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AN INNOVATIVE PROTOCOL FOR THE DEVELOPMENT AND EVALUATION OF THE TEAMWORK COMPETENCY IN VIRTUAL ENVIRONMENTS

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Under COVID scenario, it has been observed that the constraints derived from remote teaching makes harder an already challenging task: the achievement of teamwork skills and their assessment. This study, which is part of the UPC-ICE “EQUIPA'T” teaching innovation project, aims to design a new protocol for the development of academic projects and the individualized evaluation of university students regardless the field of knowledge within engineering. To that end, eight functionalities have been identified: (i) quantification of the individual contribution; (ii) group dynamics and individual roles; (iii) internal team management; (iv) communication; (v) creativity (brainstorming / concept map); (vi) design thinking; (vii) repository; (viii) content development (previous ideas about concepts). For each of them, a series of indicators, activities, and tools have been defined to allow the development of the aforementioned functions in face-to-face and remote environments. In addition, an analysis has been carried out to determine the implementation of the protocol by professors in the pilot stage of the project.

Keywords: teamwork competency; protocol; virtual environments; project management; higher education; engineering

NUEVO PROTOCOLO PARA EL DESARROLLO Y EVALUACIÓN DE LA COMPETENCIA DE TRABAJO EN EQUIPO EN ENTORNOS REMOTOS

A raíz de la pandemia, se ha observado que las limitaciones derivadas de la enseñanza a distancia dificultan una tarea ya de por sí desafiante: la consecución de la competencia de trabajo en equipo y su evaluación. Este estudio, que se enmarca en el proyecto de innovación docente “EQUIPA'T” de la UPC-ICE, tiene como objetivo diseñar un nuevo protocolo para el desarrollo de proyectos académicos y la evaluación individualizada de dicha competencia en estudiantes universitarios independientemente del campo de conocimiento dentro de la ingeniería. Con este fin, se han identificado ocho funcionalidades: (i) cuantificación del aporte individual; (ii) dinámicas de grupo y roles individuales; (iii) gestión interna del equipo; (iv) comunicación; (v) creatividad (lluvia de ideas/mapa conceptual); (vi) pensamiento de diseño; (vii) repositorio; (viii) desarrollo de contenidos (ideas previas sobre conceptos). Además, se han definido una serie de indicadores, actividades y herramientas que permitan el desarrollo de las citadas funcionalidades en entornos presenciales y remotos. Por último, se ha realizado un análisis para determinar la implementación del protocolo por parte del profesorado en la fase piloto del proyecto.

Palabras clave: competencia trabajo en equipo; protocolo; entorno virtual; gestión de proyectos; educación superior; ingeniería

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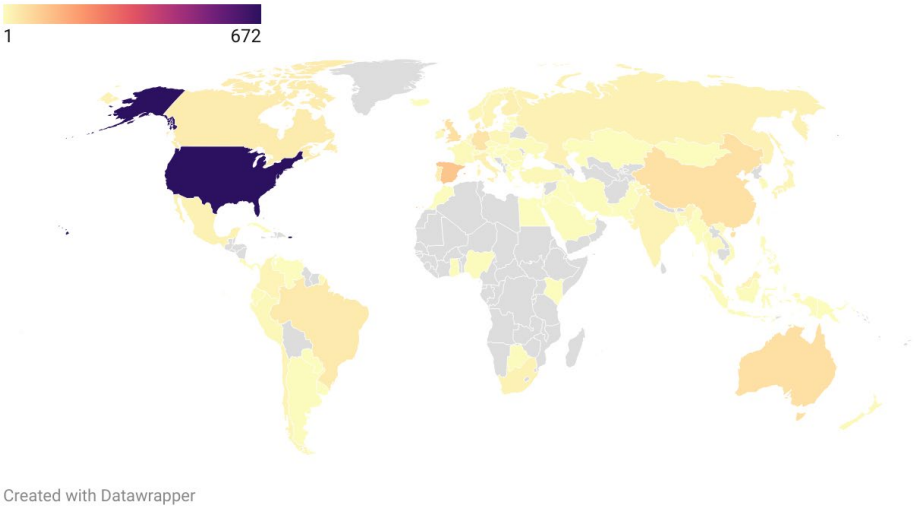
1. Introduction

In response to the pandemic, several measures and restrictions were imposed by the government authorities. Universities adopted online learning and virtual interaction to guarantee the academic course. Nevertheless, a lack of expertise in technological skills was detected in professors and students when project-based learning (PBL) course was performed in this new scenario (Ali, 2020; Awuor et al., 2022). In fact, the teamwork competency has not been extensively assessed in the last decades, especially in engineering studies and hybrid learning environments (Rajabalee et al., 2020). Some researchers stated that the teamwork competency could be defined as the integration among individual's knowledge, skills and abilities to work effectively into a group (Aguado et al 2014; Marcano 2020). The main justification is that the development of a project implies: (i) conflict resolution or internal management of people; (ii) collaborative problem-solving; (iii) communication among members; (iv) goal setting; (v) task coordination (Awuor et al., 2022). The difference between a face-to-face and a virtual environment is the student's satisfaction. When students work face-to-face, their perspective is focused on the facilities, services and educational experience. In virtual environments, the satisfaction is complex and multidimensional, since several factors are undertaken -i.e. professor's flexibility, workload, pedagogical skills, interaction process, use of learner-centred strategies, student's self-regulation mechanisms, motivational challenges, study environment, concentration etc- (Ku et al., 2013; Awuor et al., 2022; Xu et al., 2022).

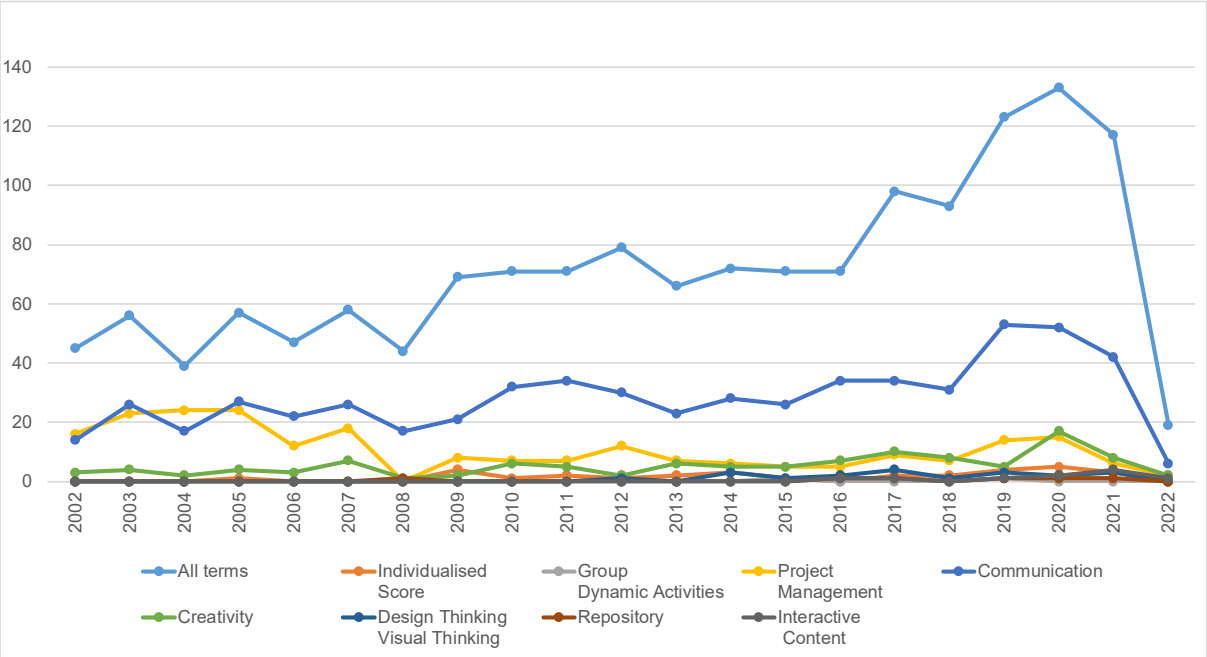
Within this context, an extensive literature review was conducted through Scopus database, since the spectrum of search is wider compared to WoS platform (Tejedor et al., 2022). A query based on the combination of five keywords was applied: TITLE-ABS-KEY "teamwork competency" OR "teamwork" AND "engineering" AND "university" OR "higher education". The total number of scientific publications was found to be 1499, where 66.60% was attributed to conference papers and 28.80% to journal papers. According to Figure 1, United States and Spain were identified as the countries with a greater representation in this topic, reaching 672 and 117 studies respectively. It should be pointed out that most of European countries presented a ratio between 15 and 30 studies. Despite this, only 7 publications were highlighted globally for hybrid or virtual environments.

Figure 1: Geographical distribution of scientific publications related to teamwork in engineering studies (2002 – 2022)



As seen in Figure 2, researcher's interest on the topic increased from 2017 to 2021, reaching the peak during the lockdown measures. Applying a refinement criterion to the aforementioned query, the core functionalities and their respective number of publications can be identified: individualised score or peer assessment -31-; group dynamic activities -2-; project management -227-; communication between parties -595-; development of creativity -112-; application of design thinking and visual thinking activities -20-; repository systems -6-; and incorporation of interactive content like game-based learning (GBL) or gamification exercises -10-. Concerning the functionalities with lower values of findings, a gap still exists and more research is needed. For example, the individual contribution is not quantified in the teamwork assessment. Consequently, some students can feel discouragement due to negative behaviours in team works, such as free-riding or social loafing (Shishavan et al., 2020). In the case of gamification, Zabala-Vargas et al. (2022) demonstrated that this type of activities stimulates thought processes, increase motivation and promote argumentation -especially in first-year engineering students-.

Figure 2: Evolution of the publications related to teamwork competency and its core functionalities (2002 – 2022)



Focusing on regional university system, the Universitat Politècnica de Catalunya –UPC- has seven competencies for all the engineering studies: (i) Entrepreneurship and Innovation (CG1); (ii) Sustainability and social commitment (CG2); (iii) Third language (CG3); (iv) Effective oral and written communication (CG4); (v) Teamwork (CG5); (vi) Solvent use information resources (CG6); (vii) Autonomous learning (CG7). In some UPC campus, an eighth competency is added, which is the capacity for analysis and synthesis (CG8). It should be noted that each of these competences has three levels. The first level is based on the participation of the students on a project, identifying the objectives, the responsibilities of each member of the group and the strategy to follow. The role of the professor is to guide. The second level pretends to consolidate the group. Here, the efficiency and the distribution of tasks could be linked to the

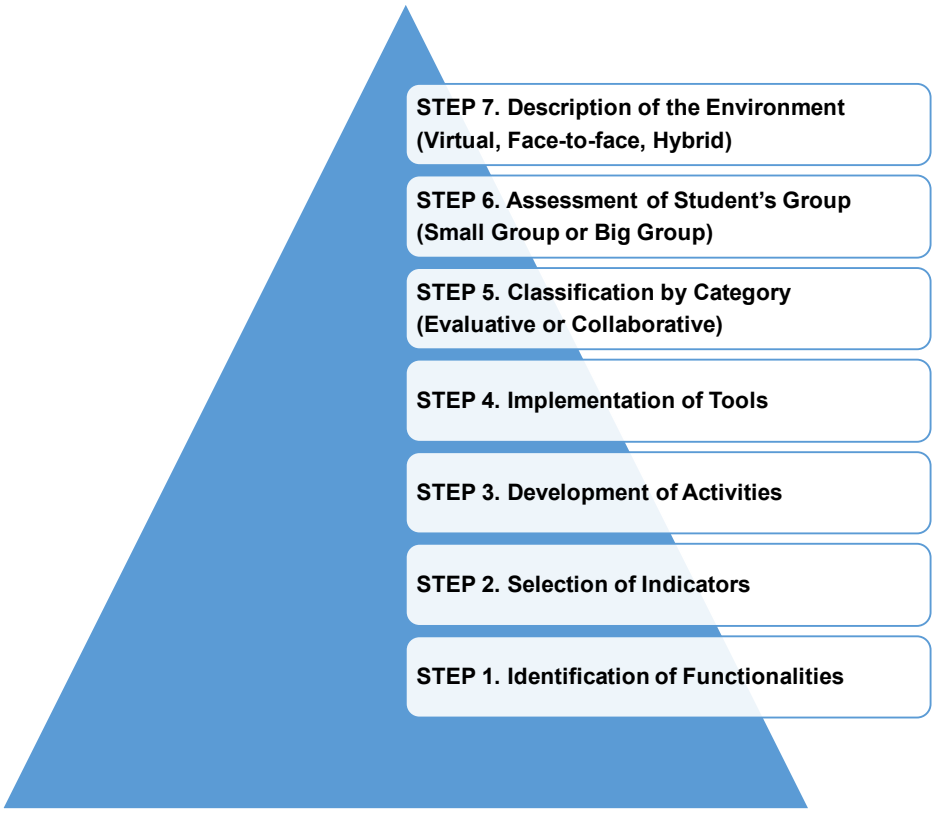
cohesion among members. The third level is focused on the autonomy of the group to work alone. Nevertheless, a standardized methodology does not exist to develop teamwork competence at these three levels. Hence, professors cannot assess this competence individually or help students to achieve it. Along this line, the teaching innovation project entitled “EQUIPA’T” is presented in this congress paper. The aim is to propose a protocol for the development and evaluation of the teamwork competency in hybrid environments.

2. Methodology

The research methodology of “EQUIPA’T” is divided into four specific objectives: (i) identification of functionalities and tools; (ii) definition of a protocol; (iii) analysis of the scalability of the project; (iv) maximization of the impact of the project. To implement the project, 19 subjects were selected from 15 different degrees -10 BsC and 5 MsC-. In this way, the validation process could contain enough variability in terms of: student’s type, size of the groups and field of knowledge. The measurement campaigns are being conducted from September 2021 to June 2022, considering two semesters of academic course and two university campus (ESEIAAT –UPC Campus Terrassa- and ETSEIB –UPC Campus Barcelona-). The impact of the project has been estimated at 1900 students, involving 19 professors from the Department of Project and Construction Engineering of UPC. Taking into account the literature review and professors’ opinion, a preliminary analysis was carried out to define the protocol (Figure 3).

Figure 3: Protocol to develop and evaluate the teamwork competency in engineering studies

and hybrid environments



The main steps of the proposed protocol are briefly reported hereafter:

- Functionalities
    - Eight functionalities were considered: (i) Quantification of the individual contribution (QIC), to evaluate the percentage and quality of work done by each member of the project; (ii) Group dynamics (GD), to select roles of each student in the project (i.e. manager, leader of the structural system, leader of marketing etc); (iii) Internal team management (ITM), in terms of coordination of tasks and conflicts resolution; (iv) Communication (COM); (v) Creativity, related to the use of brainstorming and mind maps (CBM); (vi) Design thinking or visual thinking (DVT), to explain a process or the dispositive to build; (vii) Repository (REP), to upload tasks requested by the professor; (viii) Development of interactive content or educational material (DIC), to work concepts through questionnaires or gamification exercises (i.e. video with questions).
- Indicators
    - The indicators allow to measure and validate the significance of the functionality before and after the implementation of the protocol.
- Activities
    - For each functionality, several activities were designed and reported by a "technical sheet". This sheet contained a brief description of the activity, additional information (i.e. examples of questionnaires, tutorials, books etc), recommended tools and possible indicators to measure. Taking into account

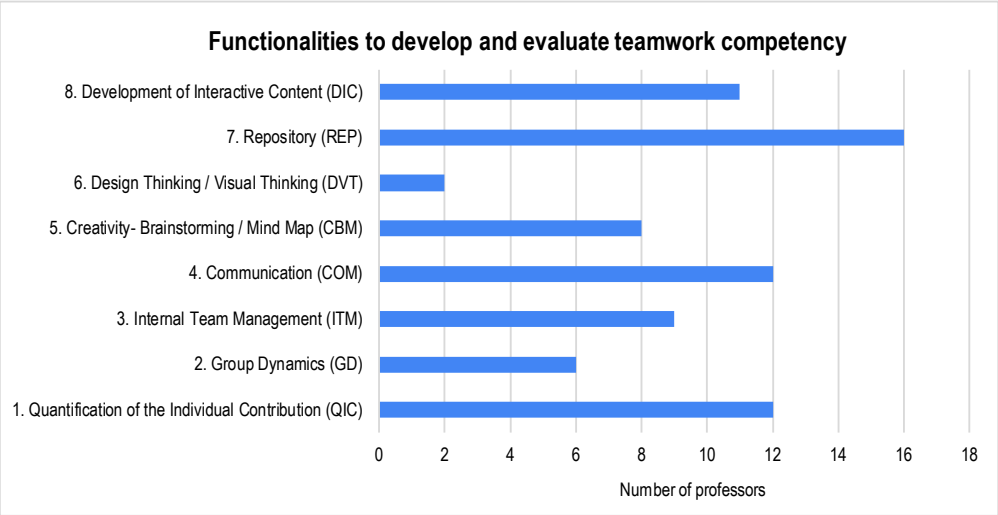
this information, all the professors could have the same rules to accomplish.

- Tools
    - A total of 68 tools were identified by a collaborative brainstorming. The functionalities and their respective tools can be categorized in two types: collaborative or evaluative. The first one allows to promote synergies during the elaboration of engineering projects. The second one helps to quantify the contribution of students in the project.
- Student's group
    - The sample size can be defined as a small group (SG = 10 – 30 people) or a big group (BG = 50 – 220 people). Normally, the subjects with higher volume of students are concentrated on the spring semester. By way of example, a subject of the 1st year of Industrial Engineering can have 160 students (BG) divided into 16 teams of 9 – 11 people.
- Environment
    - After pandemic, three environments can be given: virtual, face-to-face or hybrid. Some tools can be more important during the development of the activity in the lecture session. For example, the professor can resolve doubts or guide the exercise in the classroom or by GMeet. When the lesson has finished, the students should work together asynchronously, without the figure of the professor.

3. Results

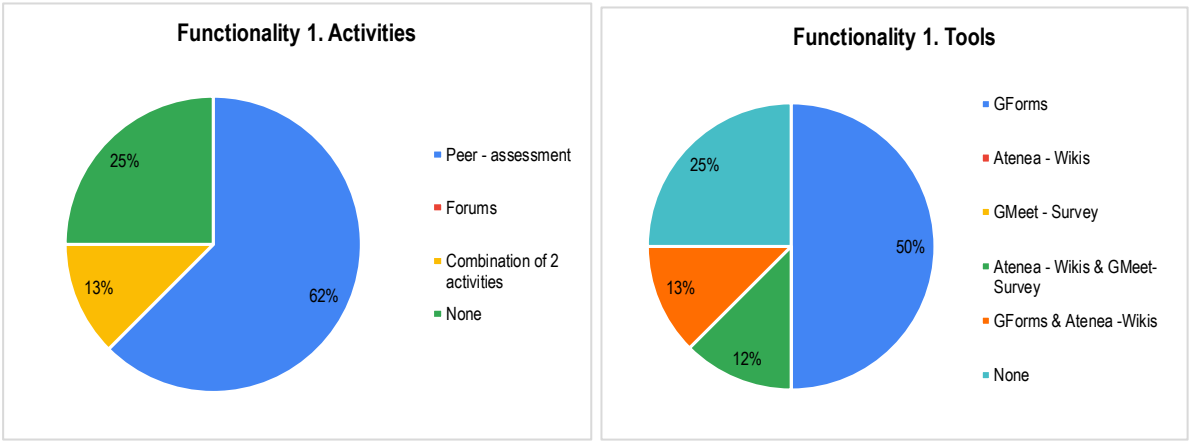
To estimate professors' participation in the implementation of the protocol, Gforms surveys and interviews were conducted. Each professor had to indicate what functionalities could be developed in his/her subjects. The activities and tools had to be selected as well. Subsequently, some questions about indicators and environment were asked. The gathered results are shown in Figures 4 to 12. Considering a participation of 16 academic members, 62.50% were affiliated to ESEIAAT –UPC Campus Terrassa- and 37.50% to ETSEIB –UPC Campus Barcelona-. As shown in Figure 4, most of professors would prefer the following functionalities: repository, quantification of the individual contribution, communication and development of interactive content. The functionality with minor representation was attributed to design and visual thinking.

Figure 4: Estimation of the implementation of each functionality in "EQUIPA'T" Project



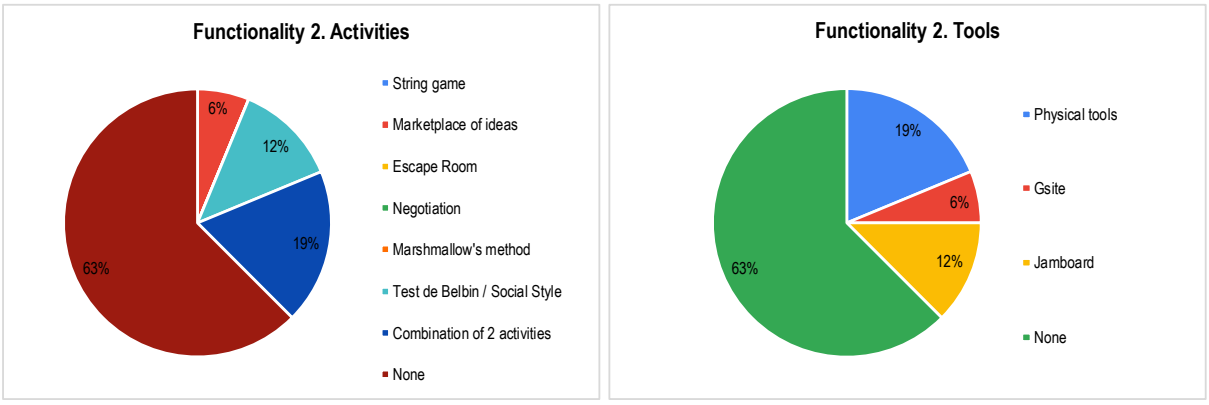
According to the breakdown analysis, it is observed that 62% of the teaching staff would carry out the peer assessment to quantify individual contribution (functionality 1), using the Gforms tool in 50% of cases. In this case, the professors stated that 3 indicators should be necessary: time to apply the tool, number of participants and variability of student's score.

Figure 5: Functionality 1 – Quantification of Individual Contribution



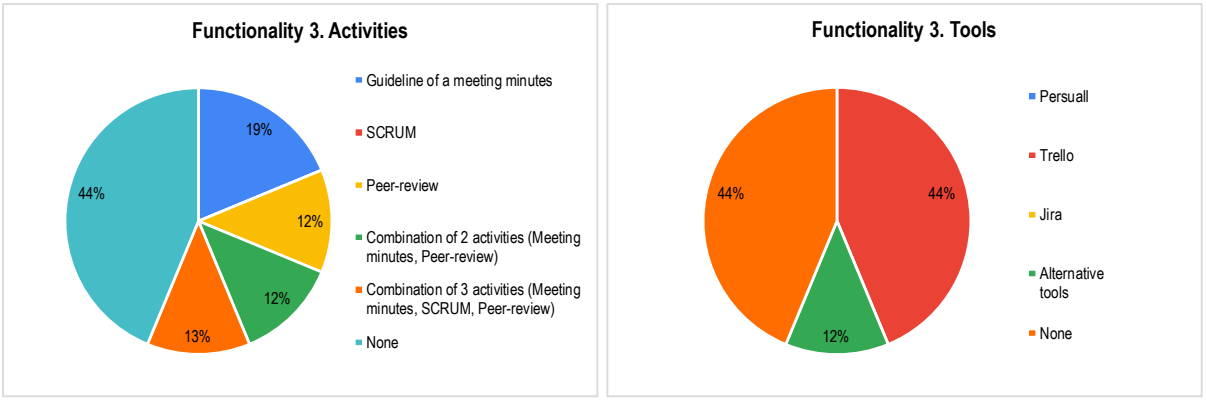
In relation to the second functionality, group dynamics, 37% of professors would choose to incorporate activities like marketplace of ideas, Marshmallow's method or Belbin Test. Furthermore, the use of physical or digital tools (e.g. Gsite, Jamboard) would represent 19 and 18% respectively. During the interviews, some professors highlighted that group dynamics activities are always more significant in subjects from initial stages of engineering studies, where the volume of students is higher. Furthermore, the indicators should be based on gender diversity and multidisciplinary vision. This means that it could be necessary to measure the number of different roles per group, the number of people per role and the ratio men vs. women per group.

Figure 6: Functionality 2 – Group Dynamics



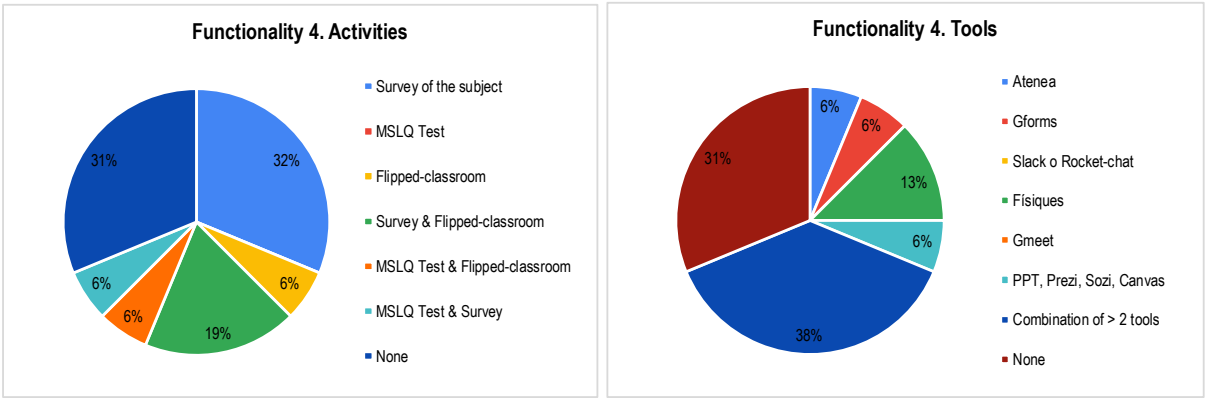
Regarding the third functionality, internal team management, 57% of teachers would prefer to combine 2 or 3 activities –i.e. Guideline for meeting minutes, Peer-review and SCRUM- throughout the semester, having explained a digital tool like "Trello" previously. The initial perception is that other tools, such as Persuall and Jira, would require training for all involved parties. In other words, an additional training period may be difficult to execute when weekly sessions are limited and closed from the beginning of the academic year. Most of professors also mentioned that several indicators could be required: number of meeting minutes, number of decisions per meeting, duration of the internal meetings, number of tools used during the sessions, % of correlation between the final score of the subject and the number of meetings or peer-reviews.

Figure 7: Functionality 3 – Internal Team Management



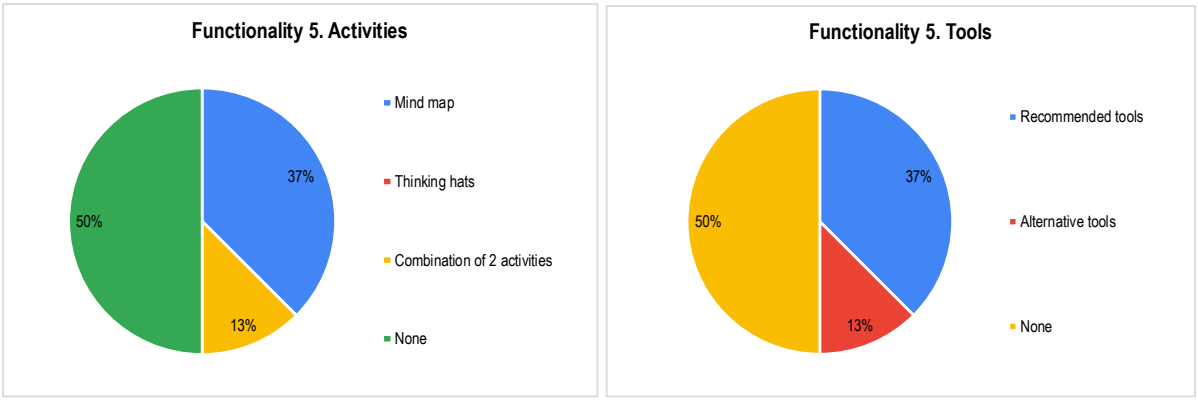
Concerning the communication, categorized as the fourth functionality, 32% of the professors would prefer to carry out a survey of the subject in two periods -independently of the official form established by the UPC-. The remaining 31% would contemplate the implementation of two activities: survey and flipped-classroom (19%); MSLQ Test and flipped-classroom (6%); MSLQ Test and subject survey (6%). In terms of tools, several ones should be applied in virtual environments, to provide an added value to the student. In this case, the indicators were linked to the number of participations and their quality, use and synchronization of tools.

Figure 8: Functionality 4 – Communication



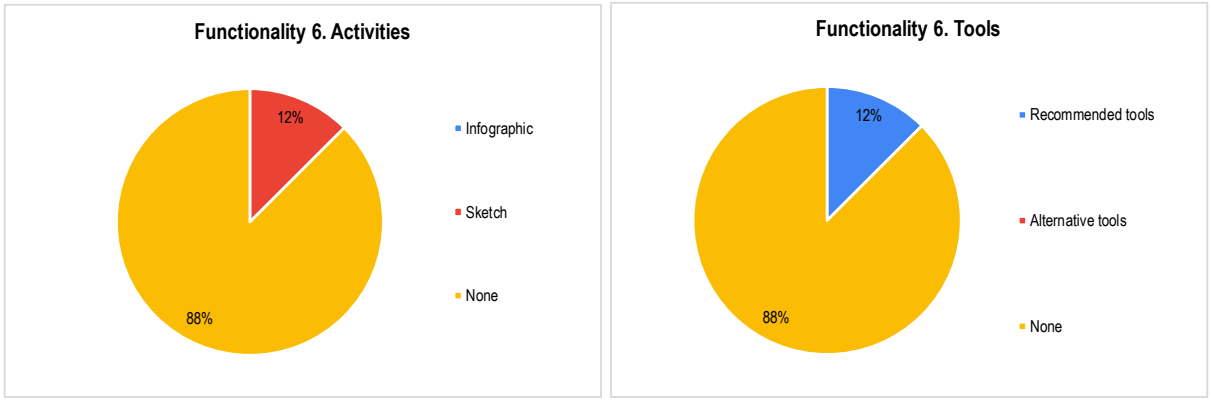
In the case of the fifth functionality, focused on promoting the creativity in projects, 37% of professors would design a collaboratively mind map using recommended tools such as the whiteboard in physical format and Mindmeister or Miro in digital format. In 13% of cases, the activity "Thinking Hats" could be incorporated. The number of branches and domains of the mind map, as well as the identification of weaknesses and potentials of the works, were the suggested indicators by the academic community.

Figure 9: Functionality 5 – Creativity – Brainstorming / Mind Map



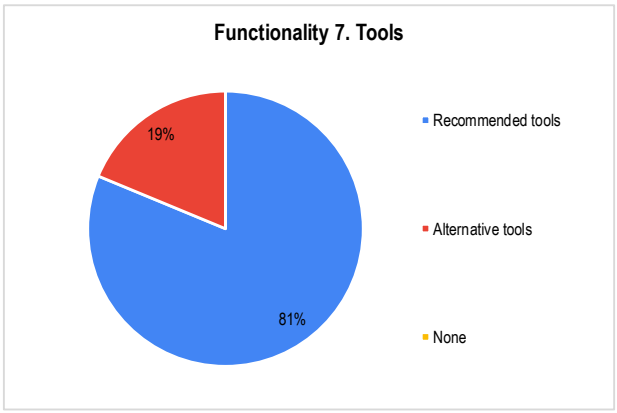
As for sixth functionality, which aims to introduce the design thinking as well as visual thinking to assimilate concepts and explain projects, only 12% of professors would do it. The most feasible activity could be the sketch of the device to build during the course. In this way, the students could apply technical drawing knowledge and develop spatial abilities. For this propose, recommended tools could be chosen –i.e. Procreate, Krita, Inkscape-. Despite having lower participation in this question, two professors stated that the number of iterations in the sketch or infographics and the proportion of visual information could be good indicators to measure this functionality.

Figure 10: Functionality 6 – Design Thinking / Visual Thinking



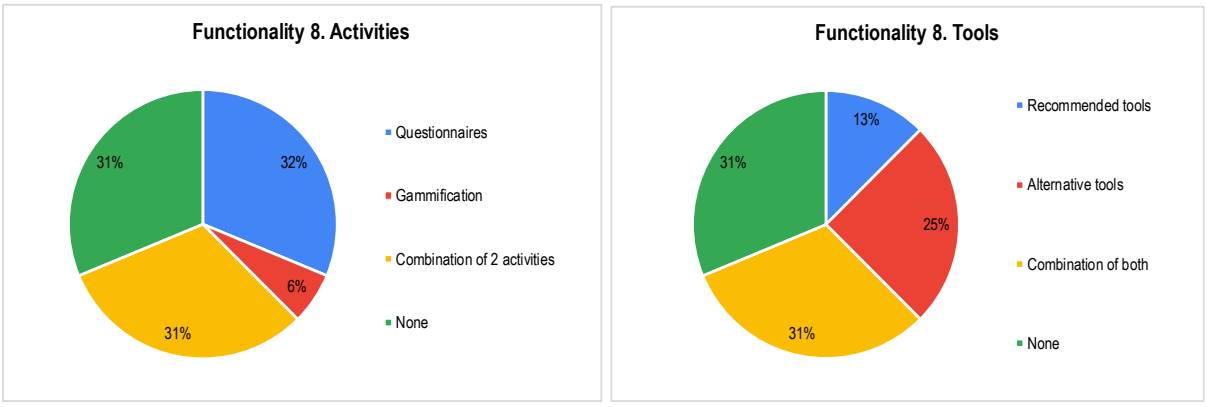
The repository, functionality 7, focuses on uploading partial and final deliverables, establishing a common point all stakeholders. After a certain period of time, professors provide the feedback for each deliverable and students can learn from mistakes. Atenea –UPC Virtual Campus- and GDrive present a high percentage of use in terms of tools. Here, all the professors affirmed that the unique indicator should be the number of tasks uploaded in the institutional platform, since the quality and the score of the tasks are completely correlated.

Figure 11: Functionality 7 – Repository



Finally, the eight functionality would be implemented by concept questionnaires (32%) or combining these with gamification exercises (31%) throughout the semester. Respect to tools, professors would use both recommended and alternative tools. In particular, the questionnaires would be developed using already known alternative tools –i.e. Mentimeter, Kahoot, Athena-, while the gamification exercises would be to performed with the recommended ones –i.e. EdPuzzle, Genially-. In this case, some professors commented that the indicators could be the results of the interactive questionnaires, the score during the "competition" and the number of students' participations in gamification activities.

Figure 12: Functionality 8 – Development of Interactive Content



4. CONCLUSIONS

Given the high percentage of grey literature in the topic (71.20%), more researches are required to establish a common protocol focused on the teamwork competency in universities, especially in hybrid environments and engineering subjects where PBL (Project-Based Learning) is implemented. Along this line, the individualised quantification of projects as well as the performance of collaborative activities are recommended to improve cooperative learning, achieve positive interdependence and provide constructive feedback.

To overcome the aforementioned problem, this congress paper presented a proposal of protocol developed within the innovation teaching project entitled "EQUIPA'T" from the Universitat Politècnica de Catalunya. In the preliminary analysis some aspects regarding the core functionalities of teamwork competency were extrapolated. The results revealed that: (i) quantification of individual contribution, repository and development of interactive content can be defined as evaluative functionalities; (ii) group dynamics and communication can be considered collaborative functionalities; (iii) internal team management, creativity and design thinking can be categorized as evaluative and collaborative. It should be noted that most of the functionalities and their respective activities can be executed in both small and big groups of students, except the selection of roles and coordination of tasks within the project. Nevertheless, no difference was detected in terms of environment –face-to-face, virtual or hybrid-. Finally, the findings also highlighted that the list of indicators is large. In fact, they cannot be interchangeable, since they completely depend on the functionality to work and the activity to conduct on the lecture session.

5. REFERENCES

Aguado, D., Rico, R., S´anchez-Manzanares, M., & Salas, E. (2014). Teamwork competency test (TWCT): A step forward on measuring teamwork competencies. *Group Dynamics: Theory, Research, and Practice, 18*, 101 - 121. DOI: 10.1037/a0036098

Ali, W. (2020). Online and remote learning in higher education institutes: a necessity in light of COVID-19 Pandemic. *Higher Education Studies, 10*, 16-25. DOI: 10.5539/hes.v10n3p16

Awuor, N.O., Weng, C., Piedad, E., & Militar, R. (2022). Teamwork competency and

satisfaction in online group project-based engineering course: The cross-level moderating effect of collective efficacy and flipped instruction. *Computers & Education, 176,* 104357:1 – 104357:12. DOI: 10.1016/j.compedu.2021.104357

Ku, H-Y., Tseng, H.W., & Akarasriworn, C. (2013). Collaboration factors, teamwork satisfaction, and student attitudes toward online collaborative learning. *Computer in Human Behavior, 29,* 922-929. DOI: 10.1016/j.chb.2012.12.019

Marcano, B. S. (2020). The role of teamwork competencies, justice perceptions and team leadership on team performance in a multicultural society (Tesis Doctoral, Universidad Complutense Madrid). Obtenido de: https://eprints.ucm.es/cgi/export/60100

Rajabalee, Y.B., & Santally, M.I. (2020). Learner satisfaction, engagement and performances in an online module: implications for institutional e-learning policy. *Education and Information Technologies, 26*, 2623 – 2656. DOI: 10.1007/s10639-020-10375-1

Shishavan, H.B., & Jalili, M. (2020). Responding to student feedback: Individualising teamwork scores based on peer assessment. *International Journal of Educational Research Open, 1,* 100019:1 – 100019:5. DOI: 10.1016/j.ijedro.2020.100019

Tejedor, B., Lucchi, E., Bienvenido-Huertas, D., & Nardi, I. (2022). Non-destructive techniques (NDT) for the diagnosis of heritage buidlings: traditional procedures and futures perspectives. Energy & Buildings, 263, 112029:1 – 112029:22. DOI: 10.1016/j.enbuild.2022.112029

Xu, J. (2022). A profile analysis of online assignment motivation: Combining achievement goal and expectancy-value perspectives. *Computers & Education, 177*, 104367:1 – 104367:17. DOI: 10.1016/j.compedu.2021.104367

Zabala-Vargas, S.A., García-Mora, L., Arciniegas-Hernández, E., Reina-Medrano, J; De Benito-Crosetti, B., & Darder-Mésquida, A. (2022). Didactic strategy mediated by games in teaching of mathematics in first-year engineering students. *EURASIA Journal of Mathematics, Science and Technology Education, 18,* 11707:1 – 11707:13. DOI: 10.29333/ejmste/11707

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