly participated via Moodle declared their satisfaction with the XA version of the OS course. It is also worth reading of their surprise in perceiving that "learning by doing" can be effective—a XA corner-stone.

According to a thematic analysis of qualitative findings, the main complaints were concerned with the limited user experience enabled by Moodle, pointing towards more gamified experiences proposed by several modern online learning systems. Such complaints were particularly voiced by students that could not attend lectures

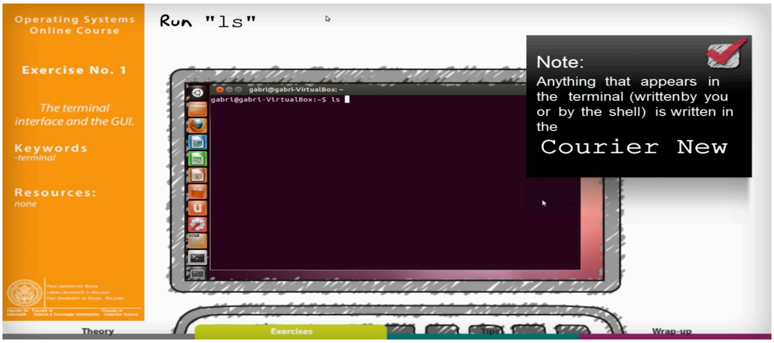

Fig. 4. A video screen-shot showing a note for less experienced learners and the usage of animation for showing learners how to run “ls”

regularly and benefit from interactions with teachers for tackling OS exercises. Their expectations were considered and fulfilled by moving one step further the blended teaching of OS with XA and Moodle: playful videos were added.

6 Part 2: Playful Videos

In Fall 2013 new learning material was designed for guiding online students through OS exercises. The material was made available online: via Moodle for UniBZ learners; via YouTube for other potential learners [22]. However, tutors cannot give all online learners synchronous or personalized feedback, which is one of the main requirements of XA for keeping students engaged. The consequences of not engaging can result in high drop-out rates, as it is the case for the majority of MOOCs. The main goals thus became to design learning material for teaching online learners how to tackle OS exercises, and to make this material engaging for them, despite the absence of synchronous interactions with tutors. Moreover, the aim was to cater for all possible online learners of an OS course, heterogeneous in terms of knowledge, attention span, skills and motivations to learn.

Such goals led to the following high-level requirements for online learning material for OS exercises: *(1) online material should show* how *to tackle tasks, namely, OS exercises; (2) online material should be usable by diverse types of students, e.g., different in terms of background knowledge and attention span; (3) self-study material for OS exercises should be engaging for all*. Requirements were turned into design choices, separately explained as follows.

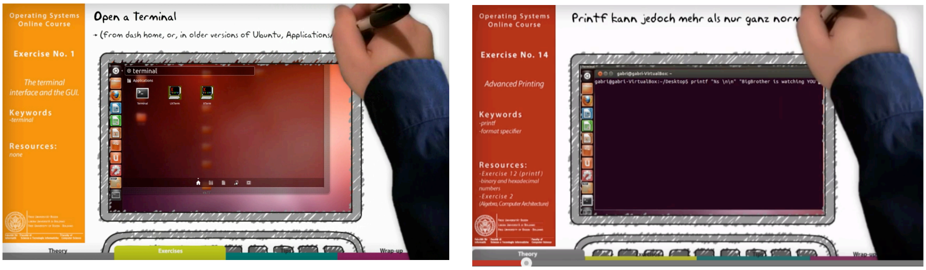

Fig.3 Video screen-shots with tasks for learners in English (left) and German (right)

6.1 Videos for Showing Tasks

The first requirement led to choose videos for delivering the learning material. Videos allow one to watch things happening in motion, e.g., tasks, and can arouse emotions more easily than static material. As stated in [13], "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 would act in order to tackle OS exercises, and to train learners as apprentices to that.

6.2 Usability for Different Learners

The second requirement was taken care of, by following classical usability design principles by Nielsen, and patterns specific for learning interfaces [13]. Visibility of system status is supported, for instance, as illustrated in Fig. 4: navigation tabs at the bottom of the interface show learners what types of material the video is currently showing them: theory, exercises or tips. 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. This also helps in supporting learners' control and freedom: tips and notes, as in Fig. 4, are fundamental for novice learners but can be skipped by experienced learners. 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 UniBZ. See Fig. 1. Users with language problems can run videos in slow motion.

6.3 Game Mechanics and Aesthetics for Engaging in Learning

As for the last requirement, a modern trend in User eXperience (UX) design sees a product designed like a game, that is, "gamified" [7]: using game-based elements for a non-game product and in a non-game context in order to playfully engage people in using the product. As Kumar and Herger point out in [11], "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. When products are intended for learning, challenges and award-winning competitions are often added to make them less "boring rote". More generally, as argued in [13], specific game mechanics and aesthetics principles as well as strategies are added to the interface designers' toolkit for playfully engaging learners: the former tell designers how to employ game elements such as rewards and progressive challenges; the latter tell designers how to support "clarity, communication, comprehension".

For instance, game-mechanics principles were applied in segmenting the learning material into topic-based progressive tasks/challenges, which were turned into videos lasting 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' [13], 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 and pointing to the relevant learning goal, as shown in Fig. 5.

Fig. 5. A video screen-shot showing: (1) the teacher-avatar addressing the learning goal, (2) with a discovery element for engaging, (3) the iconic representation of a terminal and folders for favoring recognition rather recall

Aesthetics was a major concern because it is deemed relevant for making online students perceive the learning source as more creditable; as Norman states, finding something attractive brings “a more positive mood”, to the point that students become more willing to tackle problems [12]. For instance, specific visual representations were chosen for promoting visual learning: (1) visual cues for understanding and remembering, e.g., see Fig. 5; (2) still representations for concepts, such as the representation of the terminal as in Figg. 4 and 5; (3) animations sparingly and only for showing relevant tasks, such as the animated hand that shows how to write and run the “ls” command in Fig. 1.

Fig. 6. Cloud of words related to the qualitative evaluation with OS students

	words	frequency
positive	catchy, fun, useful	8
	motivating to learn, professional	6
	clean, clean, trustworthy	4
	simple	3
	engaging, cheerful, friendly	1
negative	confusing	4
	busy	2
	complex, dull, not motivating to learn, unattractive	1

Table 3. Small-scale evaluation results for OS videos

7 Part 2: Evaluation of Playful Videos

OS videos were evaluated by 4 experts with a heuristic approach. Results are in [5]. The videos were then improved considering severe problems resulting from the evaluation and concerning consistency in using visual clues. As aesthetics was a major focus for the credibility of the learning source, a small-scale evaluation was run for assessing it with the re-designed videos. Participants were 12 in December 2014: 4 students from UniBZ, and 8 students from high-schools in the local area, who have already been using the majority of online OS videos. They had to select words describing the video aesthetics from a bag of 22 words, half describing desirable features and half describing the opposite features, as in [1]. Words pertain to 3 major clusters. They are: “engaging”, “catchy”, “fun” and their opposite for fun; “clear”, “simple”, “clean” and their opposite for clarity; “professional”, “trustworthy”, "motivating to learn" and "useful" concerning perceived credibility and utility for learning. Results are in Table 3. The majority of selected words are positive. The most frequent positive words, chosen by 67% of students, are related to the perceived fun, utility and credibility of videos for learning. The most frequent negative word, chosen by 33% of learners, was "confusing". This comes from younger students, who, according to their comments, found the videos related to the more complex parts more difficult to follow than other videos, indicating the need of reworking on those.

8 Conclusions and Future Work

This paper reports on a XA experience with a course usually perceived by students as very technical and boring: OS. The paper firstly explains how the course was organized blending XA with Moodle for delivering exercises and feedback. Secondly the paper focusses on the evaluation of students' perceptions of the learning approach. Quantitative results show that students were on average very satisfied with the approach, and perceived a significant increase in their mastery of OS tasks after taking the course. However, qualitative findings show that students, especially those not attending, were demanding a more engaging experience than that enabled by the available version of Moodle. This triggered the work explained in the second part of this paper: the design of fun videos for teaching how to tackle OS exercises. Videos were integrated in Moodle and also made available online via YouTube to a potentially larger student population. This paper ends reporting formative evaluation results concerning students' perceptions of videos. Future work foresees a regression analysis in order to examine if and which factors of the self-report surveys may predict student exam results, connecting student perception data and exam results, in line with [10] and extending XA analytics as discussed in [18].

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