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Social and Collaborative Interactions for Educational Content Enrichment in ULEs

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ABSTRACT

This article presents a social and collaborative model for content enrichment in Ubiquitous Learning Environments. Designed as a loosely coupled software architecture, the proposed model was implemented and integrated into the Classroom eXperience, a multimedia capture platform for educational environments. After automatically recording a lecture in instrumented classrooms, students and instructors can enrich its content with comments and rating features. The platform usage was monitored for three school semesters to analyze the receptivity and the impact of the proposed features over 121 undergraduate students. As a result, we observed that both system's access rate and students' performance increased, suggesting that interactive features leverage collaborative learning interactions and promote the teaching/learning process.

Keywords

Educational content enrichment, Social and collaborative learning, Ubiquitous learning environments

Introduction

Recent surveys have revealed that the number of computing devices, especially mobile ones such as smartphones and tablets, has grown to a great extent in last years (Gartner, 2014), and their usage for performing everyday tasks is now a reality (Kostakos & Ferreira, 2015). Technological advances coupled with infrastructure provided by the Internet provide a scenario in which information can be accessed anytime and anywhere. This new paradigm of interaction between people and computers is known as *Ubiquitous Computing* (UbiComp) (Weiser, 1991), and illustrates the omnipresence that technology reached in different environments, including schools and classrooms.

In the educational scenario, UbiComp systems are able to assist instructors and students during the teaching/learning process by automating pedagogical tasks, thus creating the so called *Ubiquitous Learning Environments* (ULEs) (Settle, Dettori, & Davidson, 2011). Instrumented classrooms are the most common approach for this purpose. Devices, such as electronic whiteboards, cameras, and microphones, can produce media artifacts that are able to recreate experiences that took place in the classroom. In this way, students can focus their attention on the learning experience itself, certain that details are being properly recorded and will be available for later access (Brant-Ribeiro, Cattelan, & Biase, 2015).

ULEs are quite related to *Capture and Access* (C&A) applications (Truong & Hayes, 2009), a recurring research theme in UbiComp. Supported by C&A, ULEs promote automatic authoring of multimedia content. In this context, social and collaborative interactions constitute significant functional improvements for classic ULEs (Banday, 2012; Cela, Sicilia, & Sánchez, 2015). With these systems, content presented by instructors can be extended and enriched, which encourages information sharing, experiences exchange and discussion among students who start performing active and influential roles in cognitive processes of the members of virtual communities where they are inserted (Banday, 2012; Shukor, Tasir, Van der Meijden, & Harun, 2014).

Therefore, we developed a model for extension and classification of multimedia content based on social and collaborative activities carried out by users in ULEs. As a proof of concept, we proposed and implemented a software architecture that supports assumptions of the proposed model, resulting in an application that provides features for commenting and rating multimedia artifacts. We conducted a case study with integration and validation of the collaborative application into the Classroom eXperience (CX) (Araújo, Brant-Ribeiro, Cattelan, de Amo, & Ferreira, 2013) – a UbiComp platform built to automatically capture and access educational activities in instrumented classrooms.

In addition, we also performed a comparative analysis among our proposal and related studies that include solutions for extension of multimedia content, categorization of digital artifacts and collaborative annotations. Our study, however, tries to meet all these demands through a generic model developed to support the enrichment of media components based on collaborative authoring and rating, and allows analysis of resulting applications at distinct levels of granularity.

Multimedia content enrichment model

The continuous knowledge progress coming from different educational activities is the basis of the spiral content production model (Pimentel, Ishiguro, Kerimbaev, Abowd, & Guzdial, 2001). In this model, the spiral represents all generated information in each context (program, course, class) and each pedagogical activity contributes toward the new development cycle. This way, the spiral's area is increased by instructors and students' interactions and the produced knowledge is leveraged.

The proposed multimedia content enrichment model aims at supporting the task of associating and categorizing media artifacts in Web environments in a simple and concise way. Its structure was designed to expand and to classify the associated content based on information provided by users. Also, the model fosters hierarchical digital artifacts construction, which encourages its use by personalization and recommendation systems.

This approach is based on Composite Hypermedia (Ismail, 2009; Khan & Tao, 2001), a model for building multimedia documents in which different media can be combined to create new hypermedia artifacts with their own characteristics. The proposed model contains three types of media, named "Artifact", "Comment", and "Rating." An Artifact is the main object and it refers to the digital content that will be extended with information from other components. A Comment is textual information that can be associated to either an Artifact or other Comments. Lastly, a Rating represents the users' acceptance regarding those components.

In addition to the components, association rules among them are also defined: *(i)* an Artifact may be associated only with other Artifacts; *(ii)* a Comment may be associated with either Artifacts or Comments; and, *(iii)* a Rating may also be associated with Artifacts and Comments. Figure 1 depicts an abstraction of the collaborative model, in which rectangles represent components and arrows indicate their relations, i.e., which components can be linked to others, according to established rules. As can be seen, only Artifacts have a recursive association and they are also the only components that are able to communicate directly with the collaborative platform.

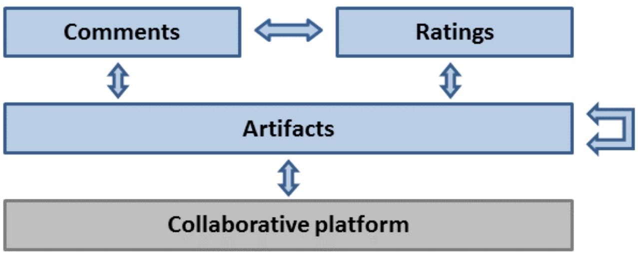

Figure 1. Multimedia content enrichment and rating components, adapted from Brant-Ribeiro et al. (2014)

The model takes into account two sources of information, called entities, which can be the Host Platform or the User. The Host Platform produces artifacts that will be enriched by means of comments and ratings made by users who share common interests, which characterizes the social nature of this model. Also, it is called collaborative because produced information extends the already existing content.

Therefore, relationships among components of this model can be used as a source of information to entities that implement content recommendation and personalization algorithms. In addition to their natural relationship, comments and ratings can be employed as parameters for helping decision making of recommendation algorithms.

Case study with the Classroom eXperience platform

Classroom eXperience (CX) (Araújo et al., 2013; Brant-Ribeiro et al., 2014) is a C&A platform deployed at the Faculty of Computing at Federal University of Uberlândia (FACOM/UFU) that was developed as an educational support tool to record classes in instrumented settings, store captured multimedia content, and make it available to students for further revision. CX automatically generates hypermedia documents in different presentation formats by synchronizing media streams coming from ubiquitous devices, such as electronic whiteboards, cameras, and projectors.

Its architecture follows a well-structured sequence of activities and implements the model proposed by Truong and Hayes (2009), which is composed by four phases, namely *pre-production*, *live recording*, *post-production*, and *access*. Besides, CX expands its scope to explore an additional phase, called *extension* (Pimentel et al., 2001), in which the content is enriched continuously by users' interactions, as shown in Figure 2.

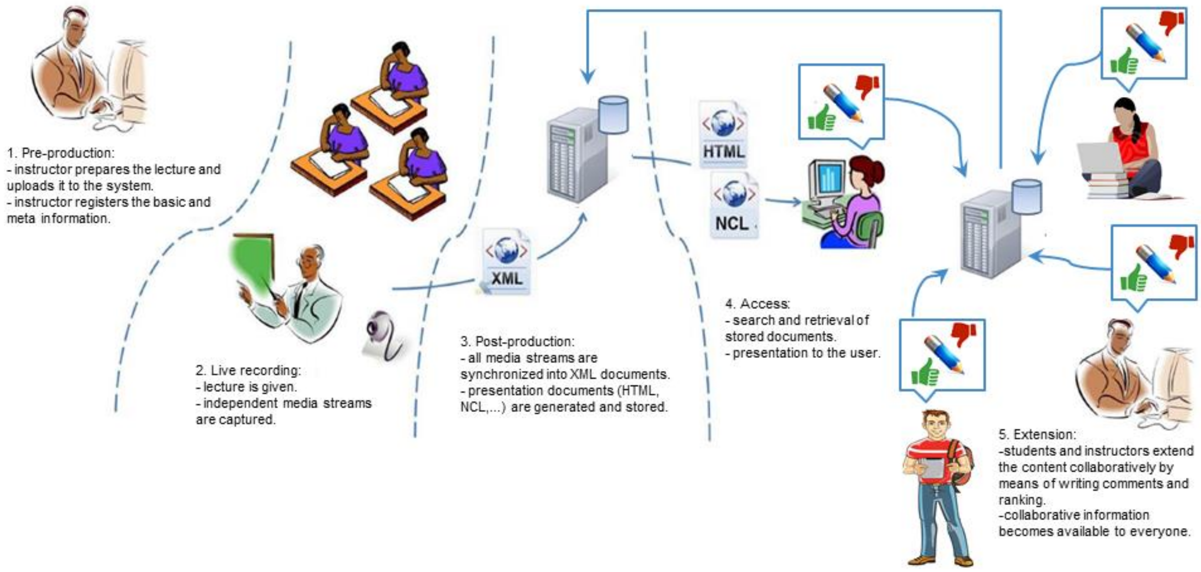

Figure 2. C&A process, adapted from Brant-Ribeiro et al. (2014)

A prototype of the proposed collaborative model was built as a loosely coupled module on top of the CX's Web front-end, providing extensibility and reusability properties, which has not changed the CX's operation.

Design and implementation

The prototype's architecture follows the principles of Domain-Driven Design approach, in which domain-specific features are built and independent of each other (Santos, Beder, & Penteado, 2015). Thereby, Web services were built to enable the communication between the two modules: one for performing service requests and display graphical components, and another for fetching and storing system information.

Lectures' slides rating is one of the implemented features which uses the star rating approach that is commonly employed in Web platforms. Also, the average rating of each slide is presented by another visual component. Once users measure slides importance by rating them, this information can be employed both as a customization parameter as well as input for recommendation algorithms.

Students can also create comments for lectures' slides and the course itself. Comments are eligible for replication and rating, which encourage debate and can be used to measure comments relevance. However, comments' rating uses a different approach from slides rating. For comments, the "thumbs-up/thumbs-down" approach that is commonly used in social networks was adopted. Figure 3 depicts the content presentation page in CX, in which region (a) presents the rating component, region (b) depicts the slides comment component, and region (c) highlights the slides rating average component. Also, the video component can be noticed at the figure's top right corner and the slides navigation mechanism at the bottom.

To illustrate an instance of the slides rating service, Figure 4 depicts the steps required to perform a slide rating registration and fetching as well as the relationships among the architecture components. When a user request for a slide (first step), an Ajax request triggers the rating registering Web service (second step). Upon the request receiving, the artifact rating is stored by a Web service (third and fourth steps) and, then, sends a JSON object back with the artifact rating information (fifth, sixth, and seventh steps). Finally, the HTTP response is handled by a JavaScript function that is responsible for building the slides rating information (eighth step) using a specific stylesheet for that.

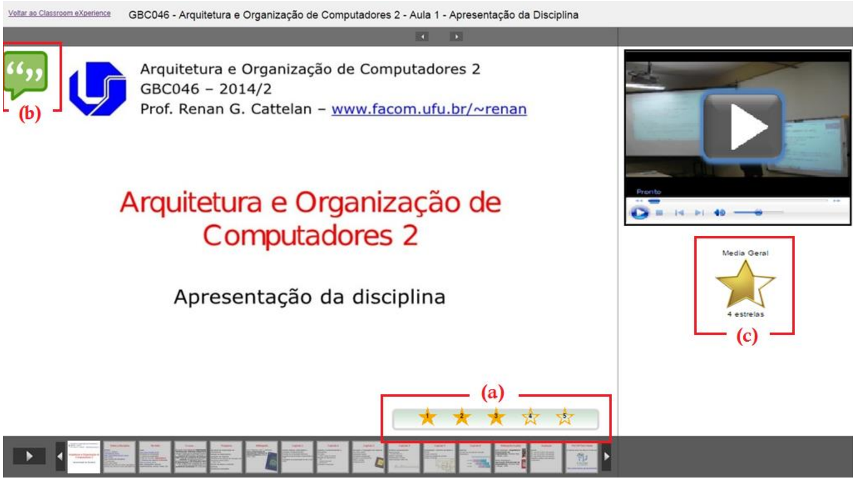

Figure 3. Lecture presentation in CX (Brant-Ribeiro et al., 2014)

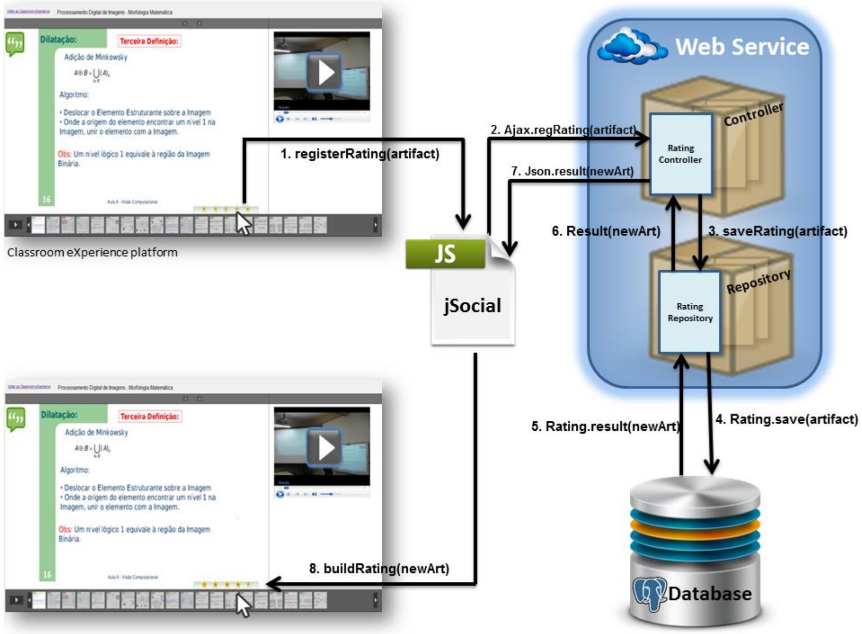

Figure 4. Slide rating requests, adapted from Brant-Ribeiro et al. (2014)

Information gathered by the collaborative module enriches the existing digital content, fostering collective learning, and producing a social network made up of students and instructors. Since some user information is also kept by the module, it is capable of generating input for expert systems based on users' interactions.

Evaluation method

An experiment employing an adaptation of the Technology Acceptance Model (TAM) (Davis, 1986) was conducted in order to analyze the impact of social and collaborative features in CX, and also to verify their acceptance by users evidencing which factors most affected the system usage intention. TAM aims at understanding the users' acceptance process of computer-supported technologies and it may be tailored to fit each application context. Several works that make changes and extensions of that model are found in the literature (Peris, Blinn, Nüttgens, Lindermann, & von Kortzfleisch, 2013; Rauniar, Rawski, Yang, & Johnson, 2014).

Two original TAM dimensions related to motivational issues were employed as a way of predicting the actions of individuals, namely Perceived Usefulness (PU) and Perceived Ease of Use (PEU). PU concerns the degree that users believe the usage of the new technology can improve their performance or usage experience. PEU can be understood as the level of effort that users believe to be necessary for using the new technology.

The following hypotheses were drawn up based on those dimensions, also considering the context of use of CX:

Hypothesis 1: The PU of both the CX platform and collaborative features directly influence users intended usage.

Hypothesis 2: The PEU of both the CX platform and collaborative features directly influence users intended usage.

In order to increase the analysis reliability and explore specific factors of the system, two dimensions have been added to the analysis criteria: Perceived Attractiveness (PA) and Academic Performance (AP). PA is often found in studies that apply TAM in Web-based platforms. Such criterion might be understood as the attractiveness level of applications' components and functionalities. Its analysis intends to identify the extent to which this relationship affects the interest in the system's usage. As a result, PA criterion was included among the evaluated dimensions and the following hypothesis was analyzed:

Hypothesis 3: The PA of both the CX platform and collaborative features directly influence users intended usage.

Finally, the adoption of information technology in the educational context aims at promoting teaching/learning processes by providing positive results for students and instructors. In this way, AP dimension has been added to the criteria set to evaluate students' academic performance, and the following hypothesis was drawn up:

Hypothesis 4: The use of both the CX platform and collaborative features affect the AP of users who had used the educational system.

For investigating those dimensions, evaluation questionnaires were administered and students' access logs were analyzed. Students from five undergraduate classes – bachelor's degree in Computer Science and in Information Systems at FACOM/UFU – were part of the experiment during two academic terms. The questionnaire was designed to obtain users' feedback about the collaborative features based on the proposed TAM adaptation. In order to ensure that thoughtless answers would not influence the research outcome and to neutralize inconsistent answers, a method for reversing and negating statements was employed during the questionnaire design (Huang, Curran, Keeney, Poposki, & DeShon, 2011; Weijters & Baumgartner, 2012).

Thus, two assertions for each dimension were prepared at first. In addition, two more assertions for each dimension were prepared with the opposite idea to the first ones (negating technique), leading to a 16-statements questionnaire containing different points of view about CX's usability and collaborative features, and also their impact in the analyzed context. For each statement, it was provided a 5-points Likert scale representing the user agreement degree about that item, ranging from "Strongly disagree" to "Strongly agree". Employed statements are presented below:

- I liked to rate slides with stars, expressing their relevance.
- I accessed only particular lectures when I logged in CX.
- I think user comments provided additional information to the slides content.
- Slides rating information, like the overall mean of stars, was more useful to study than the user comments.
- In my opinion, comments and ratings (stars) helped me to understand the presented content.
- I found it tough to use the interface and confusing how to create comments.
- Stars rating was intuitive and simple to use.
- In the user comments, I did not find relevant information that helped me to understand the slides.
- I think that rating slides with stars is not relevant.
- I accessed different lectures each time I logged in CX to study/review.
- For me, comments were not relevant and did not offer extra information about the slides.
- In my opinion, comments were more relevant to the lectures than slides ratings (stars).
- I think the slides comments and ratings (stars) features did not help in my learning.
- I liked to interact with CX interface and it was easy to create and read the user comments.
- Star rating got a bit confusing and it was tough to use.
- User comments helped me to understand the course content.

The link between questionnaire statements and TAM dimensions was as follows: statements 1 and 10 were about PA positive aspects while statements 2 and 9 had opposing ideas; statements 3 and 4 and their negated ones (11 and 12) described PU; statements 5 and 16 and their opposing ones (8 and 13) were about AP; and, finally, statements 7 and 14 and their opposing pairs (6 and 15) were related to PEU.

Additionally, a field for comments and suggestions was also provided, assuming that those responses would help to measure the satisfaction level of users' experience, indicating points of failure that could be considered for forthcoming platform evolution. Besides administered questionnaires, access logs of students who attended the two courses that used CX as a support tool were also analyzed.

Results and discussion

During the school semesters when the social and collaborative features were integrally available in the CX platform, 77 students utilized them. Of these, 25 answered our proposed questionnaires. For each pair of affirmatives with the same idea, we expected students to respond with opposing impressions, since these statements had different views about the same concept. Thus, validation of statements was carried out by inverting the item that had the negative idea of each pair and performing the calculation of grouped results, in order to confirm or cancel responses for each idea. Results achieved with the use of this legitimization technique can be observed in Figure 5, which presents the agreement and disagreement levels (in percent) of students in relation to the affirmatives.

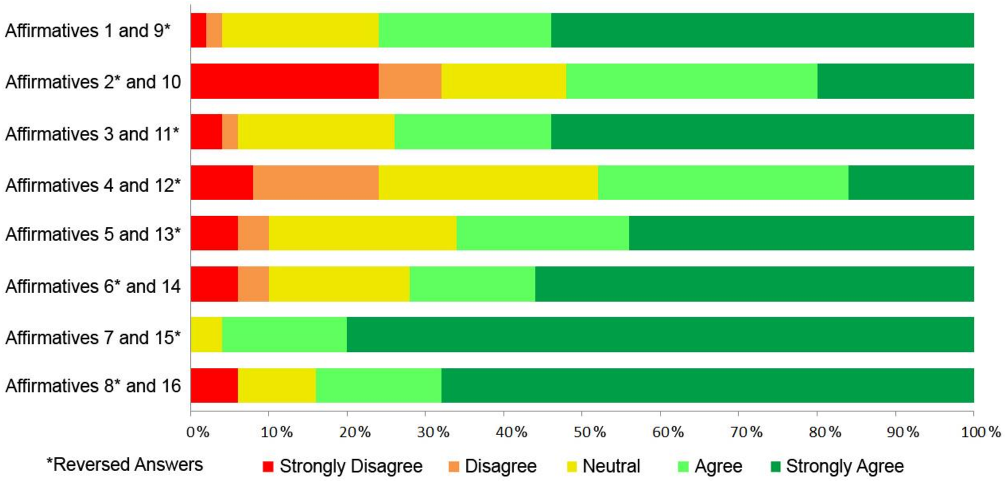

Figure 5. Student agreement levels for the questionnaires' affirmatives

In general, students agreed with the positive ideas presented in questionnaires. Affirmatives 1 and 10, which sought to measure student PA level in relation to CX, reached an elevated level of concordance. This demonstrates that users considered attractive the functions present in CX and, thus, were encouraged to navigate the system and access different recorded classes. Most of students who answered the questionnaire also reported that CX's user experience was satisfactory, since it presented an intelligible interface.

We also perceived that users acknowledged the social and collaborative features as sources of additional information which assisted them to understand the content presented in classroom. These facts can be concluded through the analysis of users responses to affirmatives 7 and 14, which comprised users PEU in relation to the platform, and 5 and 16, which ascertained if students considered the collaborative features as ways of obtaining extra content beyond the classroom. Concerning the PU dimension, analysis of affirmatives 3 and 4 revealed that students recognized the social and collaborative components as useful features in the platform.

Responses obtained through the reserved field for criticism and suggestions were also analyzed. There were some comments about CX unavailability in some periods and the possibility of downloading recorded content for offline study. Platform unavailability was due to casual instabilities of the university's network where this research was conducted, a factor beyond the reach of the platform's maintainers. About providing downloadable material for users, since CX explores the dynamics of UbiComp over existing models based on static documents, we believe this is not an issue, but an expected part of students' adaptation process. Furthermore, students pointed out that slides classification and written comments had a great value for both the interaction among peers and the recorded content extension with didactic materials for later study.

In addition to questionnaires, we also analyzed logs of usage and collaborative activities. We observed the access frequency of five classes enrolled in two courses (A and B), which used CX as a support tool. Classes' first semester represented the control group, while classes' second semester used the social module. Data was plotted to visualize the evolution of weekly accesses in the system as well as in the captured lectures. Figure 6 depicts the amount of accesses performed by students that attended course A (in both classes). Classes that attended course B presented similar access levels.

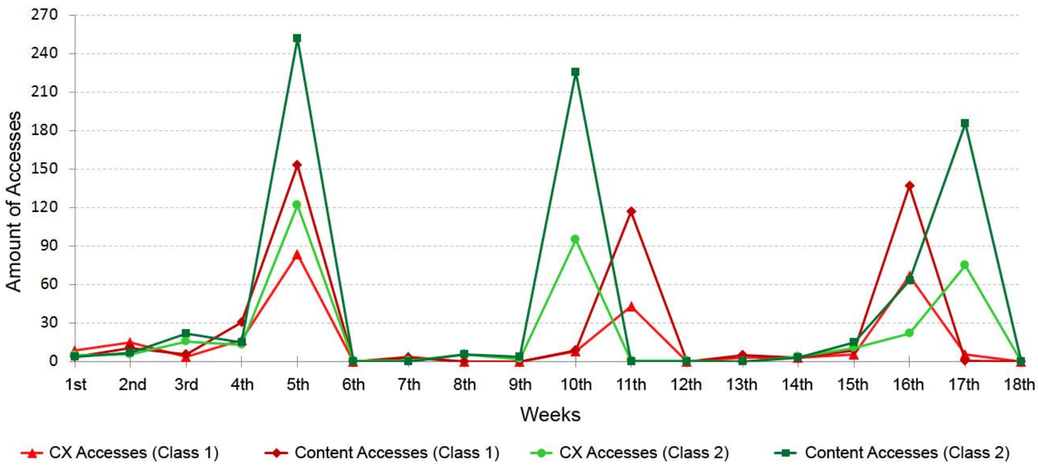

Figure 6. Weekly accesses for course A

Access peaks observed in Figure 6 illustrate weeks that students had tests. In these periods, CX received higher amounts of hits than in other weeks, a result that allows us to comprehend that students used the system to study for exams. In addition, Class 2 (which employed CX integrated with the social module) had hits peaks that exceeded Class 1 in over a hundred visits to lectures during tests periods. Therefore, we believe that students who utilized CX with the social module felt more encouraged to interact with the captured content by performing various slides ratings and comments during every visit to the platform.

We also analyzed student grades to understand whether the inclusion of new technologies brought gains to students' performance. To accomplish this analysis, statistical tests were conducted to strengthen if there were significant differences among students' grades. In order to employ appropriate sample sizes to correctly analyze student performances, we utilized a minimum of 20 observations, as established in Brant-Ribeiro and Cattelan (2015). Also, to avoid result biases, we disregarded grades of students that, at the end of the semester, presented dissonant performances if compared to other grades in the same academic periods. We understand that these students had higher chances of careless behavior at the end of the semester, since they had already reached the minimum requirements to be approved in the course.

Samples were initially submitted to the Shapiro-Wilk's test (SW) in order to ascertain if the statistical residuals of the observed variable followed a normal distribution. Subsequently, Levene's test was applied to samples from different classes who attended the same courses to check the homogeneity of variances between them. Then, the Student's *t* test was utilized to verify if there were significant differences among means of students grades who attended the same courses in different classes. Table 1 presents the results of SW, Levene and Student's *t* tests, as well as the respective performances of analyzed groups.

Table 1. Classes' performances with and without the social features

Course[1]	Class	*n*	SCM	$\bar{x} \pm s$	*W(P)*	*F(P)*
A	1	21	Absent	78.85 ± 12.89 *a*	0.961 (0.533)	0.284 (0.597)
	2	35	Present	80.19 ± 11.62 *a*	0.960 (0.231)	
B	3	23	Absent	62.16 ± 21.27 *a*	0.953 (0.340)	4.702 (0.036)
	4	20	Present	74.84 ± 14.62 *b*	0.927 (0.138)	
B	3	23	Absent	62.16 ± 21.27 *a*	0.953 (0.340)	1.665 (0.204)
	5	22	Present	74.80 ± 15.02 *b*	0.921 (0.080)	

Note. [1]Means followed by distinct letters in each course differ from each other through the Student's *t* test for independent samples with 0.05 of significance; SCM: Social and Collaborative Module; $\bar{x} \pm s$: Mean and standard deviation; *W*: Statistic of Shapiro-Wilk's test; *F*: Statistic of Levene's test; *(P)*: Probabilities above 0.05 indicate statistical residuals with normal distribution and homogeneity of variances for Shapiro-Wilk's and Levene's tests, respectively.

Every observed sample exhibited residuals' normality. Only between classes 3 and 4 of course B it was not possible to achieve homogeneity of variances through Levene's test, but the degrees of freedom were adjusted for this case and, therefore, it was possible to employ Student's *t* test to compare these samples. Despite obtaining higher grades in every class that employed the social module, only students who attended course B presented a real performance increase in their grades. In this course, besides the means increase, there were also standard deviations diminution – what allows us to understand that students of the analyzed classes started studying from common information sources, generating a higher flattening of grades.

We also analyzed grades of students who had partial contact with CX's social module. The one-sample Student's *t* test was employed to compare grades of students in the same academic period, since the features had been introduced in CX between the 13^{th} and 14^{th} weeks of the semester. Thus, students had contact with the social features to study for the final tests that took place between the 16^{th} and 17^{th} weeks of the semester. For the one-sample Student's *t* test, we subtracted the student performance obtained in the period when there was no social module from the grades the same students achieved when the social features were available. The SW test was applied to these results and we observed that all samples followed a normal distribution. Finally, the samples were submitted to the Student's *t* test. Table 2 presents the results of analysis made in both classes during the same semester.

Table 2. Classes' bimonthly performances with partial social features use

Course[1]	*n*	Bimester	SCM	$\bar{x} \pm s$	$\bar{d} \pm s_d$	*W(P)*
A	21	1^{st}	Absent	39.42 ± 6.45 *a*	0.38 ± 8.28	0.979 (0.908)
		2^{nd}	Present	39.81 ± 7.24 *a*		
B	23	1^{st}	Absent	30.86 ± 10.56 *a*	7.76 ± 12.41	0.984 (0.958)
		2^{nd}	Present	38.62 ± 8.73 *b*		

Note. [1] Means followed by distinct letters in each course differ from each other through the one-sample Student's t test with 0.05 of significance; SCM: Social and Collaborative Module; $\bar{x} \pm s$: Mean and standard deviation; $\bar{d} \pm s_d$: Mean difference and standard deviation of difference; *W*: Statistic of Shapiro-Wilk's test; *(P)*: Probabilities above 0.05 indicate statistical residuals with normal distribution for Shapiro-Wilk's test.

Analysis of Table 2 allows the understanding that there was again a difference only among students who attended course B. With regards to course A, even also presenting a visible mean increase, there was no significant difference among student grades. Therefore, analysis of classes for both full and partial utilization of the features revealed that only students who attended course B presented an increase in their performances. We believe this happened because course B had a mathematical focus, in which CX resources were extensively employed. Since the aforementioned course dealt with complex subjects, in which most of the problem resolutions demanded higher commitment by enrolled students, this suggests that courses characteristics greatly influence on how receptive is the technological support offered by CX to users.

In short, from the analysis of user questionnaires responses and observation of CX access logs, we found out that PU, PEU and PA of students were positive and consistent. Issues such as usability, attractiveness, and enjoyment were evidenced by students who used the platform. Thus, it was possible to comprehend that CX was perceived as a useful supporting tool to the educational context and that it has attractive features to users, such as an intuitive interface. In this way, the hypotheses 1, 2 and 3 were altogether supported by the CX platform.

Also, analysis of students' performances provided the understanding of a significant improvement in their grades among students who attended course B. In this context, hypothesis 4 was supported with reservations, since the expected improvement for this topic was partially supported in this research application context. However, the analysis about the influence of courses characteristics upon students along with the support of educational technology presented positive results and aspects in this research. This factor evidences that hypotheses which deal with student grades must include issues and questions that go beyond the single usage of new technologies. This way, the validation of this study's guidelines employing the TAM model was efficient for the analysis of the impact and acceptance of social and collaborative features in CX. Adjustments made in the TAM model to fit our context were appropriate and generated satisfactory results.

Related work

Several studies concerning to UbiComp in educational settings can be observed in the literature. The use of interactive technologies by academics opens doors to a new era of teaching and learning, breaking down barriers that hindered the full achievement of knowledge. Typical researches in this area deal with recommendation

(Sabitha & Mehrotra, 2012), personalization (Lopes et al., 2013; Möller, Haas, & Vakilzadian, 2013), and adaptation (Araújo et al., 2013) features for educational content in ULEs.

Collaborative learning is a methodology focused on the process of getting knowledge through social interactions, either in real or virtual environments. A common goal of educational approaches is to foster communication and teamwork skills among students (Mukherjee, Pal, Choudhury, & Nandi, 2014). Encouraging group problem solving is one way of achieving those goals.

Claros and Cobos (2013) tackle this theme by presenting the *Social Media Learning*, an educational platform that supports interactive construction of multimedia content. Content rating, management of educational content and multimedia authoring are features of the platform. In addition, they get social information from *Facebook*, and use *Youtube* services for videos delivering. However, this platform does not classify Learning Objects (LOs) in hierarchical levels and they do not provide content personalization mechanisms, as in CX.

A collaborative learning environment called *Collaborative Science Inquiry* (CSI) was presented by Sun, Looi, and Xie (2014). It consists of two functional modules, Teacher Module and Student Module, that allow teachers to design instructions and questions, attach simulations, manage groups, and review learning artifacts, and students to collaborate by means of inquiry activities in a shared workspace. Although it has a collaboration feature, the content is neither classified hierarchically nor personalized.

Mukherjee et al. (2014) explore the concept of *Mobile Learning* by proposing a Mobile Ad Hoc Network (MANET) infrastructure for setting up a collaborative educational environment. In that environment, mobile devices allow users to communicate directly with each other. Despite of promoting social interactions and discussions, approaches that consider only mobile devices may have technical constraints, such as coarse-grained content viewing due to the small size of the devices' screen. Furthermore, the way of obtaining and providing data is different from the proposed approach since it explores the Web 2.0 features.

Chen, Hwang, and Wang (2012) created *MyNote*, a system that promotes collaborative construction of knowledge by means of authoring and sharing of notes for multimedia artifacts in Web 2.0 environments. It allows to create comments on notes and classify them in order to foster debates and exchange of information. *MyNote*'s architecture is similar to the one presented in this article, since it has components embedded in the host platform that are responsible for calling Web services. Nevertheless, they store the content in a different way by carrying out a copy of the entire HTML code (raw page and notes) along with its URL and the notes' timestamps, while in CX the notes are linked to the multimedia artifact itself, regardless the way they are presented to the users.

Fan et al. (2010) developed a Web platform that provides tools for creating notes on images. It allows users to create text or multimedia annotations in specific areas of the images, which may facilitate further discussions and analysis of figures and graphs. Azouaou, Mokeddem, Berkani, Ouadah, and Mostefai (2013) created *WebAnnot*, a Web tool for creating, categorizing and sharing online notes, which uses an ontology-based model that has standard properties such as attributes that allow the search and recommendation of semi-automatic or manually created annotations. Yet, *WebAnnot* does not support neither classification of annotated multimedia artifacts nor their hierarchy.

In the work of Morgado, Penalvo, and Hidalgo (2012), they presented a methodology for categorization and classification of LOs considering students' skills and abilities. This way, it is possible to present LOs suited to students with different skills. However, the inference process for LO categorization is done manually by instructors and, thus, collaborative aspects are not exploited.

Foll, Pontow, Linner, and Radusch (2006) developed a conceptual framework for building applications to classify and manage multimedia content produced by social and collaborative activities. It includes features such as content management, collaboration, personalization and recommendation based on contextual and social activities. They implemented a Web blog, called *Online Community Life* (OCL), which enables the distribution of multimedia content in communities managed by ubiquitous platforms. However, that approach does not provide mechanisms that enable users to create and manage their social and collaborative information within those ubiquitous platforms that are integrated with the OCL.

In order to better illustrate related work, Table 3 summarizes the information presented in this section. For comparison purpose, we used the main features supported by the proposed social and collaborative model. In this way, the following criteria for evaluation were highlighted: (a) support for enrichment of multimedia artifacts;

(b) support for classification of multimedia artifacts; (c) support for collaboration among users (sharing and discussion); (d) hierarchy of artifacts, and (e) support for content personalization based on collaborative activities. For each criterion, three levels of compliance were determined: an unfilled circle (○) for works that do not support the evaluated criteria; a half filled circle (◖) for works that partially support the evaluated criteria and fully filled circle (●) for works that support the evaluated criteria.

Table 3. Comparative table among the proposed and related work

Work	(a)	(b)	(c)	(d)	(e)
(Claros & Cobos, 2013)	●	○	●	○	○
(Sun et al., 2014)	●	○	●	○	○
(Mukherjee et al., 2014)	○	◖	●	○	○
(Chen et al., 2012)	○	◖	●	◖	○
(Fan et al., 2010)	●	◖	●	◖	○
(Azouaou et al., 2013)	●	◖	●	○	◖
(Morgado et al., 2012)	○	●	○	●	●
(Foll et al., 2006)	◖	●	●	◖	●
This study	●	●	●	●	●

Some approaches have their focus on multimedia content enrichment, while others go deeper in the classification of artifacts. In most studies, collaborative authoring is also taken into account as way to encourage the collective constructivism and improve results against user satisfaction. However, our approach differs those by presenting a generic model for annotations and their types and relationships in addition to considering content enrichment and classification (ranking) requirements, supporting content hierarchy at different levels.

Conclusion and future work

The approach discussed in this paper sought to explore social and collaborative features within real ULEs. To do so, we proposed a software architecture model capable of supporting collaborative interactions for content extension and enrichment via annotations and classification (ranking). Such architecture also provides support for content recommendation and personalization. Based on the proposed model, a collaborative system was implemented to create annotations and classify multimedia content.

As a case study, the proposed approach was integrated into the Classroom eXperience (CX) platform as an add-on module. For the sake of validation, the Technology Acceptance Model (TAM) adapted to the educational context was carried out. Our experiment comprised the administration of questionnaires to obtain users' point of view, analysis of access logs, and study of students' grades. Results demonstrated that features offered by the collaborative module were well accepted by users and brought some benefits, such as higher number of access to the system and higher final grades. We found that the social features have encouraged CX's usage and fostered collaborative learning among students, which is an important resource for enriching the content beyond what was discussed in class. In addition, customized TAM revealed itself appropriate for the validation of this proposal.

Although including social and collaborative features in CX has proved to be valid for the students investigated in this study, we cannot generalize the results because they may be biased by the domain of the studied courses (Computer Science and Information Systems). Students of those courses might have a greater willingness to accept new technologies than students of adverse areas. This assumption leads to the need for a larger and more diversified sample, considering an interdisciplinary scope, so that it is possible to obtain results in diverse technological axes and achieve greater conviction about the importance of developing and studying social and collaborative features in educational systems.

Also as future work, gamification elements have been investigated in the context of the CX platform as a complementary approach to increase students' motivation. Moreover, social information obtained through the proposed model will also be used to adjust the students' model, which may include cognitive aspects such as their learning styles, and as input for recommendation and personalization algorithms.

Finally, we believe that the exploitation of UbiComp premises in the educational field remains as a potential alternative to refine the teaching/learning processes since it aims to assist people through applied technologies in a non-intrusive way. Such approaches match the construction of environments in which the real and virtual worlds are blended in a way to support the use of information technology.

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