Web Annotations in an Online Mathematics Course using UOCLET

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ABSTRACT

Communication is a key issue in the student learning process. In mathematics education, it is essential to overcome specific difficulties such as the learning of abstract concepts and its language of expression and communication; mathematical notation. At the Open University of Catalonia (UOC), students face the challenge in a somewhat "handicapped" way, since this is an online learning environment involving asynchronous communication. One of the problems students have to handle is that individual work, based on a set of well-organized learning resources, is physically separated from the "dialogue space" where they interact with fellow students and tutors. This separation makes it difficult to ask questions about some topics in the study material. Being aware of this situation, a web annotation tool called UOCLET has been designed and developed by the UOC. This tool, conceived for a pedagogical framework, enables students to highlight the text, add comments and share them. This communication tool has been incorporated in a mathematics course for online pre-engineering students during 2 semesters. This experience shows that it is difficult to introduce a new technology, as well as a new methodology, in a traditional learning process.

Keywords: web annotations, collaborative learning, interaction analysis, instrumental theory, online teaching and learning, mathematics education.

1. INTRODUCTION

How technological advances influence the student's learning process is a key issue in distance and online mathematics education. In order to confirm that learning is supported using web technologies, the mode of communication is an important factor that must be considered, as pointed out by Han and Hill in [1]. They point out that this is one of the challenges in conducting research in theories related to collaborative learning. Moreover, maths contents pose communication difficulties for students (mostly due to the unique notation) and specific cognitive difficulties; both kinds of difficulties are augmented in an online context, since tutor-student communication is not instantaneous [2]. In this study, we bear these difficulties in mind since it is carried out in an introductory course on mathematics for Engineering at the Open University of Catalonia (UOC).

The pedagogical model at the UOC is based on a virtual classroom organized into four independent sections: planning, communication, resources and assessment, see [3]. Hence, students interact with study materials following a working day schedule and, when a doubt arises or when they want to make a comment or ask a question, they contact the tutor through their personal e-mail or the forum of the virtual classroom. The channels of communication with the rest of the students are the same. Therefore, the individual work of a student is clearly separated from the dialogue space. Being aware of this situation, a web annotation tool called UOCLET has been designed and developed by the UOC. Specifically, this web annotation tool, created with an education purpose in mind, enables us to write comments and raise questions in the study material website, which are shared by students and tutor. Any Students and teachers in the class can read these annotations and edit them or contribute comments.

In this study, we analyze the introduction of this new communication tool in an online classroom and the influence of using UOCLET on questions relating to the learning process of online students. We look for possible improvements, due to the use of UOCLET, both in the student's mathematics learning process and in the students' self-confidence in their mathematical abilities.

We focus specifically on a course, *Introduction to Maths for Engineering* that has a twofold objective for students: 1) to acquire fundamental concepts, techniques and terminology in Algebra and Analysis; and 2), to facilitate the practical use of these contents. It is worth knowing that students are adults with professional experience, with not much time to study and with insufficient prior knowledge in maths.

The basic assumption of this research is that the integration of contents and communication spaces will lead to a significant improvement in the acquisition of basic mathematical competencies for pre-engineering students. There are two reasons for this expectation: on the one hand, it will allow the

teacher to better follow up the student's learning process and, therefore, a better personalization of this process may be achieved; on the other hand, it should contribute to increase the student's confidence in his or her abilities in the mathematical handling of concepts and procedures.

Our main research purpose is to analyze the didactic effectiveness of UOCLET and make interaction measurable. This information can help us in the future to include it in students' assessment. Therefore, the experience reported in this paper is a preliminary study and it has a threefold purpose:

1) To design, develop and implement a new communication tool, UOCLET.
2) To outline aspects that should be taken into account in introducing a new communication tool and strategies that should be considered in order to promote interaction.
3) To outline elements that enable us to produce an assessment tool based on interaction.

The paper is structured as follows. Section 2 presents the conceptual framework. Section 3 is devoted to introducing the main features of the web annotation tool UOCLET, designed and developed by the UOC. In section 4, the research methodology is stated. The results of the analysis of annotations and of the complementary data are presented and discussed in section 5. The degree and type of interactions, the interaction profile of students and the strategies to promote the use of the tool are discussed. Section 6 presents the conclusions and finally, the future trends are described in section 7.

2. CONCEPTUAL FRAMEWORK

The conceptual framework which supports this research is structured around three axes: interaction axis, instrumental axis and situational axis. In the interaction axis, we look into interaction and its analysis in a distance learning context. In the instrumental axis, we present a framework for questions referring to the instrumentation of a website annotation tool. Finally, in the situational axis, we briefly discuss the instructional inflexibility which occurs in distance and online learning.

Interaction axis

The theory of interaction in distance learning is one of the frameworks of this study. According to Roblyer and Wiencke: "research yields consistent indications that increased interaction in distance courses is associated with higher achievement and student satisfaction" [4]. According to Kozma, the technologies can offer unique opportunities for quality learning as long as the procedures are well substantiated in the cognitive and social processes by means of which knowledge is constructed. One of the objectives of the present research is to contribute evidence towards an empirical verification of the arguments given by Kozma, in the specific context that we deal with.

Roblyer and Wiencke also state that distance learning environments designed for the effective use of technology resources can be a chance to obtain the student's commitment and lead to gains in learning once this commitment is obtained, see [4]. In this sense, it must be stressed that the tool investigated here is used in conjunction with several other technological resources (interactive applications, videos, symbolic calculators and self-evaluation tests).

The difficulties in going from theoretical benefits of interaction to practice are the complex nature of the interaction in distance learning courses and the difficulty of designing the evaluation of the interaction process, as pointed out in [4]. There are, then, difficulties in developing practical guidelines to make the interaction concept measurable and useful to teaching and research staff. Furthermore, Varsidas and McIsaac point out special difficulties in obtaining high levels of interaction in an asynchronous communication in [5].

Taking into account these difficulties, in [4] and [5], they study the characteristics contributing to the interaction and the factors influencing it. These aspects will allow us to obtain measurable variables in the analysis of the data gathered with the present study. In [5], the variables are established with respect to:

- the students: number of students in the classroom, quantity and kind of feedback given by the instructor to the students, experience in distance learning
- the instructor: knowledge level, experience in group management, facilitation abilities
- the messages: characteristics of the feedback, message content.

We have also taken into account Bales' categories for the interaction analysis, namely, the Interaction Process Analysis (IPA). Although IPA was put forward in 1950, it has been applied and justified in recent studies of computer-mediated discussions [6], where it has been considered as a useful tool to describe interaction processes in online groups.

Instrumental axis

A new communication tool (UOCLET) has been integrated in an online study material. This material includes contents, activities, different learning resources, study guides and complementary material. On the other hand, we must not forget that this experience has taken place in a specific context: students who hold a priori conceptions about curriculum content based on traditional methodologies (pen and paper) which do not integrate technological resources. In this context, regarding the instrumentation of the tool becomes of special relevance.

Artigue describes in [7] an instrumental approach derived from the analysis of questions involving the integration of computer environments in maths teaching. Furthermore, she develops a point of view about these questions which will also underlie the instrumental axis. In [8] she points out that for an individual, a given artifact -in our case, the new communication tool- does not have, in principle, an instrumental value. The artifact becomes an instrument through a genesis, i.e., through the construction or the appropriation of social schemes.

Artigue also argues that this process or instrumental genesis works in two directions; one directed towards the artifact, or "instrumentalization", and the other one directed towards the subject, or "instrumentation" [8]. The process of instrumentalization endows progressively the artifact with potentiality and transforms it for specific applications. The process of instrumentation leads the individual to the development or to the appropriation of the schemes of the instrumented action.

Finally, Artigue proves in [7] the contrast between the discourse sustained about the potentiality of the instruments introduced for learning mathematics, and the reality of their functioning in the observed students' classes. Likewise, she shows the unsuspected complexity of the instrumental genesis and discusses the real legitimacy of computer technology since the technical knowledge is foreign to the official curriculum. These results are taken into account in our analysis of the introduction of UOCLET.

Situational axis

From a situated learning point of view, "the construction of meaning is tied to a specific context'', [1]. This is a virtual one in our study and we must focus on specific features of the context and their link with the learning process.

According to Barberà [9], in a virtual learning context, a certain instructional inflexibility is produced, since the teaching process often results in an accumulation of tasks with fixed deadlines. This can affect the learning process and even impede it. However, the integration of contents and communication should improve the follow-up and orientation of the student's learning process and, therefore, to overcome this inflexibility.

But from a sociocultural approach, the virtual learning context not only facilitates or impedes learning (van Oers, quoted in [10]), but also modifies the activity setting – in the sense of Gallimore and Goldenberg [10]–. One of the variables that determine an activity setting is the script for conduct that governs students' actions. It is worth noting that the introduction of the communication tool in this virtual learning context modifies the script of the students from an independent task to an instructional conversation ("classroom discourse that permits the coconstruction of meaning between teachers and students" defined by Tharp and Gallimore, quoted in [10]). Then, it will be important to consider how the introduction of a communication tool will change task demands.

3. TOOL DESCRIPTION

Once the theoretical framework is established in this section, we present the web annotation tool UOCLET which has been designed and developed by the UOC. This tool enables us to highlight a sentence on the online study material and write comments or raise questions about the content. Annotations are shared by all students and the tutor.

First of all, the student has to install the tool. Concise instructions are provided by the tutor. Once the student has installed the tool, a link in the bookmarks bar appears as shown in figure 1. When the student clicks on this link and introduces his/her personal password, the UOCLET tool bar appears on the website material (also highlighted in figure 1).

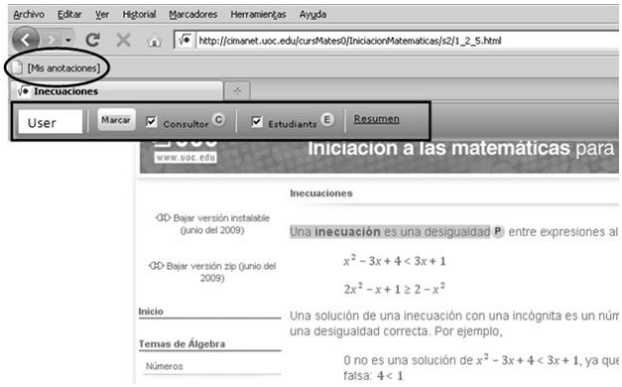

Figure 1. *UOCLET link and tool bar.*

An annotation in the material is shown in figure 2. It can be seen that the text is perfectly readable despite the tool: in the design, it was a priority not to disturb the reading.

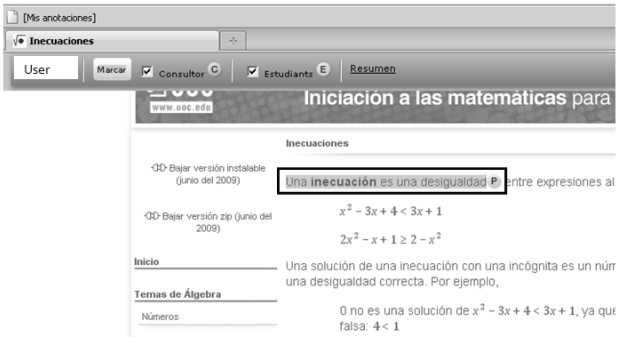

Figure 2. *Annotation in the web study material.*

Just by clicking on the letter behind the highlighted text, the annotation is fully displayed (see figure 3). The frame that pops up allows the user (students or tutor) to easily add a comment or response.

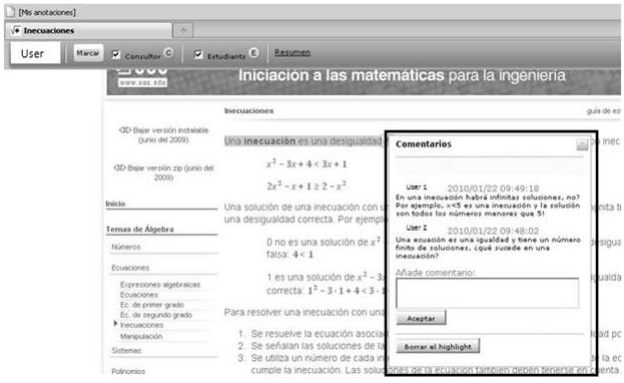

Figure 3. *A comment on the material.*

4. RESEARCH METHODOLOGY

Methodological Approach

In order to analyze the interactions produced via UOCLET, a combined model is used. This model includes quantitative data (who interacts, how much and where) and qualitative data (how one interacts).

Through quantitative analysis we will see: 1), who initiates the interaction; 2) among whom it is produced; and 3) which aspects of the contents of the subject are the reason for more interaction. A quantitative analysis is also proposed in order to evaluate the degree of interaction among the students and between them and the teacher and students' willingness to interact.

The qualitative approach of the model allows the investigating of the type of interaction that is produced. We analyze qualitatively the contents of the annotations and also of the messages in the forum or email. In these messages, the students state their opinion about the introduction and the use of the tool. The model for the analysis of the interactions presented in [11] has been used for this analysis.

Experiences in the virtual classroom

This study is based on the use of UOCLET in an introductory course on mathematics for Engineering at the UOC. The first experience in the virtual classroom was carried out during the second semester of the academic year 2008-09, and a second one, the first semester of 2009-10. Prior to UOCLET development, a preliminary experience was carried out using DIIGO [12]. This commercial and external tool is not conceived for pedagogical purposes, but this preliminary experience allowed us to specify the new tool design, to establish relevant aspects for UOCLET introduction and to define an interaction model [11].

The student profile of this subject is an adult with work responsibilities and often also with family responsibilities. Usually, students have insufficient prior knowledge in maths or there exists a gap of 10 to 15 years since they studied mathematics.

In every experience, students used the tool voluntarily and some students were asked explicitly for their voluntary collaboration in the research.

Data

Students and tutor annotations are the main data. Moreover, the student profile (mainly in relation to interaction), forum and email messages and students' collaboration messages are also taken into account in the analysis.

5. RESULTS AND DISCUSSION

In this section, we analyze the two experiences using UOCLET, taking into account the results obtained in the preliminary experience using DIIGO. Firstly, we shall offer the results of the quantitative analysis of annotations and forum messages, and then, the results of qualitative analysis of students' collaboration messages and annotations.

Annotations are the main data of this study. In a quantitative approach, our interest is to analyze the degree of interaction through observing who initiates the interaction (Table 1) and which aspects of the contents accumulate more interaction (Table 2).

Who annotates?	2007-08 (DIIGO)	2008-09 (UOCLET)	2009-10 (UOCLET)
Starting annotations	Students-tutor	Students	Tutor
Comments	Students-tutor	---	Tutor

Table 1. *Who initiates the interaction?*

In Table 1, we can observe relevant differences among the experiences since different strategies were carried out. In the preliminary experience, once we realized that there was a very low or null use of the tool during the first month of the experience, it was decided to force the use of the tool through the area of partial evaluation. Some students made annotations but in some cases, the rejection towards this decision was so great that the possibility to use the tool was blocked. An opposite strategy was raised in the first experience with UOCLET: the tutor introduced the tool and invited students to use it without putting pressure on their use of it. Then, few students annotated and there were not any comments or responses. This leads us to set out a half-way strategy for the last experience: the tutor often annotated the content with questions or comments that allow the students to reflect on contents and contribute comments. Although students appreciated it, there was not a noteworthy increase in the number of annotations.

	2007-08 (DIIGO)	2008-09 (UOCLET)	2009-10 (UOCLET)
What is annotated?	Solutions of proposed problems and examples	---	Solutions of proposed problems

Table 2. *Aspects of the contents that accumulate more interaction*

In table 2, we can observe that the process followed by students in interacting with the tool starts at a basic procedural level. Students intend to solve those more practical questions that worry them when interacting with the study material: procedures in examples or in solutions of proposed problems. In the first experience using UOCLET, the diversity of aspects annotated does not allow us to emphasize any one of them.

Forum messages are complementary data and allow us to observe the predominant topics when students interact publicly with their usual communication tool. Analyzing forum messages also allows us to study characteristics of each experience in depth.

	2007-08 (DIIGO)	2008-09 (UOCLET)	2009-10 (UOCLET)
Predominant topics	Technology Relational Math procedures	Relational Technology Math procedures	Technology Relational Assessment
Is the tool a source of debate?	Yes	No	No
Are there any technological questions about the tool?	30%	4%	45%

Table 3. *Forum data*

The three predominant topics, sorted by the number of messages related to them, are shown in Table 3. It is worth noting that students do not use the forum a lot to make questions about the contents. They usually prefer to ask the tutor through email or to search information on their own. Then, the introduction of a web annotation tool in order to do these questions requires a change of learning methodology.

Technological questions are clearly predominant, mainly at the beginning of the semester. The introduction of the new tool increased this sort of questions. In table 3, the percentage of technological questions with regard to the whole of the technological questions is shown. In the preliminary experience,

students must register as a DIIGO user and join the subject-matter group and a lot of questions arose. The percentage decreases in the first experience when we introduce UOCLET with easy instructions and no registration was required. In the last experience, there was some external trouble.

It is also worth noting the importance of the pedagogical strategy in order to introduce the tool. As is shown in table 3, only in the preliminary experience, the tool was a source of debate due to the pressure exerted. It is also shown in table 4, where the results of the qualitative analysis of students' collaboration messages are reported. As well as using other strategies, we make promotional videos with positive students' evaluation and then, the tool was naturally assimilated in the experiences with UOCLET.

	2007-08 (DIIGO)	2008-09 (UOCLET)	2009-10 (UOCLET)
Do students show contempt for introduction of tool?	Yes	No	No
Evaluation of promotional videos	---	Positive	Positive

Table 4. *Results of collaboration messages*

Although different strategies are carried out in each experience, a low use of the tool is a common feature. Analyzing the students' collaboration message, we observed some reasons behind the low use of the tool, collected in table 5:

	2007-08 (DIIGO)	2008-09 (UOCLET)	2009-10 (UOCLET)
Feeling of lack of time to understand the contents of the subject	Yes	Yes	Yes
The moment in which the tool was introduced	Yes	Yes	No
Specific time is needed to learn tool functionalities	Yes	Yes	No
Reservations about the pedagogical legitimacy of the tool	Yes	Yes	No
Technical hitch	Yes	Yes	Yes
The need to work online	Yes	Yes	Yes

Table 5. *Reasons behind low use of the tool*

First of all, we wish to stress the importance of the moment of the introduction of the tool. In the preliminary experience and in the first experience with UOCLET, the tool was introduced in the middle of the semester, at the beginning of the second block, at a different time to the rest of the resources. Then, students questioned the need to learn to use a new tool when they were already immersed in learning the subject:

I battle more in trying to understand how the tool works (it took me an hour last Friday) than understanding the subject of mathematics itself which is the whole purpose of it(...). I'd prefer to spend time on understanding maths than on how the tool works.

and, in some cases, with the added feeling of a lack of time to understand the contents of the subject and to respond to its instructional structure:

I would be pleased if this proposal would have appeared on dates that were less stressful for me (...).

As is shown in table 5, reservations about the pedagogical legitimacy of the tool and the need of specific time to learn tool functionalities disappear when the tool is introduced at the beginning of the semester with other resources in the last experience.

Nevertheless, the feeling of lack of time is an important factor that appears in all the experiences. This feeling is due to both the profile of the students, with professional and family responsibilities,

(...) I've been very tied up and on top of that, I've had a business trip and this has left me with very little time.

(...) Nowadays, I'm trying to find time from nowhere, taking into account that work and family take up most of my time.

and the low priority of the subject so it is not in a syllabus of a career but it is preliminary:

I've decided to put this subject off and devote time to the core subjects of the degree.

Technical hitches are also a common reason in all experiences. Although we took a great deal of care over easy installation and tool use in the UOCLET design, we only achieved a certain reduction in technical problems.

The need to work online is another factor that influenced the use of the tool in all experiences. Some students were reluctant regarding the possibility of studying with the support of the computer and manifested the need to work exclusively with "paper and pencil".

I follow this subject more in pdf format (which I have printed on paper) than using the online materials (Which I have already installed) (…)

Some resistance appears here to a change in a traditional learning process that was already taken on board by the students in former educational stages, and which was probably deprived of any technological tool. Some students do not appreciate the advantages of a process enriched by a diversity of technological resources.

Finally, we set out the results of the analysis of the interaction and of the interaction profile of the students in relation to the annotations carried out. This analysis was carried out following the model of interactions provided in [11] and based on three dimensions: instrumental dimension, interlocutive dimension and thematic dimension. All the students analyzed throughout their experiences are situated in an intermediate or low level. A low level means that the student starts to use the tool but does not go into its potential in depth. An intermediate level means that the student starts to incorporate the tool in his learning process in a practical and reflective way.

In the preliminary experience, the poor level is mainly due to a low level on the thematic dimension: students did not exploit the possibilities of interaction that the tool potentially provides and the annotations mainly referred to the evaluation questions and not to the contents of the study material. In the first

experience with UOCLET, the lack of discussion and comments is pointed out as a reason for the low levels obtained. Students did not collaborate on the learning process of fellow students. This is clearly observed in the last experience too, where students always addressed the tutor. Then, specific mediation is necessary in the promotion of collaboration among students.

6. CONCLUSIONS

In this section, the results of the experiences carried out are discussed in terms of the conceptual framework. Therefore, the ideas that have been presented will follow the same structure: firstly, we shall offer some conclusions in relation to the interaction axis, next in relation to the instrumental axis, and, finally, on the instructional axis.

In the interaction axis, we exposed Kozma's position, according to which the technologies can offer singular opportunities for learning as long as the instruction is well supported in the cognitive and social processes by which knowledge is produced. We also presented the stance of Roblyer and Wiencke, according to which the technologies can also offer unique opportunities for achieving the students' commitment. Although we have obtained only minor evidence of this influence on the students' learning and commitment, but we have been able to ascertain that the technologies do not lead to the achievement of these opportunities in a spontaneous and immediate way. We have stated the special importance of the promotion of interaction that has to take into account different strategies and factors. Furthermore, specific mediation is also necessary to change the traditional learning process of students.

With respect to the instrumental axis, the unsuspected complexity of the instrumental genesis pointed out by Artigue has been reflected in this study of the multiple factors that have influenced the incompleteness of the instrumental process. And in relation to the question of the pedagogical legitimacy of introducing technical knowledge which is alien to the official curriculum, we have stated the importance of the moment of introduction of the tool. In our context, this question disappears if the tool is introduced at the beginning of the semester since the students assume that specific technological requirements will be given at the beginning of each subject.

Finally, in referring to the situational axis, it has been shown that the instructional inflexibility has consequences in the process of the students' learning and in their capacity to accept and use the new communication tool.

7. FUTURE TRENDS

The aforementioned results lead us to state two main future trends in order to advance in the integration of contents and communication: on the one hand, the technological development of UOCLET and, on the other hand, the revision of the assessment model.

In relation to UOCLET:

- to check the web annotations tool requests and reformulate them
- to improve the application's interface
- to revise the user's guide
- to allow the annotating of pdf files

In relation to the assessment model:

- to revise the current assessment model
- to validate effective strategies in order to promote interaction among the students
- to obtain effective and useful elements to assess the interaction in order to add them to the assessment model.

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