Promoting creativity and innovative thinking in software engineering teaching: a case study

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***Abstract*—In this paper, we present an hybrid educative methodological approach to promote creative and innovative thinking in software design and development, and at the same time, to promote the development of transversal and professional skills. So, we combine teaching and learning strategies based on projects (PBL), computer supported collaborative learning (CSCL), design thinking (DT), visual thinking (VT), gamestorming (GS) and gamification techniques. Moreover, we present a case study applying this methodology to teach software engineering.**

Keywords— Creativity, Innovation, PBL, Design Thinking, Visual Thinking, Gamestorming, Game Thinking, Gamification

I. INTRODUCTION

There are teaching practices that encourage greater student participation and creative and innovative thinking. These teaching practices enhance the student's autonomy and facilitate the development and acquisition of transversal learning and professional skills. In this sense, project-based learning (PBL) [1] is an holistic approach rather than a complement, where students plan, implement and evaluate projects that have application in the real world beyond the classroom. Moreover, students learn by building new ideas or concepts based on their current and previous knowledge and they are more motivated to take an active role in planning their own learning.

In this sense, a methodology based in learning projects and collaborative work has been used at the School of Computer Science Engineering at the University of La Laguna since 2004. During the first course, collaborative learning activities using wikis were performed [2]. Moreover, the PBL and collaborative learning methodologies has remained during ten years, varying the type of activities and experiences in the laboratory. It has worked since the integration of multiplayer 3D videogames with Moodle [3], studying the motivational factors of its use in teaching, until the creation of collaborative concept maps and collaborative work environments to support the development of software projects using the UCD methodology (User Centered Design) [4]. So, in the UCD methodology it has also incorporated techniques from the area of creativity and design thinking [5], especially in the prototyping phase [6]. During the last two years, we are focused on the transversal and professional skills learning [7, 8]. So, concepts like e-portfolio have been worked with students. To build the student's e-portfolio, Mahara and social networks, like Twitter or Linkedin, have been used [9]. Since the 2012-2013 course, we applied teaching and learning strategies based in PBL using project management tools (Trello), embedded design thinking techniques (DT) [5], visual thinking (VT) [10] and gamestorming (GS) [11]. And, finally, in the 2013-2014 course, we added the gamification techniques to the whole teaching-learning process [12]. In this article, we present this innovative teaching methodology and its application to teach software engineering, as a case study.

II. PROPOSAL FUNDAMENTALS: STRATEGIES AND TOOLS

A. E-Portfolio

The e-portfolio is a methodology that consists primarily of collecting the student's productions to assess their learning around a specific topic. Thus, the works collected by the student in the e-portfolio, feature a picture of the evolution of student learning, allowing an assessment not only of the product but also of the process [13]. Also, the use of e-portfolios can help to improve and adapt the assessment methodologies required in degrees in European Higher Education. But this requires that teachers should be trained to perform this kind of evaluation, and that students prepared for the creation of the e-portfolio. Moreover, the assessment must be authentic, i.e. an assessment of expertise as realistic as possible, which requires that the evaluated tasks are as close to reality or as real as possible [14]. In this sense, our proposal presents the use of e-portfolio as an evaluative skills strategy.

B. Social Networks

There are technological tools that can help in the development of transversal and professional skills, such as social networks, which can serve, for example, in job search. In this way, students can use social networks professionally, to search and select expert or relevant professional groups, national and international, of the topics covered in the grade. It should be noted that the technical issues of engineering, most of the documentation, videos, professional forums and communities, are in English, which gives us the opportunity to work this transversal skill routinely. Similarly, students can create and manage groups, schedules and events, find, select and share current contents, identify trends, among other possibilities currently offered by social networks. Also, social networks facilitate the coordination and work of learning groups (class, subject, group of students in a course, etc.). From the educational point of view, social networks allow online services for teachers and students to promote the development of skills and aptitudes such as socialization, teamwork and the importance of sharing. They also contribute to the awareness of the digital identity of teachers and students, noting how to work the social processes of participation and opinion formation. They also allow students to learn by doing, developing cognitive abilities such as reasoning, the ability for synthesis and analysis, and decision making. Also, social networks promote informal and experiential learning [15] and, of course, social learning [16].

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C. PBL

PBL becomes essential to work transversal and professional skills [7]. Moreover, students learn by building new ideas or concepts based on their current and previous knowledge and, they are more motivated to take an active role in planning their own learning. Given that, a teaching methodology that applies the above items (e-portfolio, social networking and PBL) is presented in this paper.

D. DT, VT and Gamestorming

Also, Aiming to promote creative thinking and innovative students in project development, technical design thinking (DT), visual thinking (VT) and gamestorming (GS) were incorporated in this educational methodology.

The DT is a methodological approach for solving challenges and problems creatively. Through DT the students can investigate problems that are not clearly defined, gathering information, analyzing content and proposing solutions in the fields of design and planning [17]. The methodology goes from divergent thinking and fuzzy goals, trying to find practical solutions achieved through a convergent thinking. The DT is based on the following principles: empathy, imagination, experimentation, prototyping collective, integrative thinking and iterative learning. These features make DT as the main part of a highly consistent methodology in the area of Human-Computer Interaction, the UCD.

Besides, visual thinking is closely related to innovation, because the ultimate goal of this methodology is to improve systems or ideas. In the field of innovation people constantly are working with "fuzzy goals" and "hypotheses", so visual thinking becomes an ideal place to explore new lands, test hypotheses and as a result, make better decisions. Thus, visual thinking can be used to solve systems, study and explore innovative concepts, enabling the visual understanding of how people and elements of these systems work.

Regarding gamestorming [11], it allow us through different games to work all the phases of the project, analyzing from the first steps of the divergence or idea generation and setting objectives and analyses of the current situation, until the convergence into practical solutions. It also allows to break down barriers and improve communication in the group and generate new ideas, visions and strategies. It is therefore a powerful tool to develop innovative thinking and creativity.

Ideas through prototypes, both in interface software design and physical objects, are explored allowing the experimentation in the design phase. Games allow to find solutions through prototypes and lead to designs of the real world quickly. Moreover, to think about experiences, and put the students into different scenarios and situations, a role play game (RPG) was used. RPG tries to develop the "empathy of designer". So, the students, as future software designers, should test the proposed solutions in a RPG.

E. Gamification

There are related works [18, 19] applying gamification in higher education that indicate some benefits of introducing these mechanics in university classrooms [20, 21]. In this sense, Merquis (2013) [22] indicates that the gamification in higher education can give students better opportunities for:

- Commitment: basically, makes students more interested in what they are learning.
- Flexibility: to introduce elements of gamification allows students to develop greater mental flexibility and problem solving skills.
- Competition: games and elements of game-based learning are closely related to the natural human desire for competition, in this case, allowing students to learn from their mistakes and not to be penalized for them.
- Collaboration: In a hyper-connected world, students must be able to collaborate with other colleagues both locally and online.

Then again, game-based learning and gamification techniques have been applied in different subjects in computer engineering with excellent results in student motivation, increased participation and learning specific subject skills such as compilers construction or different software development methodologies [23, 24].

Based on the learning strategies and techniques explained above, we designed a hybrid educational methodology and apply it to the teaching of a Computer Science course at University. In the following sections we describe the experience and the main results.

III. EXPERIENCE

The main objective of this experience was the application of a methodology based on blended learning, project based learning, different techniques from the creativity area (design thinking, gamestorming, etc.) and social and collaborative learning (Fig. 1).

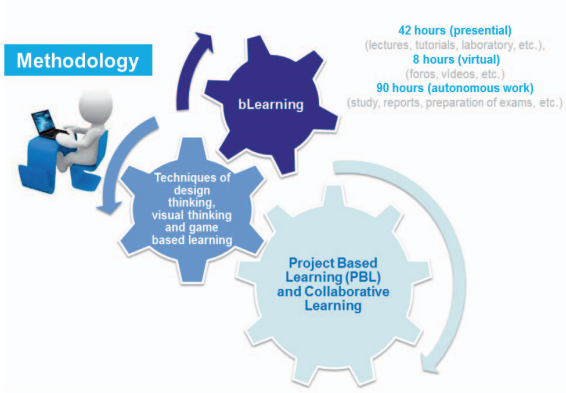

Fig. 1. Methodological approach

The study sample consisted of 116 students aged between 20 and 42 years (82% male and 18% female), from 3rd Grade in Computer Engineering. The objective of the course was to develop software projects following the principles and techniques of UCD and Agile methodologies.

The course was organized under the methodological approach (Fig. 1), where activities were developed in 15 weeks of the first semester. 42 hours were spent under traditional learning activities and 18 hours under virtual learning. The remaining hours (90 hours) were spent as autonomous student work.

The group learning activities were designed on the computer-supported collaborative learning [25] and project-based learning guidelines [1]. Thus, all students (113) were organized in 33 working groups of 3-5 members. Afterwards, individual roles and responsibilities were distributed into the group.

In order to manage the projects, different activities were organized weekly, such as:

a) Selection of working topics (software projects).

b) Training with agile methodologies (Scrum).

c) Training using project management tools (Trello) (Fig.2).

d) Training with techniques of design thinking.

e) Creation of groups and self-administration.

f) Creation of collaborative calendars and task assignments.

g) Training on 2.0 tools for the creation of virtual learning environments.

h) Evaluation of skills acquired (general, specific, transversal and professional) through interviews, observation of the work developed in the learning environments and questionnaires.

i) Spoken explanations and reviews of work's group.

Then, students applied hybrid methodologies for the project development, combining agile software engineering methodologies (SCRUM), with the other innovation methodologies (UCD, DT, VT, GS). Thinking, planning, gathering requirements, monitoring, implementation and evaluation of activities were necessary for a successful development of the projects. They must have the following requirements:

- Being led by the student.
- Being clearly defined (from the first step to the end).
- Having meaningful content for students (be directly observable in their environment).
- Treating problems of the real world (contributions and solutions to existing problems).
- Being the subject of current research.
- Containing specific objectives related to the teaching guide (methodology design, human factors, user experience).
- Ending in a final product (prototype).
- Having connections between theory and professional skills (related to the contents of the subject and the developing of the skills applied by the companies).
- Having the opportunities for feedback and evaluation by experts (post results and progress in professional forums and social networks).
- Having opportunities for reflection and self-evaluation by the student (group discussions with other groups and the teacher).
- Being a real evaluation (including contextualized assessments: professional skills, social skills, speech and communication, engagement, commitment and initiative, cooperation, fieldwork, creation and invention, values, critical thinking and inquiry, problem solving, learning in situ, understanding and integration of concepts, interpretation, analysis and synthesis, decision making, judgment and evaluation).

With the aim of improving the cross skills in technical engineering by social and open 2.0 platforms, we used a mix of tools. By a traditional learning process, we explained the tools they must use. We worked on the concept of a digital portfolio (using Google Drive and Trello) [26] and social networks (Twitter) for the swapping of contents, analysis and selection of relevant career information. The inclusion of professional experts (national and international communities) was done at the end.

A pre-test and post-test was also designed to assess cross and professional skills of students. Furthermore, continuous assessment and final examination were performed. In addition, the teacher carried out a diary with observations of group's developments in the classroom sessions, lectures and interviews.

The subject was supported in the virtual classroom environment of the University of La Laguna (Moodle) where instructions were updated: news, content, and evaluation guidelines. We can assert that it was created using a technology environment for the development of collaborative work itself:

- A repository of students contents made in the task assignments (Google Drive);
- A site for the group itself, where they could self-manage their own schedules, track tasks and internal evidence, with a quick message format, and spoken display (Trello) (Fig. 2);
- A site for collecting addresses and display the deliveries on the network (Google Drive, Youtube, Twitter).
- A place for delivery of reports, evaluations and final evidence for the teacher (repository subject) (Moodle).

Fig. 2. Project management on Trello system.

On the other hand, in order to promote cross skills through meaningful learning, the course was focused on current issues for professional development under the Human-Computer Interaction, such as social networks, natural, tactile and mobile interfaces, and creating video games, developed by agile projects.

Furthermore, to enhance the student's creative and innovative thinking in software development, technical design thinking (DT), visual thinking (VT) and gamestorming (GS) were applied in the development of our experience, such as:

a) Mind maps,

b) People and scenarios (Fig. 3),

c) Empathy map (Fig. 4),

d) Benchmarking,

e) Sketches,

f) Storyboard,

g) Cardsorting,

h) Analysis of hierarchical task,

i) SWOT analysis,

j) OZ wizard and RPGs (theatre) (Fig. 5),

k) Paper, video and functional prototyping.

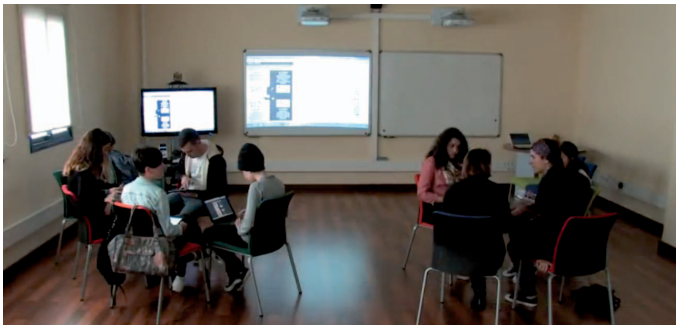

Fig. 3. Example of "people and scenarios" worked in groups.

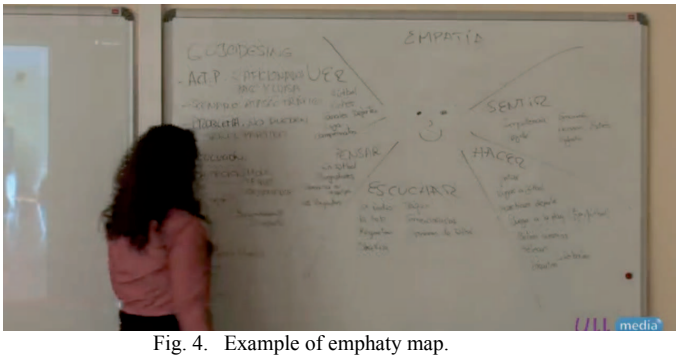

Fig. 4. Example of emphaty map.

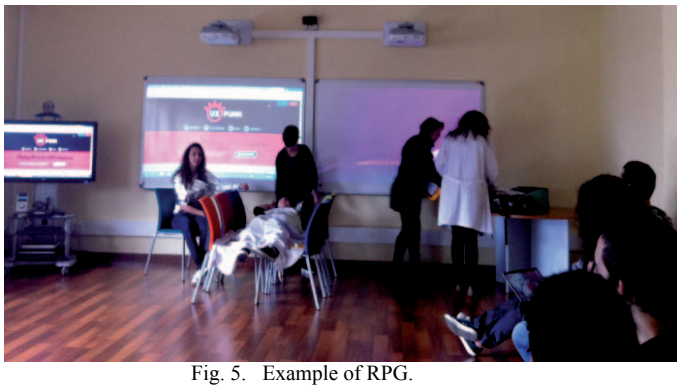

Fig. 5. Example of RPG.

We considered the following resources gamification: a) Tracking of student progress in learning; b) unit of measurement, for determining achievement (points, time, etc.); c) level: amount of unit as necessary to achieve the level; d) rules: what students can or cannot do in the activity; and e) feedback or reinforcements of the teacher or other classmates given to the student to learn and see the progress.

In our case, the tracking mechanism were the partial deliveries made by students in the periods of time (unit of measure) established by the teacher for each one. Also, each task was associated with the achievement of points (unit of measurement) and each level had a maximum score. The rules were established in the same directions of the activity. Also, a group voting system has been designed for each group to assess the other groups (other than itself). Finally each group had to present in class their project (feedback).

Fig. 6. Example of semiautomatic tracking the gamification process (PBL).

IV. RESULTS

In order to assess this experience, we have used different tools (questionnaires, interviews, diary of the teacher) several times in the season (pre-test, test, post-test, during practice/work sessions). We show the results of this experience for discussion:

- 82% of students worked in the "cloud" (Google Docs, Dropbox, etc.) and 70% worked as collaborative. However, 61% of them didn't use any calendar system to schedule their own work

and 78% had never used it to organize the work of the group.

- 99% of students used services as Youtube or similar for leisure, although 77% used them to consult the study topics.
- Students shared network information and open licensed work (73%), highlighting the type of study (Engineering) codesharing on Github software (55%) type repositories.
- The mobile was a reality in their lives, 100% of students owned a mobile phone, but only 83% have Internet access (type smartphone). It is used primarily for talking (98%), sending messages (86%), browsing (64%), chatting (65%), playing (60%) and signing into social networks (60%). However, tablets had not yet entered strongly in university classrooms, because only 24% of students owned an iPad or similar.
- The favorite social network of college students was Facebook (90%), followed by Tuenti (70%), Twitter (61%) and Google+ (44%). Professional-type social networks such as LinkedIn, had low engagement (17%).
- 97% used social networks to communicate with their friends, but to a lesser extent for finding information for class work (22%), sharing technical information (33%), job seeking (16%) or looking for interesting information on professional groups (18%).
- About social media and engagement, the result showed a division between 54% that thought that little or nothing favors them and 46%, quite or very much. They also argued that social networks encourage written communication skills (58%), creativity (52%) and teamwork (62%).
- 75% of students were unaware of the concept of e-portfolio, but the thought that it was "a useful collection of works developed along the course for learning" (55%), which could be useful for learning (53%), developing their professional skills (46%) and their planning and management skills (54%).
- 71.7% of students had expectations to apply the course content knowledge in future personal projects.

V. CONCLUSIONS

This work has showed an innovative educational experience applied to the students of university environment based on b-learning methodology that intends to enhance the traversal and professional skills through project-based learning creativity and innovation through design thinking, visual thinking and playful thought.

In order to develop this expertise, it had been designed a 2.0 technology environment including social platforms and other tools for filling a digital portfolio. Trello was used to manage group projects. Twitter as a social network to share useful information and professional interest. Moodle virtual classroom was used to manage the formal learning, the planning and organization of activities, communications and evaluations.

Additionally, the problem of competency assessment (which requires a real or realistic assessment and evaluation of the execution or performance of tasks requiring student's involvement, planning, development, communication and argumentation) were analyzed. The e-portfolio, social networking and project-based learning will enable us to work the previously selected while cross and professional skills, making it possible a different assessment to the traditional: authentic assessment.

Moreover, it is important to note the promotion of generic skills through meaningful learning. The course was focused on current issues under professional development in Human-Computer Interaction (such as natural, tactile and mobile interfaces, developed through agile projects).

We realized that both social networks and mobile devices are very usual in the student's life. However, its use for academic and professional life is low. We emphasize the use of the mobile application Whatsapp as a communication tool and work group management.

Qualitative results showed that teamwork is one of the most important issues in project-based learning. The application of this type of hybrid methodologies supported by technological tools is very important in the academic and professional development. Also, working on real projects with methodologies for innovation and creativity, promotes the involvement and motivation of students in them. They also feed the entrepreneurial spirit of the students in these phases of education. So, we tried to include in the activities, the intrinsic motivation of students, besides extrinsic considered in mechanical highlighted. Therefore, we believe it is necessary to make an initial assessment to analyze our students and context, and then design the activity according to these interests and characteristics, as proposed in the methodology of gamification we have presented in this article.

Given that the gamification process was a very hard task for the teacher (manual registers, tracking and monitoring of different learning environments and tools, giving immediate feedbacks to each action, etc.), we are currently designing and developing a gamification platform, connecting formal (LMS) and informal learning tools (social networks, etc.) with a semiautomatic mechanism for immediate feedback and automatic tracking of the learning process (Fig.6).

Finally, the experience was very rewarding, highly motivating for the students, and their creative and innovative projects. The participation in both the networks, the sessions and the tutorials, was high, with excellent academic results. This encourages us to continue working for the constant improvement of learning processes that promote professional, generic and specific skills, as well as traversal and professional skills, that are so important for our graduated students to find a job .

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