Software Engineering Competence-Based Learning in Collaborative Virtual Environments

Nicolás Battaglia
Universidad Abierta Interamericana
Centro de Altos Estudios en Tecnología Informática (CAETI)
Buenos Aires, Argentina
nicolas.battaglia@uai.edu.ar

Carlos Neil
Universidad Abierta Interamericana
Centro de Altos Estudios en Tecnología Informática (CAETI)
Buenos Aires, Argentina
carlos.neil@uai.edu.ar

Marcelo De Vincenzi
Universidad Abierta Interamericana
Centro de Altos Estudios en Tecnología Informática (CAETI)
Buenos Aires, Argentina
medevincenzi@uai.edu.ar

***Abstract*—The constant change in learning due to new possibilities provided by emerging technologies makes us think about how effective the traditional method of teaching is. Teaching students how to be competent instead of simply giving them content for their formation might change learning, where not only new graduates will know the content of an area of knowledge but will also apply that content into professional tasks that they experimented through their formation. To boost learning with the use of competences, it is important to use tools and applications, such as Computer-Aided Software Engineering tool (CASE, a type of software tool which is primarily used to design applications), that allow learning anywhere and anytime. It is necessary to use an evaluation method adapted to a competence-based learning, allowing students to comprehend and follow each of the competences, for which we recommend the use of rubrics that facilitate evaluation and self-evaluation.**

Keywords— Learning, Competences, Virtual Environments, CASE Tools, Rubrics

I. Introduction

The change and evolution in technology makes us think whether some systems with its roots found hundreds of years ago should evolve. One of these systems that we think should be re-evaluated is learning and education. For the past few years, education has been changing from teacher-focused learning methods to student-based learning methods [1]. One of the most important changes is the current ability of students to access information ubiquitously thanks to the Internet and mobile devices. These technologies allow students to access information at any moment and to participate in tools like chats, forums, blogs and networks that promote interaction with other people [2], [3].

Based on what we mentioned, we will focus on learning methods used in universities, where soon-to-be professionals are training. The current teaching method is slowly changing. The knowledge is not only what someone actually knows, but also the abilities that he can develop and that allow him to obtain more knowledge [4]. We propose the inclusion of competence-based learning as a tool to improve professional training and the use of virtual environments to take advantage of new technologies. The idea is to move from the university of teaching to the university of learning, having a more productive and less academic vision that is oriented to problem resolution [5]. The use of a competence-based model in learning helps prepare students to adapt to the always-changing processes of technology and computers today [6].

II. Competence-Based Learning of SE

Before explaining how competence-based learning works, we need to explain what a "competence" is. McClelland [7] defines a competence as a characteristic of a person that allows him to perform better than another person in a certain position, role or situation, showing a difference between a person with average performance and a person with an excellent performance [8]. Tejeda [9], in his first synthesis defines a competence as the functions, tasks and roles of a professional to develop its role in the workplace correctly and that are the result and object of a process of training and qualification. In his second synthesis, he defined competences as a set of knowledge, procedures and attitudes combined, coordinated and integrated, in the sense of the individual "knowing how to do" and "knowing how to be" in the professional exercise. The ability to master this knowledge allows him to "be capable of" acting efficiently in professional situations [9]. This step from knowledge and wisdom to acting indicates us that a competence is a process and that a competence is needed to be in practice to be "competent" [5] (Fig. 1).

Fig. 1. Competency-Based Education: What It Is, How It's Different, and Why It Matters to You

Competence-based evaluation is based on the access to multiple sources of information to determine the achieved level by the students and how it compares to the expected level in all the developed competences [6], [10]. One of the most efficient methodologies for evaluation are rubrics. This is a set of criteria and standards, generally related to learning objectives used to evaluate a performance level or a task [11] and are known for their easy use and the ability to evaluate both objective and subjective aspects [1], [6], [11].

While evaluating a competence, various instruments that decide the outcome of complex learning activities and allow to evaluate them can be used, and rubrics are the instruments that stand out because of their versatility [1], [12].

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A. Colaborative Work in Virtual Environments

It is common to find today that part of education occurs in a virtual environment where students can access the content ubiquitously thanks to the development of new technologies like smartphones that can access the Internet immediately.

Virtual environments produce changes in teaching and learning processes, allowing students to learn competences and to adapt the evaluation criteria in a way that students can see their progress while learning these competences [6]. The teaching and learning model of these ubiquitous environments, also called m-learning, is a transformation of e-learning [13]. In teaching methodologies related to Information and Communication Technologies, it is important to make progress using new strategies that allow integration between the learning methodologies used in classes and the virtual, ubiquitous and collaborative education technologies, making universities and other teaching institutions responsible for the implementation [4], [14].

For some authors [4], learning is considered ubiquitous when it is developed under certain technologic infrastructure that allows students to obtain knowledge anywhere and anytime and when it has the following characteristics, also mentioned by Japanese authors Hiroaki Ogata and Yoneo Yano [15]:

- Permanency: student's work is not lost unless manually deleted.
- Accessibility: it is possible to access documents and resources anywhere.
- Immediacy: information is obtained instantly everywhere.
- Interactivity: the students and teachers can interact everywhere synchronically or not synchronically.
- Context of the activities: learning can be present at any time of normal day-to-day life.

One of the primary benefits of virtual and ubiquitous environments is collaborative work, that can be done using tools like chats and forums, allowing students to work together [11]. Collaborative work is referred to as multiple individuals working together in a planned way, in the same process or in different processes connected [16].

Collaborative work is achieved when all participants involved share a same goal or objective, where each individual task that members complete both individually or as a group takes the team a step closer to completing the end objective. For this, it is necessary for members to be in constant communication and to share ideas and information that helps their partners to complete the tasks.

B. CSCW: Computer Supported Collaborative Work

Evolution in the development of Information and Communication Technologies along with collaborative work allowed the emergence of Computer Supported Collaborative Work (CSCW) environments.

Bowers and Benford [17] say that Computer Supported Collaborative Work environments test the possibilities and effects of technologic support for humans involved in communication and collaborative work processes, while Stahl [18] defines CSCW as a set of activities coordinated by the assistance of computers like communication and the resolution of problems that are done by a collaborative group of individuals.

From Computer Supported Collaborative Work, the term "groupware" arose. This term refers to technical systems that resulted from the development of the CSCW that are in charge of assisting the group of individuals to coordinate and collaborate in their activities. These were defined as computer-based systems that support groups of people that participate together to complete a task or objective in common that provides an interface for a shared environment [19].

The CSCW paradigm, integrated with e-learning environments, creates the Computer-Supported Collaborative Learning (CSCL) [6], [13].

C. CSCL: Computer Supported Collaborative Learning

Computer Supported Collaborative Learning is one of the new learning methodologies that raised in the era of communication and information technologies, and one of its strong points is the ability to be useful in all teaching levels. CSCL is based on three dimensions: Psychology, Computer Science and Pedagogy, and a new tool must be added to allow ubiquitous work, which is normally a CASE tool. It is necessary to have an evaluation process related to the collaborative learning that allows the CSCL model [6], [13].

The CSCL model is a learning approach based on the psychology of social interactions, the pedagogy of teaching, and computer science. This means, building knowledge from the knowledge and skills of other process participants in computer-assisted environments. In this sense, del Dujo [20] assures that it is important that during the process of inserting technology in education, a pedagogical perspective is constructed that allows to understand the processes of social interaction and the impact on training. In detail, CSCL environments are based on the integration between Collaborative Work, ICT and learning environments: On the one hand, collaborative work supported by the concept of the Zone of Proximal Development (ZPD) proposed by Vygotsky at the beginning of the 20th century [21] and, on the other hand, ICT within the framework of the proposals of e-learning or blended learning. The growing development of ICT together with the concept of collaborative work, make up the CSCW environments. This concept, integrated into teaching and learning environments, gives rise to CSCL environments (Fig. 2)

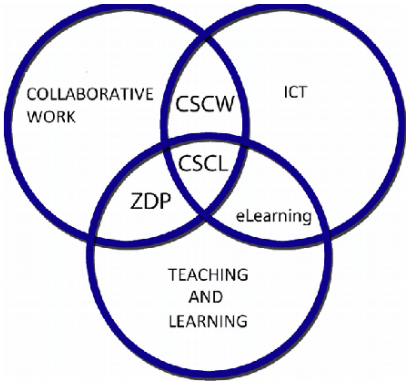

Fig. 2. CSCL model

Between the changes that CSCL offers from the traditional model, one of the most notorious ones for the students is the ability to use applications and tools that provide creative and interactive activities to learn [18].

Particularly in engineering and in the use of software and technologies, the CSCL model offers the ability to do exercises like professional tasks done in the working environment. This benefit is what differentiates the CSCL methodology from the traditional learning methodology and e-learning.

D. Rubrics for Competence-based Evaluation

As a tool to judge and evaluate the level of competence of a student when performing a task or work, we propose the use of rubrics. A rubric, according to [11], is a set of criteria and standards, generally related with learning objectives that is used to evaluate the level of performance of a task. Rubrics have three fundamental characteristics: evaluation criteria, a rating scale and a grading strategy [1]. The evaluation criteria establish the objective to achieve through learning. The rating scale describes the different levels of performance of a certain student in a certain evaluation criterion gradually. The grading strategy can be either holistic or analytic. According to [24] and [25], a holistic rubric is the one where the teacher grades the process or the final product as a whole, without judging the elements separately, and an analytic rubric is the one where the teacher grades all elements separately and then gets the total score based on the score of all the elements.

We feel it is important to clarify that rubrics are effective when used correctly and developed following certain recommendations, but it is necessary for students to be willing to improve their learning methods and dedicate enough time to perform self-evaluations and evaluations between peers that are effective for rubrics to be useful.

The results obtained from experience when using rubrics show four improvements on students [26]:

1) The clarification of evaluation criteria helps students understand what is expected from them. It is possible to perceive an improvement in students' confidence and a reduction in their anxiety when they know how they will be evaluated.

2) The feedback given by rubrics allows students to think about the quality of their work and to find mistakes.

3) Students noted improvements to their efficacy and autoregulation when they know how they will be evaluated.

4) Students noted that their motivation improved and had more interest in knowing the used methodology.

Below is an example of a rubric that could be used for a work presented orally or physically. Only three criteria were included, but more can be added, or the existing criteria can be divided and evaluated in detail (Fig. 3).

Category	Excellent	Very good	Good	Bad
Score	9-10	6-7-8	3-4-5	0-1-2
Written Presentation	The work is tidy, it is divided into segments to distinguish the introduction, the development and the references. There are no spelling errors and a large vocabulary is demonstrated.	The work is tidy. There are no spelling errors and a fairly large vocabulary is demonstrated.	The work is tidy. There are some spelling errors and poor vocabulary is demonstrated.	The work is not tidy. There are many spelling errors and poor vocabulary is demonstrated.
Oral Presentation	It was given in a fluent way, demonstrating high knowledge on the subject and all doubts and questions were answered.	It was given in a fluent way, demonstrating knowledge on the subject and almost all doubts were answered.	It was given fluently, showing knowledge on the subject but without answering questions.	It was not given in a fluent way nor was knowledge demonstrated on the main subject. No doubts were answered.
Quality of the information	The information is related to the main topic and adds new concepts. Examples are included and the source of the information is specified.	The information is related to the main topic and adds new concepts. Few examples are included and the source of the information is not always specified.	The information is related to the main topic. Examples are not included and the source of the information is not specified.	The information has little or nothing to do with the issue at hand.

Fig. 3. Rubric Example.

III. Software Engineering Competence-based Learning in Collaborative Virtual Environments

A. Transformation of the CSCL model

The new standards for the Accreditation of Engineering Careers in Argentina (Red Book of CONFEDI) [27], realize about the need for CSCL environments to consider Competency-Based and student-centered learning, in addition to all the monitoring and evaluation tools required by this paradigm (Fig. 4)

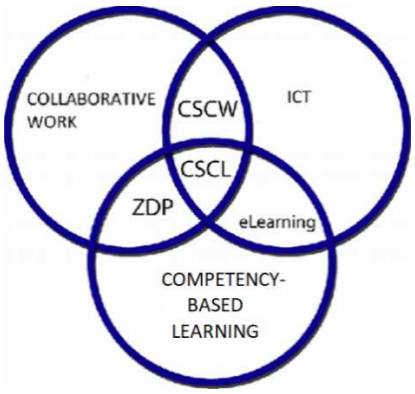

Fig. 4 - CSCL model including Competency-Based Learning

B. Software Engineering Competence-based Learning

In previous works [13] we have presented the uCASE-CL model. The purpose of this model is to define all the functional and technical blocks to carry out the integration of a CASE tool and a virtual ubiquitous and collaborative learning environment. We identify that although the main challenge is to design an infrastructure to provide education services mediated by technology, it is also necessary to allow students to work collaboratively and optimize the training process proposed by this modality to the maximum.

In this line, distance education environments also allow changes in the teaching and learning processes, including student-centered and competence-based learning, giving rise to new challenges: designing collaborative virtual environments for competence-based learning and, also, modify and adapt the evaluation criteria and strategies motivated by this disruption.

Due to the above, we believe that it is necessary to redefine the uCASE-CL model to include all the necessary tools to develop and evaluate generic and specific competencies, as well as the collaborative learning objects that will be developed throughout the courses involved in this modality.

C. CASE Tools in CSCL environments

A CASE tool (Computer Aided Software Engineering) is an application used to improve the balance in software developing, reducing the cost in time and money. These tools help in all aspects of the life cycle of the development of software, including the project design, the calculation of costs, the implementation of a piece of code automatically using the given design, the automatic compilation, the documentation, etc.

The use of CASE tools in teaching Software and Systems Engineering (SE) has various pros and cons [13], [14], [22]. As a pro, we can highlight the facility that they offer in the scalability and maintainability of software, especially in complex software. This not only helps students understand better, but it also introduces them to professional tasks that they will do as professionals in the future in the work environment. As cons, we can mention that CASE tools have a big variety of functionalities and uses, and a lot of them are not very useful for academic purposes and can confuse students while using the tool. Another con is the lack of an environment where the teacher can follow students while they learn and obtain knowledge for a later evaluation of their work.

As mentioned before, it is necessary to have a tool that allows students to learn ubiquitously to complete the CSCL methodology. The CASE tools are strong candidates to fulfil that role. This new component transforms the CSCL model and extends it, integrating new tools for learning [13].

In this line, we are working with the development of an application that integrates a CASE tool in a collaborative virtual environment for the teaching and learning of SE [13]. This software, called UAI Case [23], is a prototype that implements the uCASE-CL model. This development aims to unite the traditional academic environment with the control and evaluation of the SE teaching in virtual environments [14].

This project strengthens the work of curricular integration developed in the Faculty of Information Technology of the Universidad Abierta Interamericana (UAI). The UAI Case tool implementation will allow students to enrich themselves with knowledge.

D. Using Rubrics During Software Engineering Competence-based Learning in Collaborative Virtual Environments

It is in our interest to promote the necessity of rubrics for SE students so they can review their work and evaluate its quality, especially when using CASE tools. We strongly believe it would boost students' learning process and it would also introduce them to a path in their career where they could teach themselves as well as evaluate how they are doing it. Based on our study [13], we identified that SE learning lacks tools that allow teachers to evaluate and follow students' work, but rubrics simplify this problem when switching to a competence-based learning environment. They still require collaborative work to complement evaluation, such as co-evaluation [6].

We believe it is necessary to start using applications based on collaborative and ubiquitous environments when teaching Software Engineering. Students must perform tasks and capacitate themselves to work like professionals so they can get experience since the beginning of their training. These collaborative environments promote teamwork, which is another skill that they must work on before joining the work environment and that is taken very seriously by recruiters.

A change like this in teaching will take time, so it is necessary to start soon. The days where teaching consisted in memorizing content should be part of the past to leave the ground to a teaching method boosted by new technologies.

We insist that teachers should analyze the possibility of using rubrics or e-rubrics to evaluate and to motivate students to use them for self-evaluation. Each student should be able to develop competences and evaluate their progress by themselves.

IV. RELATED WORKS

The main problem to be addressed in this work is the one presented by the absence of virtual collaborative learning tools in the SE area. In these terms, we know that during the software development process, CASE tools are used to assist it in its different stages and that these tools are not prepared to assist the teaching and learning process in collaborative settings.

In previous works, we identified that the main challenge in virtual education related to SE courses consists in designing solutions to be able to provide education services mediated by technology and collaborative work spaces, called CSCL [13]. However, the proposal does not contemplate the changes by the document recently published by the Argentinian Federal Council of Deans of Engineering (CONFEDI) called "Propuesta de estándares de segunda generación para la acreditación de carreras de ingeniería en la República Argentina" [27], in which the concept of competence is incorporated, describing within the common curricular conditions the Graduate Competencies that a student must accredit to access graduation.

In different works [2], [28] we identify that these new standards account for the need for CSCL environments to take into account competency-based and student-centered learning, in addition to all the monitoring and evaluation tools that are required by this paradigm. We know that this paradigm gives rise to new challenges: designing collaborative virtual environments for competency-based learning and, also, modifying and adapting the evaluation criteria and strategies motivated by this disruption. On one hand, there is a significant number of works that study the evolution of CASE tools and they generally have a very objective look at their integration in software development companies. In general, these studies do not consider the impact of CASE tools on teaching SE in CSCL environments.

On the other hand, there are various works that focus on the teaching of SE without considering collaborative aspects. These studies propose new CASE tools and improvements on existing tools for database design and UML modeling [29]–[33].

The works studied so far have the teaching of SE as their main theme. Although in some cases they propose collaborative solutions, in none of them are evaluation tools proposed.

Based on this until now, we can question the existence of works that integrate all these aspects: collaborative learning of SE in virtual environments, evaluation and monitoring, and competency-based learning.

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