Eliciting features to build collaborative learning objects

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***Abstract*— Teaching abstract concepts is a challenging task, and the lack of connection between theory and practice is a demotivating factor for students, causing drop outs and off-task behavior. Learning objects (LO) are digital resources that can be used for more active teaching approaches. Many LOs for IT and engineering disciplines are available in public repositories, but mostly directed to individual use, contrasting with current theories of learning, which consider learning as social processes of knowledge construction and meaning making. This work examined how an LO might be extended to effectively support collaborative activities in Computer Science topics, namely, process queuing and scheduling algorithms, usually very theoretical and taught on an instructionist basis. We used an existing LO and a script with pedagogic tasks to compare both individual use and use in groups, to contrast possible differences and to elicit what sort of mechanisms they missed most. We conducted a user study with 13 individuals. Qualitative data from observations, focus group and interviews were collected and analyzed using the 3C model of groupware development as theoretical foundation. The main advantage observed was the mutual help in the groups and as drawback, the coordination of the tasks. As specific pedagogic issues, we point the immediate need for help and traces of interactions to increase the awareness.**

Keywords — learning object, CSCL, collaborative learning.

I. Introduction

Being a teacher of information technology (IT) in technical or college level courses is a challenging task, because a demotivating factor commonly cited is the lack of connection between theory and practice. Several resources have been developed to improve learning experiences in IT courses, and learning objects are resources worth taking into account. Learning objects (LO) are defined as: "any entity, digital or non-digital, that may be utilized, reutilized or referred to in technology supported learning" [1].

The practical nature of this content simulating the concepts presented in theory is an advantage in the learning process. Through visual interaction, it is possible that the students better understand the content without leveraging a possible demotivation imposed by the traditional lecturing method [2]. The educational approach adopted by most of the LOs, the *instructionism* - highly prescriptive and non-interactive - conflicts with contemporary learning theories, such as *constructivism* and *socio-constructivism*, which consider learning as active, intentional, and motivational social processes of knowledge construction and meaning making. According to [6], in these contemporary theories teaching is seen more as a means of supporting and gradually increasing student-centered activities, engaging students to think and providing environments for collaboration, knowledge building and reflection. However, the typical LO approach emphasizes the learning content and its effective delivery to the student based on the information transfer, neglecting the learning processes' essential nature and personal knowledge construction. Many LOs for IT and engineering disciplines are available in public repositories, but they are mostly directed to individual use, contrasting with these theories of learning. To the best of our knowledge, there are no systematic studies on how to develop LOs that support collaborative work natively.

Comparisons of LOs in these topics were performed in [3] and [4], including SOsim, which is the focus of this work. In [14] the author tested different LOs in both conditions and concludes that although the LOs were primarily developed for individual use, they may also help students working in peers and highlights that "using the learning objects in different modes is possible and designing and developing learning objects for the use of multiple modes is crucial". In [5] is pointed that constructivist learning objects directed to the student seem to have not been well explored. In [7] is investigated the collaborative use of LOs with one group where students formed pairs, reporting that those who collaboratively studied the content with LOs benefitted more from the LOs.

This work aims to explore perceptions on the collaborative use of LOs, originally developed for individual use and provide reference for design requirements. This sort of study can help understand which features students perceive as more useful and are not currently for us in small groups.

II. 3C Model

As a theoretical framework for this analysis, we adopted the 3C model [9]. It is a model for the analysis, representation and development of groupware by means of the interplay between the 3Cs, namely: communication, coordination and cooperation. This combination aim to stimulate the awareness of users in collaborative settings, as illustrated in Figure 1.

The *communication* is related to the negotiation and decision-making through an augmentation process. The *cooperation* is related to the joint operation in the shared workspace. The *coordination* is the management of people, their activities and resources, in the context of collaboration. The *awareness* is the capability of perceiving the activities of others and their own in a shared workspace.

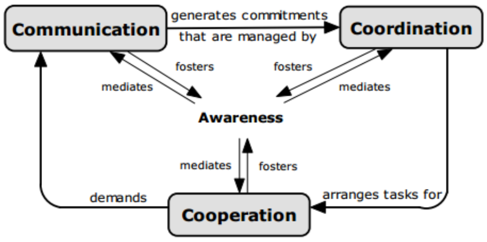

FIGURE 1. 3C COLLABORATION MODEL INSTANTIATED FOR GROUP WORK [9].

This model appears in the literature with different applications: as a means to classify collaborative systems [10], for groupware implementation [11] and evaluation [12], or the analysis and representation of groupware [13].

Although this is a simple model, it enables the design of the (arguably) most fundamental features of collaborative artifacts. Thus, we believe that this model provides a good framework to analyze the current limitations of LOs.

III. METHOD

We investigated how technology can be designed to improve the learning experience in these difficult topics, addressing the research questions that guided the collection and data analysis process: (RQ1) *What were the participants' perceptions during the use in groups of an LO developed for individual use?* (RQ2) *What were the advantages and drawbacks observed and reported in the collaborative use of an LO developed for individual use?* By answering those questions, we hope to shed some light towards basic features for LOs capable of providing such support. We adopted a more qualitative approach since we had few students available for this experiment - yet, an entire actual class.

A. Participants

Thirteen students were selected for the experiment: 7 males and 6 females, aged between 20 and 49 years (mean: 34.5 years; SD: 11.5), taking the Operating Systems classes in Computer Science vocational course. Although it is a quite diverse population, we argue that this is a valid sample, since it is an actual class of students in a technical course (vocational college). In Brazil, over 1 million students are currently enrolled in such technical courses of similar diversification, with over 100 thousand students in computer technical courses.

B. Materials

To achieve the goal of this study, we selected the topic of process scheduling in a technical-level Operating System course. The experiment was conducted using the SOsim learning object [8], a well-known simulator in academic settings and used in many college courses. With SOsim, one can introduce the concepts of multiprogrammable and/or multitasking operating system mechanisms, such as Unix / Linux and Windows in a simple and interactive manner, with the multiprogramming concepts' visualization, process and its status changes, processor management (scheduling) and virtual memory management as shown in Figure 2.

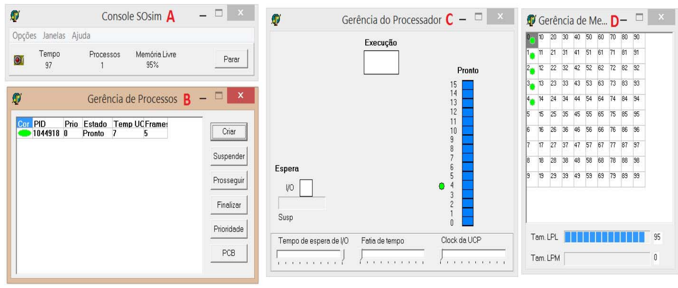

FIGURE 2. SOSIM'S INTERFACE. *A*-CONSOLE: GENERAL INFORMATION AND SCHEDULING PROCESS' TYPE ; *B*-PROCESS' MANAGER: CREATE AND MANAGE PROCESS' CHARACTERISTICS; *C*-PROCESSOR MANAGER: PROCESS STATE AND MANAGE PROCESSOR'S CHARACTERISTICS; *D*-MEMORY MANAGER: PROCESS' MEMORY ALLOCATION.

In its configuration options, one can select different scheduling policies, create different processes' types (for example: CPU-Bound and IO-Bound), change the processes' priority, the processing time limit (quantum), time that a process waits for a resource (blocked time), CPU clock time and also suspend or terminate the processes. Thus, the student has the opportunity to view the theoretical concepts presented in classroom lectures in a simple and lively manner, for example, how the states of a process change during its lifecycle among: ready, running and blocked states. As it is very modular, we could easily assign roles to perform some tasks in different parts of it. When SOsim simulator was first introduced, the authors pointed that they followed a constructivist pedagogical approach, "whose collaborative and support processes to social negotiation of meanings are highly relevant because each student has a unique perspective" However, it is not clear how these collaborative requirements were met in their study. We chose this LO both for individuals and for groups to contrast the way they are used in classroom. Based on those differences, we hope to collect some initial evidences on basic collaborative features, to be iteratively tested, extended and refined.

C. Study design

The study has an emphasis in qualitative analysis, exploring the small number of participants in the experiment. There were two conditions for using the learning object: *individual use* and *use in groups*, performing a collocated pedagogical activity in the classroom. When used in group, the pedagogical activity was broken in small pieces, according to the SOsim modules, and each module was assigned to different roles and the participants assumed a role for the activities execution, while in the individual use, participants executed all the script by themselves, i.e., played all the roles.

Through analysis of pre/post-test tests and qualitative analysis through questionnaires on the collaborative use, the individual use of the object was compared with the use in group in order to investigate the perceptions of collaborative user experience of the LO. Besides, a focus group was conducted to discuss some collaborative principles (according to the 3C model, also used to ground the interpretation of results) with those on the group condition and individual along with semi structured interviews to investigate some special cases detected in the observations.

D. Procedure

The experiment lasted 4 hours and consisted of a pedagogical activity composed by 11 tasks. Firstly, all 13 participants were gathered in a classroom and an introduction to the study was given for 20 minutes. During the presentation, all participants were identified to enable the follow-up of their activities and responses throughout the experiment. After the presentation, participants answered a test (pre-test) for 15 minutes, containing 7 multiple-choice items related to the topic of scheduling processes. The theoretical content used to formulate the questions had been previously taught in the classroom and this test was carried out to assess the knowledge that each participant had watching the regular discipline lectures for the chosen topic. After all participants completed the pre-test, the teacher arranged the students according to their scores, balancing the composition of groups. Thus, 3 groups with 3 participants, with varying scores, were assembled to conduct the group activity and the remaining 4 participants performed the activity individually. Before the practical activity with SOsim simulator, the teacher held an introduction to the basic functioning of the LO for 15 minutes and then the 3 groups were directed to different rooms and the other participants were in another room, far apart from each other so to avoid personal contact. The students in individual condition interacted with the LO on separate computers. For groups, only one person was handling the simulator at a time but the screen was projected to the blackboard so that everyone could follow what the colleague's actions and give their opinion.

The practical activity using SOsim was held for 70 minutes and contained several tasks that addressed the theoretical content taught in classroom. The tasks requested participants to interact with the learning object by: creating CPU-bound and IO-bound processes; analyzing processes behavior; changing the processes priority; changing the processing timeout (quantum); changing the waiting time for a resource (blocked time); and by suspending and finalizing processes. The activity script also contained mobilizing questions so that students could reflect on what was being worked in the activity, encouraging metacognition and discussion, providing a greater knowledge exchange. The same script was administered to all the students, both for individual and group conditions. The teacher did not interact with the students during the practical activity, so to not interfere the results. The LO was conceptually divided into three interdependent modules, where the first one allowed the management of the processes, the second one allowed the scheduling of processes and the third one allowed the processor management - each one with its didactic tasks separately. The participants were asked to operate one of them at a time (different roles), with feedback from other members, with the role assignment negotiated by the group members. After a participant completed the tasks in his module/role, another member took over as operator of another module and the former operator sat back with the other member, and so on, until all participants could operate, collaborate and discuss the execution of the activity proposed. In the individual condition, participants operated all modules and reflected on their own activities, according to the script. During the practical activity, users were also observed by the authors of this work. Although individuals had more operational effort towards the activity, the group members also had to elaborate and engage in discussions while they were not operating their respective module, balancing the total effort.

At the end of the pedagogical activity using the learning object, we applied a new test (post-test), composed of other 7 items related to the same pre-test concepts and with similar difficulties, as determined by an expert, in order to estimate differences in their scores after the experiment. When all participants completed the post-test, those in the individual condition were dismissed, leaving only the participants of the group condition. For these ones, we used another technique to collect data regarding the collaborative use: the focus group. Lasting about 40 minutes, the semi structured interview contained open questions about collaborative principles derived from the 3C model and it was carried out with participants involved in group condition. Based on the results of the tests, we decided to conduct a new interview only with participants who showed more fluctuation in their pre/post scores – significant increases or decreases in scores. In addition, a participant (#4) assigned to the group condition, spontaneously stated a preference for individual use and we also interviewed this participant to investigate the causes of this preference.

IV. Results

This section elicits evidences collected for the research questions posed for this work, using 3C model components.

RQ1: What were the participants' perceptions during the use in groups of an LO developed for individual use?

Communication: Participant 8 highlighted the importance of collaboration among members of the group. According to him, one of the tasks of their group could not be completed due to a knowledge limitation of a member performing the active role. However, in this case, other members of the group intervened and were able to help him in his difficulty and scaffold the completion of the activity. Another participant (#9, individual condition) reinforced this statement. According to him, the completion of all the tasks proposed was not possible due to misconceptions in the subject matter. Participant 6 pointed that some doubts and perceptions around the tasks in the script were spontaneously raised, generating constructive discussions. Participant 2 mentioned the lack of a tool for communicating with the group to exchange messages while developing a task, directed to one or all members of the group.

Cooperation: Participant 7 proposed that the LO should also show all the steps made by the members of the group so that everyone could understand how the task was being performed. In addition, Participant 13 commented on the importance of a community of people who have already made use of that LO, to share experiences of use and make it easier to reuse. He also noted that this sort of 'gallery' could also store the steps that resulted in the completion of the tasks performed by other users. Thus, it would be possible to see and compare different ways to achieve the task's goal.

Coordination: Participant 4 highlighted the lack of coordination of tasks, as one of his group members started exploring the LO disregarding the pre-determined tasks, what made him felt lost with the attitude of his colleague. According to most of the participants in group condition, a collaborative LO should allow different forms of coordination tasks, but there were differences on how the roles should be assigned. Participants 2 and 6 proposed that at the beginning of use, LO should automatically assign the role to the user, determining which tasks would be carried out. In addition, the user's role should be maintained for the completion of all activities. On the other hand, another group stated that the division of labor should occur in a more negotiated way between the group members themselves, and may trigger a change in the role of a member during the performance of activities.

RQ2: What were the advantages/drawbacks observed in collaborative use of an LO developed for individual use?

Communication flowed properly because the experiment environment was co-located. If the experiment environment was distributed, maybe this parameter could be further explored and analyzed. To this scenario, it would be important to use a chat tool in LO, allowing them to exchange online messages among group members while developing a task, as reported by the Participant 2.

The main advantage observed was with *cooperation*, emphasizing its importance in a group activity. Contrasting the participant who made individual use of LO and could not complete all the tasks (#9) and #8 who reported that group members intervened and were able to help one another, helping in their difficulties and making it easier the completion of a task, we can see the importance of groups in this sort of activity. However, a factor that may discourage students is their technical limitation - with respect to the subject or the object itself - to solve a task. At this point, cooperation between members of the group becomes crucial, because the members who have the knowledge can assist in his learning and motivate to continue the use of the LO.

The *coordination* of tasks were diverse. The script defined the tasks and roles to be performed, but participants should negotiate who would perform each role and how the group would interact. Analyzing the statements of participants 2, 4 and 6, it became apparent the lack of coordination in the execution of the tasks. After distributing the tasks, #4 reported that one of the members of his group began exploring the LO not related to the given activity, what made him get lost in the activity, and frustrating his experience with the LO. According to Participant 2, the LO would assume the role of pessimistic coordinator and not allow the execution of different tasks of pre-determined or optimistic coordinator, allowing exploration in parallel without affecting the planned activities and/or hindering the curiosity of one or more participants.

V. Discussion and Future Work

This paper presented a case study of collaborative use of an LO developed for individual use with the goal of eliciting features to build native collaborative LOs, based on the application of a simulator in a classroom setting. The choice of the 3C model as basis for the observation and collection of results seemed a good starting point, by focusing only on few aspects of collaboration. Regarding the *communication* among members, even being in a collocated setting, the participants mentioned the possibility of having some kind of communication mechanism, particularly for reasons of signaling the need for help when another member is in charge of the LO and the requester needs specific help to continue accompanying the task execution. This support was the main difference between both conditions. The *coordination* should be flexible, to enable the creation of more static or dynamic roles and their attributions. As pointed in [13], flexibility should be pursued by groupware designers to enable temporary modifications and redefinitions in the mechanisms of coordination for the users instead of embedding them into the system. The *cooperation* can be supported and improved by the existence of an activity log, to allow the group awareness towards all the actions taken to perform the activities in the LO, so that every member can trace what has been done until that moment. Another possible aspect to improve cooperation is a mechanism for parallel execution, so other members can explore the object without interrupting the group activity. This behavior caused one participant to reject the group activity because a colleague was exploring outside the scope of the script.

There were no apparent distinction among different ages, considering test scores or evolution in pre/post-test. One of the main issues was the lack of familiarity with this sort of technology or with the topic at work. However, the membership to a group helped to alleviate this issue, in case the users could watch their colleagues interact with the software. The social interactions helped to cope with the limitations and cognitive conflicts, helping the students to interact with colleagues with higher levels of specific competences, as pointed in Piaget's and Vygotsky's work.

Some students also pointed the efficiency to pedagogic success rather than task completion success. In traditional CSCW settings, one of the main goals is to provide support for the most effective way to get a job done. In educational scenarios, this may hinder the learning process, since a student must desirably perform all tasks in a pedagogical script.

This topic of collaborative LOs has been little described in the literature. Those impressions should be tested in further iterations, to check for the generalization of these features. As in previous literature [7] and [14], the collaborative use seems good complement for pedagogical practices with technology such as LOs, but still there are some obstacles to be overcome. We expect to take this further, by refining feature requirements to create or adapt LOs to collaborative settings.

The external validity may also pose a problem for generalization. This work was conducted with an actual class of students in formal learning, but in a scenario that may not be the same for other contexts, such as scenarios of formal learning of kids, with more homogeneous individuals. Despite that limitation, we believe that the impressions are still valid for initial rounds of validation.

Although with some limitations, we argue that this work brings some contributions to the CSCL field. By exploring the use of LOs in classroom settings we believe that we can provide some guidelines to design features that support collaborative work for a broader range of LOs, in a scenario dominated by instructionist/individual artifacts. We plan to do so with an iterative design approach, eliciting and validating requirements as they appear in the experiments.

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