Designing Learning Tools: The Case of a Competence Assessment Tool

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Abstract. Advancements in technology offer new challenges and opportunities for online education. The interaction design of digital learning and assessment tools directly influence the learning experience. The aim of this work is to show the process of user-centered design and development of an online assessment tool that allows setting, monitoring and displaying the achievements of educational skills and competences. The main challenges addressed were: dealing with a rich and complex educational context; researching the actual needs of the actors involved and managing the different requirements for the tool; the process to generate design solutions and the evaluation of the tool. It was evaluated in a real case scenario in a virtual learning environment of a fully online higher education institution.

Keywords: User-Centered Design, Learning Tools, Assessment Tools, Competence Assessment, Virtual Learning Environment.

1 Introduction

Online education is reshaping the way we teach and learn. Technological advancements, computer devices and interaction styles provide new opportunities for teaching and learning [1]. Online and distance teachers and learners need digital tools to communicate, interact, share contents and practice skills. Every day, innovative and specific solutions appear with the goal to address concrete online teaching and learning needs [2 -3].

There is a need for adequate processes, methodologies and techniques for conceptualizing, designing and evaluating digital learning tools and environments. The design of virtual learning environments has a deep impact in the way people learn. For instance, the time and effort students save on trying to use digital learning tools can be spent on learning content and skills. Therefore, instructional and UX designers and developers have a great responsibility around digital learning tools [4]. Consequently,

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online education can be positively affected by Human-Computer Interaction (HCI), User eXperience (UX) and User-Centered Design (UCD) [5].

The impact of digital products and devices are causing changes on people's habits and behavior. In particular, learners demand educational institutions to continuously evaluate their pedagogical approaches to the learning and teaching process, both in face-to-face and virtual classrooms, taking advantage of the technologies. There is a large sample of digital tools for learning and assessment. These tools facilitate learning through interactivity, provide guidance and feedback and increase learner's engagement [6 -7].

In Europe, the whole educational scenario is changing according to the European Higher Education Area (EHEA) [8] and the use of information and communication tools. Higher education institutions are introducing a competence model centered on learners and activities. Learners have to interact with learning resources and tools in order to show competence performance. Competences tend to convey meaning in reference to what a person is capable or competent of, the degree of preparation, sufficiency and/or responsibility for certain tasks. These elements constitute a combination of attributes (with respect to knowledge and its application, attitudes, skills and responsibilities) that describe the level or degree to which a person is capable of performing them [9].

Learning objectives differ from competences because competences describe how learners gradually acquire a dynamic combination of knowledge, understanding, skills and abilities that can be applied to a variety of jobs, situations or tasks. In general, competence assessment is a complex educational process. The concept of competence is hard to understand especially from the learners' point of view. In addition to that, from the teachers' perspective, it is difficult to measure and quantify the learners' competence acquisition level.

In such a situation, digital learning tools offer new opportunities for learners to deal with the concept of competence. However, there are few tools that support competence assessment, and the existing ones have some issues to be addressed: very specific (not usable in different educational contexts), complex to use and understand and incomplete in terms of facilitating assessment. Everything results in a limited learning experience. All this motivates the need for designing and creating a tool that can reduce the problems associated with competences in learning environments, approaching competences to students and helping teachers on competence assessment.

The purpose of this paper is to present the user-centered design and development of an online assessment tool that allows setting, monitoring and displaying achievements of educational skills and competences. The tool is designed to be used in a fully virtual learning environment, but it is also useful for blended educational systems.

The paper is organized as follows: section 2 introduces the competences and the challenges associated with designing competences in education, while section 3 describes the context and the development of the competence assessment tool following a user-centered design process. In section 4, evaluation of the tool and the results are explained and finally, in section 5, conclusions and discussion are presented.

2 Competences as a Challenge for Design in Education

Based on the EHEA approach, teachers have to design courses taking into account a set of competences. Also, activities should be designed in order to provide learners with a specific level of these competences and learner's performance in activities is essential for competence achievement. Therefore, activities can be understood as a means for learners to achieve new competences improving their performance and skills. Nevertheless, the learning process through competences is not as easy as teachers and learners expected. Learners are assessed by competences (processes) and not just by content (knowledge).

Competences are usually assessed across rubrics [10]. A rubric is defined as "an assessment tool that identifies criteria for a work which includes different quality scales for each work". Rubrics are based on a table with criteria for the assessment and the associate mark for each one. This table can be paper based or embedded in a digital tool. The rubric associated to a competence allows providing assessment criteria based on established levels and/or qualification sections based only on marks. Teachers are using rubrics in a wide range of courses [11 -13]. Despite this, these experiences are centered on typifying the assessment criteria with the objective of establishing the level of achievement of the objectives and a mark [14]. In most cases, the relationship between the specific competences of the course, the mark and their visibility in the proposed activities is scarce. Establishing the appropriate links and relationships between the previous elements is essential to ensure both consistency and good teaching-learning process focused on the acquisition of competences. In particular, competences, activities and the criteria used by teachers in the assessment of the activities must be considered [15]. Then learners will be provided with a report based on their competence acquisition through activities.

Dealing with a competence-based learning model requires that, in the context of a course, teachers carry out a reflection, revision and analysis process. This process consists of 3 main steps: 1) Identification and definition of competences. 2) Design of course activities that conforms the assessment. 3) Make competences and the level acquisition, as clear as possible for learners.

For competence definition, it is needed to identify the set of general competences (at the Bachelor degree level) that are related to the course. Following this, specific competences must be defined at the course level. This can be done by a refinement process that arises competence hierarchies. In each hierarchy, intermediate and leaf nodes represent the specific competences attached to the course at different levels of description. Also, in a given hierarchy, each root node represents the specific competence (at the Bachelor degree level) that has been refined.

The design of activities that conforms the assessment must be guided by the specific course competences to be acquired by learners. Therefore, it is required to establish appropriate mappings between the activities and the specific competences (thus, the alignment with the Bachelor degree specific competences is also guaranteed). It is important to note that one activity can deal with several specific competences. In a similar way, a specific competence can be practiced in several activities. For each

competence that is being assessed in every activity, its expected acquisition level should be defined.

When the teaching and learning process takes place in a fully virtual learning environment, this process is even more challenging. Different users are interacting with educational purposes for teaching and learning competences. Then the virtual scenario has to be simplified for working with different levels of competence acquisition and for making it clear for learners but also teachers. The virtual environment provides learners full access to knowledge, above and beyond the usual scheduling and location constraints. Courses take place in virtual classrooms which include learning resources, activities, but also competences are evaluated there by teachers. In this context, the key challenge is to find an appropriate way to store and visualize competence information in a simple but useful way for all users. The challenge we address consists of a solution to facilitate teachers' tasks and provide learners significant feedback about their competences acquisition.

3 Design and Creation of a Competence Assessment Tool

This work takes place in a virtual learning environment of a fully online higher education institution, Universitat Oberta de Catalunya (UOC)[1], a very rich environment for both users and stakeholders in terms of collecting requirements and designing interactions. The UOC is a fully online university with more than 53,242 students and 3,666 teachers. The university offers more than 16 degrees and 36 masters. Taking into account these numbers, it is clear that the design of the tools and learning environments are a strategic issue for the university since the learning experience will be strongly affected by the interaction design. In addition to that, in this kind of environments, technology plays a strategic role, specially affecting educational tools and their users (students and teachers). Therefore, interaction between tools and users should be carefully designed.

The UOC has a user-centered educational model based on activities. The whole learning process takes place through its virtual learning environment composed of a Learning Management System (LMS), learning materials, digital syllabus and assessment tools. UOC students have a specific profile since they are not full time students. Students choose UOC to update their skills and competences because they can overcome time and space constraints.

According to the EHEA, each UOC course provides learners with a set of cross curricular competences as well as a set of specific competences. Competences tend to be a non intuitive concept for students when they are doing activities. Thus, competences have to be clearly defined and teachers should be able to communicate them easily.

Currently, learners obtain a mark for each assignment activity with no explicit connection with the competences. Our proposal mainly focuses on creating a tool that teachers can link competences with activities and students can easily visualize it. For

[1] http://www.uoc.edu

teachers, the tool should allow them to introduce and edit the competences related to each subject and to make explicit how each competence is achieved through the assignment activities. For learners, the tool should provide a general view about the competence acquirement progress.

3.1 The Design Process

The design process of this work followed the principles of ISO 13407 [16]: the active involvement of users and a clear understanding of the user and task requirements, an appropriate allocation of functions between users and technology, iteration of design solutions and multi-disciplinary design. Following these principles, a user centered design approach [5] was taken. In order to identify detailed requirements of the tool, user research techniques were carried-out throughout the project lifecycle to better understand users and their behaviors [17]. Also, these techniques were used to identify user groups that should be of highest priority during the project and their needs. Basic steps of user research include defining primary user groups, planning for user involvement, conducting research through data collection methods such as user interviews, validating user group definitions and as a result generating user requirements [4]. Two main types of requirements and user needs were identified: educational and technological. Educational requirements came from three main actors; educational institutions, teachers and students.

The purpose of studying the educational requirements is to understand the need for a competence assessment and how it can be adapted to the actual context. To obtain educational requirements, interviews with the teachers and coordinators, and observations in the actual context were carried-out.

Educational institutions received regulations for the administration on how to organize teaching, especially in relation to the acquisition of skills and competences. Teachers received instructions from their educational institution, making them add the concept of competence acquisition on each course and fit it into specific educational plans for each course. Finally, students are the third actor who is the end users of everything. Therefore, they should understand the concept of work and acquire skills and competences while progressing in the courses they are enrolled. Teacher and student requirements are user defined and were obtained through the interviews and UOC databases.

When it comes to learner profile, most of the students are following an online educational course for the first time and out of that 23% of students had a previous university degree. Average age of students is 32 years and 85% are male and 15% are female. Also, 91% of the students have a full time job, whereas the rest are full time students. In addition to that, students mostly use the virtual learning environment to complete assignment activities, mainly in weekdays evenings and at night. They prefer to have clearly defined learning goals and work on activities that require looking for contents rather than just reading learning contents.

The purpose of analyzing the technological requirements is to understand the technical issues associated with the competence assessment tool and how they can be solved [5]. The most appropriate technologies, tools, standards, web services

and protocols that can be used to design and develop an appropriate competence assessment tool are also analyzed. Requirements such as security, interoperability, reliability, user-friendliness and consistency of the tool have to be considered. More consideration was given for security and interoperability. Technological requirements were mainly established by the technological architecture of the virtual learning environment of the university.

To obtain technological requirements, interviews with the system experts and administrators helped to identify the appropriate standards and protocols that can be used. At the same time, study of the relevant literature was also carried-out. In this research, when it comes to development, the existing marking tool used at the UOC for all courses were also studied. However, this tool only provided marks and direct feedback about the marks. The competences achieved by the students were not displayed. Considering this, the main concern was to design and develop a generic competence assessment tool which can be easily adapted to any subject and organization. Also, characteristics such as reliability, consistency, usability, interoperability and security are needed to be considered while designing and developing the tool.

The definition of the competence assessment tool included several functionalities which were really important for improving the students' experience in terms of skills and competences outputs. From the teachers' point of view, the competence tool should allow to register competences, but also to establish some relationships between learners-competences-activities on a course. It means that general competences have to be included in the tool as well as the specific ones. At the same time, these competences need to be related to each activity including the expected level of acquisition. From the students' point of view, the tool should be able to visualize when a competence is acquired. Therefore, when teachers introduce acquired competences students will be able to see them. As students advance in the course and activities are carried out, a competence progress bar may indicate their situation regarding the final competences to be reached. It can be noted, the marks are not included in the competence assessment tool because they are included in the university's register, which is an independent module.

Once the requirements were collected and analyzed, first the conceptual design of the system was finalized with the assistance of user profiles and scenarios. Conceptual design was understood as a description of the proposed system in terms of a set of integrated ideas and concepts about what it should do, behave, and look like, that will be understandable by the users in the manner intended [18]. User profiles describe the characteristics of typical target users and it helps to provide a clear representation of the person who is using the system, and potentially how they are using it [4]. Furthermore, creating user profiles helps to focus on representative users by providing insight into "real" behaviors of "real" users. This helps to resolve conflicts that arise when taking design and development decisions [4 -5]. Data about user profiles were obtained from interviews, UOC databases and questionnaires.

A scenario is a plausible description of the future based on a coherent set of assumptions. Scenarios are among the most powerful tools in product and service design, with uses ranging from developing requirements for ensuring that a design accounts for the full range of possible interactions [5]. User scenarios associated with

each user profile are defined to understand how they interact with the system. A goal-directed scenario is a textual description of a user's interaction with the system. Each scenario begins with a specific situation, and then describes the interaction between user and system from the beginning of a task or session through its completion [5].

Based on the three main actors of the tool, three profiles were created. For each profile, three scenarios were created to depict the interaction between the user and the tool. Then the structure and the navigation of the system was designed based on the tasks identified through the scenarios. This is a visual way to display how content has been organized in the web application according to a hierarchical structure in order to aid the development process [4]. After designing the structure of the system as a visual hierarchy, interaction flow diagrams were constructed which identify the paths or processes that users or systems will take as they progress through the web application [4].

3.2 Prototyping and Developing the Tool

The user interfaces were first designed as prototypes for the competence assessment tool which was later used for the development. The main challenge for the prototype was to provide a simple design solution that took into account the rich and complex requirements. The prototype was improved by some design iterations, through the evaluations carried-out with the users, before coming up with the final design of the tool for the development.

The competence assessment tool was developed as a module for Moodle [19]. One of the reasons is that Moodle provided user management facilities and therefore the main consideration was needed for the tool. Another reason is that Moodle is one of the most commonly used LMS and any educational institution who doesn't have their own LMS can use it as their own. Finally, Moodle is a standardized tool and the modules should also be developed according to e-learning standards. Therefore, by developing the competence tool as a module with the Moodle LMS, it is possible to maintain the required technological requirements such as security and interoperability.

For the development, a predefined module [20] was selected and later modified according to the requirements and the given activities. The tool required to include taxonomy, which consisted of the competences and subcompetences that should be achieved by students. Overall, the tool was developed using PHP and it stores only the essential information needed for this research work. Thus, the tool consists of only main functionalities as tabs: “Module configuration", “Subjects & topics", “Assign activities", “Overview of competences" and “Assessment of competences".

Taxonomy for a particular subject is uploaded to the competence module using the "Module configuration" tab. Through the module configuration tab, it is possible to select the taxonomy for a particular degree program or a course by making appropriate changes to the XML file. Therefore, this tool is developed in a general way which can easily be adapted to any subject or degree program only by changing the taxonomy through the XML file.

“Subjects & topics" tab allows selecting the appropriate subject and the topics based on the subjects available through the uploaded XML file. Here, it was also

necessary to add the new activity types, quizzes and tests from an external tool based on the activities given in the UOC classroom. Therefore, a link was added to display both quizzes and the tests from the external tool which directed teachers to a page consisting of marks. Also, some developments were made in order to display the marks
of the tests from the external tool, when teachers use the mouse over facility. Additionally, some changes were made to the look and feel of the module to suit the requirements.

After carrying out the required modifications and after the selection of the required subject, the related competences were displayed in the “Assign activities" tab. Then, teachers had to select appropriate competences related to each activity by marking a tick in the appropriate box. Here the activities were displayed horizontally and competences were displayed vertically as a grid.

In the “Overview of competences" tab, a table of competences and students of the course was generated. The names of the students were displayed in a row and the marks they had obtained for each activity were visible by hovering over the given icon. The attainment of a competences was assessed on the level of individual activities. Based on the marks, if the students had acquired the competences, the teacher could mark a tick next to the competence. For all students, the competences can be ticked off as a whole. The “Overview of competences” tab can be displayed as shown in Fig. 1.

In the competence module, the tabs including “Module configuration", “Subjects & topics", “Assign activities" and “Overview of competences" were only visible to teachers and administrators. Only tab that was visible to students was the “Assessment of competences" tab.

Then finally, in the “Assessment of competences", students could view the competences they had achieved as a progress bar as well as a list of tables. The assessment of competences for a particular student can be displayed as shown in Fig. 2.

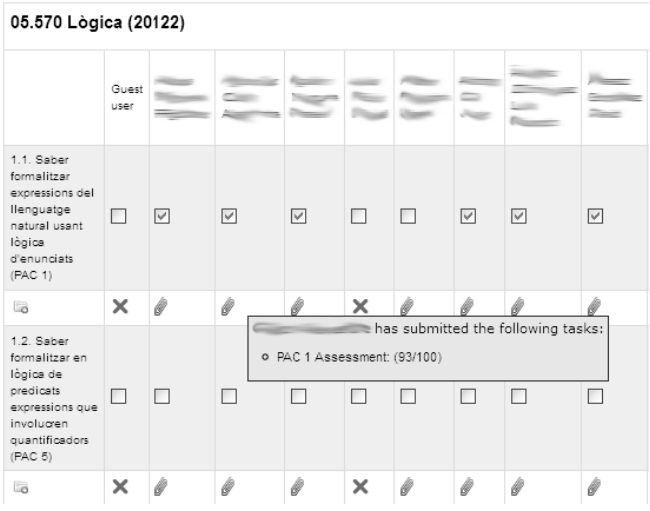
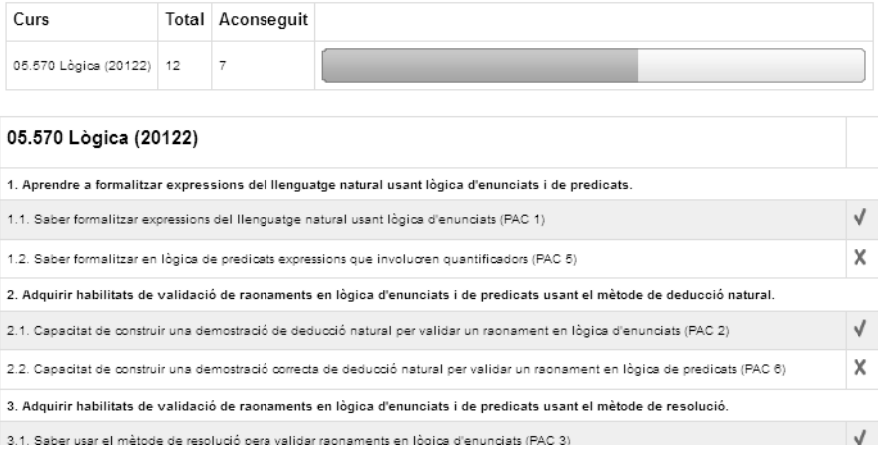


Fig. 1. Overview of Competences Tab



Curs	Total	Aconseguit
05.570 Lògica (20122)	12	7

05.570 Lògica (20122)	
1. Aprendre a formalitzar expressions del llenguatge natural usant lògica d'enunciats i de predicats.	
1.1. Saber formalitzar expressions del llenguatge natural usant lògica d'enunciats (PAC 1)	√
1.2. Saber formalitzar en lògica de predicats expressions que involucren quantificadors (PAC 5)	X
2. Adquirir habilitats de validació de raonaments en lògica d'enunciats i de predicats usant el mètode de deducció natural.	
2.1. Capacitat de construir una demostració de deducció natural per validar un raonament en lògica d'enunciats (PAC 2)	√
2.2. Capacitat de construir una demostració correcta de deducció natural per validar un raonament en lògica de predicats (PAC 6)	X
3. Adquirir habilitats de validació de raonaments en lògica d'enunciats i de predicats usant el mètode de resolució.	
3.1. Saber usar el mètode de resolució per a validar raonaments en lògica d'enunciats (PAC 3)	√

Fig. 2. Assessment of competences for a particular student

4 Evaluation and Results

The competence assessment tool was introduced in an online learning scenario in order to assure the interoperability and usability during the teaching and learning process. A pilot study with teachers and students was carried out. It was a first year Logic course of a Computing Engineering Bachelor at UOC. The Logic course is based on Propositional and Predicate Logic. It is a fundamental course in the whole area of programming languages because of its relevance in formal verification and the derivation of algorithms. It is also essential for the study of databases following the relational data model, because the standard language is based on predicate logic. The skills and abilities needed to formalize and to validate or refute arguments in the logic formal language are essentially the same as detecting the problems of an incorrect specification that requires a high-order skills acquisition. This course was selected as it is a subject which requires a higher-level of skills in order to qualify in the subject. Therefore, competence based assessment plays an important role in this subject.

This pilot study took place during 14 weeks and involved more than 80 students. Student and teacher interaction and perceptions were collected through observations, interviews and questionnaires. The results showed that both teachers and students were satisfied with the competence assessment process and the ease of use of the tool.

Using the tool, teachers were able to track students' progress throughout the whole duration of the course. Overall, the activities of the Logic course were allocated with 12 competences. Based on the student performance in the continuous assessment activities, the progress of competences achieved for each activity was calculated. In order to obtain a particular competence, students had to obtain a minimum of 50 marks for each test. Based on the statistics stored within the tool, it showed that, overall, students had performed well in the Logic course with an average of 62% progress for all competences. Even for the individual competences, students were able to obtain a progress of more than 50%.

At the end of the course, students were given a questionnaire, to obtain their feedback regarding the tool. Based on the results, 86% of students think that the grading system and evaluation for each competence is appropriate and it allowed them to see how they are progressing in the course on a weekly basis. Regarding the feedback, 80% of the students appreciated it. They further mentioned that it also helped them to advance in the acquisition of skills and understand what it meant to acquire a competence. Accordingly, it can be concluded that the inclusion of competences in each activity along with its evaluation criteria based on personalized feedback has been well appreciated by the students and it helps them to understand the process of acquiring competences.

Teachers' perspective was obtained through interviews. Teachers observed that the process of establishing the relationships between specific competences, the activities and the students' assessment process is a laborious process, especially the first time it is performed. Moreover, they mentioned that the alignment between competences and activities required a continuous analysis to adjust and clarify issues regarding how competences have to be acquired and evaluated. However, teachers believe that such work is required in order to improve a teaching-learning model based on competences. Finally, in regard to the feedback, teachers think that setting the assessment criteria for each activity facilitates the students' evaluation process as well as the feedback to be provided. That is, a clear assessment criteria helps each student understand which competences have been acquired continuously.

5 Conclusions and Discussion

The main contribution of this paper is related to the process for designing and developing an educational tool for competence assessment. This tool summarizes the acquisition of learning competences in a visual and simple way. Also, the tool helps teachers to easily incorporate assessment based on competences and at the same time, learners are provided with a diagnostic profile related to the competences developed.

In addition to that, some interesting conclusions can be considered. A first consequence of the introduction of the tool in the real case scenario is that competence assessment based on activities through the tool can be done. Besides, teachers mentioned that the work of linking activities with competences through the tool has allowed them to adjust activities and competences in an accurate way. From learners side, they have understood the assessment process based on competences as well as the use of clearly specified evaluation criteria and feedback. In summary, the approach and the tool facilitated the overall process of assessing learners.

Also, it is interesting to remark that following a user-centered design process helped to match teachers and learners needs. In our opinion, the conceptualization, design, development and evaluation in a real case scenario have been essential to obtain a simple and efficient tool. The definition of the tool would not have been possible without previously carrying out a requisite analysis and a detailed, reflective process, revision and analysis about the implications and consequences of dealing with a competence-based learning model. Therefore, this work sketches a methodological approach which

offer guidelines that can help teachers to structure an assessment model based on competences. Furthermore, using the tool in a real case scenario has shown that it provided enough support to this process, from both teachers and learners perspective.

Regarding the future work, we consider two main issues to be investigated. On the one hand, it is necessary to progressively extend the use of the tool to different kind of courses, to make it as general as possible but adaptable to different learning needs. On the other hand, it is necessary to study how to capture the students' global progress regarding to the acquisition of the whole specific competences associated with the degree, because one specific competence should be acquired and assessed (probably at different levels) in several (related) courses. This implies, at least two different objectives: firstly, to represent new data in the competence assessment tool, in order to keep track of the learners' competence progress in the different courses; secondly, to define new functionalities to be added to the tool. For instance, from the learners' perspective, the tool should show their progress about the whole degree where they are enrolled. Moreover, this functionality should be available outside of the context of a specific course, probably attached to their academic information.

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